California LED Lamp Market Characterization Report

Prepared for the California Public Utilities Commission Energy Division

Prepared by DNV KEMA Energy & Sustainability

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Table of Contents

Table of Contents

List of Tables:

Table of Contents

List of Figures:

Table of Contents

E. Executive Summary

E.1 Report Overview

In late 2011, the California Public Utilities Commission (CPUC) requested that DNV KEMA Energy & Sustainability perform a preliminary market characterization for light-emitting diode (LED) lamps in California as part of CPUC Work Order 13 (Lighting Programs Process Evaluation and Market Characterization). The purpose of this report is to provide a high-level assessment of LED lamp market characteristics and a snapshot of LED lamp availability, diversity, and pricing with a focus on California's market to the extent that data are available. Whenever possible, we compare U.S. LED lamp market data with California data to highlight similarities and differences between the national and California LED lamp market. This report provides information regarding the current state of the LED lamp market as well as insights into future market directions. This report provides preliminary insights into the LED market in anticipation of a more comprehensive LED Market Effects study being conducted under CPUC Work Order 54 (Market Effects).

E.2 Methods

The California LED Lamp Market Characterization study draws on data from three key data collection efforts:

(1) **LED lamp market literature review.** DNV KEMA staff reviewed more than 30 reports with information on LED lamp market characteristics published between 2008 and 2012. The purpose of this review was not only to provide information with which to populate the report but also to identify key themes in the literature around which to organize the report. Researchers identified the following six themes:

- **Diversity** of LED lamps available to consumers in terms of characteristics such as lamp style (i.e., A-lamp, Reflector, etc.), lamp life, wattage, and lumen output;
- **Availability** of LED lamps in retail channels that typically sell light bulbs, including the types of stores that sell LED lamps, the average number of LED lamps per store, and the number of LED lamps available compared to other lamp types;

- **Pricing** of LED lamps currently available in the market and forecasts for average LED lamp prices and price ranges;
- **Market Size** for LED lamps (both globally and in North America);
- **Installed Base** of LED lamps in the United States and California, and;
- **Barriers** to LED lamp adoption faced by consumers including high first cost, low lumen output, lamp performance issues, and lack of consumer education.

(2) **In-depth interviews.** In early 2012, DNV KEMA staff conducted in-depth telephone interviews with representatives of 37 different LED lamp manufacturers, distributors, and retail channels (both brick and mortar and online) as well as LED market experts. The purpose of the in-depth interviews was to elicit information on the current status of the market for LED lamps in the U.S. and (to the extent possible) in California.

(3) **Fall 2011 California Lighting Retail Store Shelf Survey data.** In support of the Fall 2011 California Lighting Retail Store Shelf Survey Report, DNV KEMA field researchers conducted complete inventories (shelf surveys) of lighting products in 184 California retail stores across seven channels (discount, drug, grocery, hardware, large home improvement, mass merchandise, and membership club stores). Researchers collected detailed information on product characteristics and prices. These data form the basis for analyses of LED lamp availability, diversity and pricing in California for this report.

E.3 Findings and Conclusions

Below we summarize the findings and present conclusions regarding the LED replacement lamp market for each of the six key themes revealed in the literature review (diversity, availability, pricing, market size, installed base, and barriers to consumer adoption of LED lamps).

E.3.1 Diversity

Below we summarize the findings and present conclusions regarding LED replacement lamp diversity, including lamp style, lamp life, wattage, and efficiency.

- **Style.** Reflector lamps continue to dominate the national LED replacement lamp market as of mid-May 2012 with respect to the number of unique lamp models available, and in Fall 2011, the LED lamp models observed during the shelf surveys suggest the same

was true in California. Because LED technology is inherently directional, these results may reflect the initial market focus on reflectors (which are directional lamps) versus other lamp types (such as omnidirectional A-lamps).

While reflector lamps will continue to comprise a large component of the LED replacement lamp market, manufacturer and retailer representatives perceive great market potential for LED A-lamps and have begun focusing on these products in addition to LED reflector lamps. There may be some early evidence of this in California, as A-lamps comprised a greater proportion of all LED replacement lamp models observed in the Fall 2011 shelf surveys in California (approximately 18%) than of LED lamp models available throughout the U.S. (about 10% according to DOE data). The differences between California and the national market can most likely be attributed to the fact that DOE Lighting Facts product data is cumulative and spans multiple years whereas the data collected as part of the shelf surveys in California was a snapshot of the products on the shelves of retail stores in late 2011.[1]

- **Lamp life.** A 2012 DOE report suggests that the average rated LED lamp life was 25,000 hours in 2010 and is projected to increase to 33,000 hours in 2011. These estimates align with those produced from data collected in California during the Fall 2011 California Lighting Retail Store Shelf Surveys. Manufacturers suggest that rated LED lamp life will increase in the future and DOE predicts that this will be true at least through 2015 (the last year for which rated lamp life projections are currently available). Interestingly, DOE has recently scaled back its earlier projections regarding the rate at which lamp life will increase between 2010 and 2015.

[1] Caution should be used when drawing comparisons between national DOE Lighting Facts data and 2011 California Lighting Retail Store Shelf Survey data throughout this report due to significant differences in the datasets. DOE Lighting Facts product data referenced in this report is reflective of LED products voluntarily submitted by manufacturers for evaluation by DOE from 2008 to May, 2012. While D&R International, who manages the Lighting Facts product data, suggests that this data is representative of the LED market, it should be noted that there is often a lag time for products to reach market and often a very different mix of products for sale compared to what has been evaluated. California shelf survey data is simply a snap shot of products available for sale when field researchers visited stores in California in Fall, 2011.

- **Wattage.** DOE data from May, 2012 suggests that LED replacement lamps for sale in the U.S. range from 1 to 30 watts and average 9.5 watts across all lamp styles. Reflector lamps had the widest wattage range (from 1 -30 watts) and an average wattage of 10.2 watts, while A-lamps had a narrower wattage range (2-22 watts) and lower average wattage (8.2 watts) in May, 2012. Fall 2011 data from California suggests a narrower wattage range for A-lamps (0.6-13 watts) and lower average wattage than nationally (5.6 watts), while reflector lamps have a narrower wattage range than nationally (0.9-24 watts) but a higher average wattage (14 watts). Reasons for the differences between national and California data are unclear but are likely related to the fact that the California data is lamp weighted whereas the DOE data is reflective of cumulative lamp models reviewed by the Lighting Facts Program.

- **Lumen Output and Efficacy (lumens per watt).** DOE data suggest that LED replacement lamps had a limited range of available lumen options in the U.S. market during 2011, with the majority of lamps in the lower lumen ranges (roughly equivalent to the lumen output of traditional 40 and 60-watt incandescent lamps). LED lamps with lumen outputs equivalent to traditional 75W have begun to appear in the national market but were not widespread as of 2011, and higher output lamps are not expected to reach the market until 2013 or later. DOE data suggest efficacy levels averaging approximately 48 lumens per watt for LED replacement lamps in 2011, approximately three times as efficient as a traditional 100 watt incandescent lamp.

  The average LED lamp efficacy observed during DNV KEMA's Fall 2011 California Lighting Retail Store Shelf Surveys is closely aligned with the national-level estimates from DOE for 2011. The overall average observed for lumens per watt among LED lamps in the Fall 2011 shelf surveys (54.5 lumens per watt) is very close to the national average for 2011 based on DOE estimates, the efficacy range for lamps observed in the Fall 2011 shelf surveys in California -- 3 to 136.4 lumens per watt -- is fairly broad, suggesting a variety of light output options available in California during 2011.

E.3.2 Availability

Findings in California suggest that LED replacement lamps were widely available in the home improvement and membership club channels and, to a lesser extent, in hardware stores as of Fall 2011. In most channels, the range of product options is slim, with only a handful of models available in all channels except home improvement stores (in which field researchers observed an average of 32 models per store during Fall 2011). Researchers observed no LED lamps in

discount stores (which is logical given that the price point for LEDs is typically higher than discount stores tend to stock).

California's membership clubs and home improvement stores collectively accounted for almost 90 percent of all LED lamps (across all base types) observed in the California market during Fall 2011. All together, however, LED lamps represented a small fraction of lamps observed in California during the Fall 2011 shelf surveys (less than 4% of all observed lamps), while incandescent lamps represented 51 percent of observed lamps and CFLs represented 45 percent. Comparable data for the national market are not available.

E.3.3 Pricing

California data from late 2011 (based on the Fall 2011 California Lighting Retail Store Shelf Surveys) suggest somewhat lower average prices and broader price ranges than reported by DOE in 2010. Based on DOE data, the average retail price for an LED replacement lamp averaged approximately $36 in 2010, with average prices in the $20-40 range for A-lamps and in the $20-60 range for reflector lamps. Based on the Fall 2011 California Lighting Retail Store Shelf Surveys, average California LED lamp prices were just over $15 per lamp with a range of $2-40 for A-lamps (averaging $10.53) and $3-70 for reflectors (averaging $38.28). The majority of LED A-lamps observed in California were lower priced, low lumen output A-lamps at membership clubs, which may explain why the average California A-lamp price observed during the Fall 2011 shelf surveys is lower than the average price range reported by DOE for A-lamps in the national market in 2010. LED A-lamps with lumen output roughly equivalent to a 75 watt incandescent lamp had an average price of $31.22 in California.

E.3.4 Market Size

As of 2010, LED replacement lamps represent a small percentage of the overall global and North American general lighting markets (less than 10% of each), but these shares are expected to increase exponentially over the next ten years, and by 2020 LEDs are projected to be the dominate technology in the lighting market. A 2010 report projects that the value of the global LED general lighting market will increase sixteen-fold between 2010 and 2020 to reach a market value of $75 billion, while the value of the North American LED general lighting market is expected to grow fifteen-fold to $15 billion in 2020. Comparable data for California are not available.

E.3.5 Installed Base

In 2010, LED lamps represented less than 1 percent of the total lamps installed across the U.S., the majority of which were installed in the commercial sector. In California households, data collected during 2008 and 2009 suggest that less than one percent of residential light sockets in California were filled with LED lamps.

E.3.6 Market Barriers

The literature review and interviews with representatives of LED lamp suppliers and LED market experts suggested that four barriers are most prevalent to increased consumer adoption of LEDs, including high first cost, relatively low lumen output, poor performance claims, and lack of consumer education.

- **High first cost.** Among the barriers identified for LED lamps, high first cost was most frequently cited by literature review sources as the largest obstacle to LED lamp adoption by consumers. This perspective was reiterated by LED market actors who participated in the in-depth interviews conducted in support of this study in early 2012. Retail pricing of LED lamps observed during the Fall 2011 California Retail Store Shelf Survey suggests that the average cost of LED A-lamps, the most common household replacement lamp style, is over three times more expensive than non-discounted CFL A-lamps and almost ten times more expensive than discounted CFL and incandescent A-lamps. It is widely anticipated by market actors, however, that high first cost will become less of an issue over the next few years as LED lamp price continues to decline rapidly due to increased economies of scale, manufacturing technology improvements (i.e. enhanced automation), and pressure from competition.

- **Low lumen output.** There are currently few LED replacement lamps on the market with lumen output in the range of traditional 75 watt and 100 watt incandescent lamps. LED product offerings are continuing to expand – including products with higher lumen output – driven by upcoming lighting standards for manufacturers and improvements in LED technology.

- **Performance issues.** The literature review sources (primarily those from DOE's CALiPER program) suggest that poor performance (such as inaccurate and/or exaggerated manufacturer claims regarding lumen output or lamp life, flickering, poor color, and so on) present barriers to consumer adoptions of LED lamps. If these barriers

are not addressed, these claims could lead to consumer dissatisfaction and slower rate of market growth compared to projections.

- **Lack of consumer education.** As traditional incandescent lamps are phased out over the next couple of years by AB 1109 and EISA, consumers will be faced with a different set of lamp choices than they have had in the past. Literature review sources and interview results suggest a need for improved consumer education regarding the costs and benefits of LED lamps.

1. Report Overview

In late 2011, the California Public Utilities Commission (CPUC) requested that DNV KEMA Energy & Sustainability perform a preliminary market characterization for light-emitting diode (LED) lamps in California as part of CPUC Work Order 13 (Lighting Programs Process Evaluation and Market Characterization). The purpose of this report is to provide a high-level assessment of LED lamp market characteristics and a snapshot of LED lamp availability, diversity, and pricing with a focus on California's market to the extent that data are available. Whenever possible, we compare U.S. LED lamp market data with California data to highlight similarities and differences between the national and California LED lamp market. This report provides information regarding the current state of the LED lamp market as well as insights into future market directions. This report provides preliminary insights into the LED market in anticipation of a more comprehensive LED Market Effects study being conducted under CPUC Work Order 54 (Market Effects).

2. Methodology

The California LED Lamp Market Characterization study draws on data from three key data collection efforts:

(4) **LED lamp market literature review** of secondary source materials with information on LED lamp market characteristics;

(5) **In-depth interviews** with representatives of LED lamp manufacturers, distributors, retail channels that sell LED lamps, and LED market experts; and

(6) **Fall 2011 California Lighting Retail Store Shelf Survey data** collected as part of another DNV KEMA study.[2]

This section of the report summarizes the methods associated with each of the above efforts.

2.1 Literature Review

The literature review involved gathering and reviewing numerous secondary source materials regarding the LED lamp market to help identify key themes to organize and form the structure of this report.

Because the number of potentially-relevant studies on the LED market was large, the first step in this task involved preparing a list of source materials that each met a set of specific criteria. To be included in the list, a study had to be:

1. Published between 2008 and 2012, with emphasis on publications from 2010 and later;
2. Published and available (i.e., not "work in progress");
3. Focused on the California LED market if possible, with attention to national and global data for topics for which California data is not available;

[2] DNV KEMA, 2012. See Appendix A for complete citations of all secondary data sources referenced throughout this report.

4. Unique/not redundant with another study on the list (e.g., if an evaluation report is included, a conference paper summarizing the results of this report would typically be excluded); and

5. Available free of charge.[3]

Table 2-1 lists the relevant studies that met the criteria described above (organized in descending order of publication date and author) – approximately 30 in all – and includes a brief, high-level summary of each source. Appendix A includes complete citations for all sources included in the literature review as well as other sources consulted in support of this report.

[3] Appendix B includes a list of relevant data sources identified that are available for purchase.

Table 2-1

Published Studies with LED Market Assessment Elements

Date	Author(s)	Study Title	Study Sponsor(s)	Study Overview
01/2012	Navigant Consulting	2010 U.S. Lighting Market Characterization	U.S. Department of Energy	Outlines lighting market for U.S., including commercial, industrial, and residential sectors.
01/2012	Navigant Consulting	Energy Savings Potential of Solid-State Lighting[4] in General Illumination Applications	U.S. Department of Energy	Discusses LED energy savings, prices, lumen outputs and general characteristics. Gives forecasting when possible.
11/2011	KRC Research	4th Annual SYLVANIA Socket Survey	OSRAM SYLVANIA	Results of a telephone survey of US consumers regarding their lighting purchase habits, awareness of the Energy Independence Security Act (EISA), and other topics.
10/2011	IMS Research	IMS Research Downgrades 2011 Packaged LED Market Growth to 1% Despite 29% Increase in Lighting Revenues		Presents LED market share data and forecasts. Info for LED lighting market, automotive and backlighting markets. Press release.
10/2011	U.S. Environmental Protection Agency	U.S. EPA Report on Opportunities to Advance Efficient Lighting		Highlights the remaining opportunities for energy efficient lamps in the U.S.
08/2011	LEDstar.net	Global LED market growth takes transitions to lighting application section		Discusses trends in the LED industry and presents forecasts. Discusses Taiwanese and Japanese markets.
08/2011	The Economist	Charge of the LED Brigade		Discusses changes in LED market and future potential. References McKinsey report for most of data.
07/2011	Bardsley Consulting; Navigant Consulting; Radcliffe Advisors; SB Consulting; SSLS, Inc.	Solid-State Lighting: Research and Development: Manufacturing Roadmap	U.S. Department of Energy	Addresses future planning for DOE Research and Development (R&D) actions including funding of solicited cooperative R&D projects. It is divided into two sections, giving equal space to LEDs and OLEDs. The goal of the paper is to identify one promising strategy to achieve more reasonable costs for OLED panels.
07/2011	International Energy Agency (IEA)	Impact of 'Phase-Out' Regulations on Lighting Markets		Presents the results of the benchmarking of domestic lighting. Looks at policy actions supporting lighting efficiency, and in some cases as it pertains to LEDs.

[4] Solid-State Lighting refers to lighting technology that uses light emitting diodes (LEDs) to produce light. As described by Sandia National Laboratories, "the term "solid-state" refers to the fact that the light in an LED is emitted from a solid object—a block of semiconductor—rather than from a vacuum or gas tube, as in the case of incandescent and fluorescent lighting" (Sandia National Laboratories, n.d.).

Table 2-1 (continued)

Date	Author(s)	Study Title	Study Sponsor(s)	Study Overview
07/2011	McKinsey and Company	Lighting the Way: Perspectives on the Global Lighting Market		Describes global lighting market with a focus on LED market share, pricing, and product forecasting. Results from the report forecast a growth in LED presence throughout the world due to demand driven from population increases, with China strengthening its share of the general lighting market due to its high economic growth. Presents findings that both revenue increases and cost reductions of 30% p.a. are likely to occur through 2020 for LEDs. Also finds a shift in general lighting industry toward new fixture installation and away from replacement, which would benefit LEDs due to their improved effectiveness using new fixtures.
07/2011	Pattison, Lisa	DOE Market Introduction Workshop 2011	U.S. Department of Energy	Discusses OLED technology, covering barriers, benefits, DOE research efforts. References DOE Multi-Year Plan 2011 for OED statistics.
07/2011	Radcliffe Advisors	Cost Trends for Solid-State Lighting	U.S. Department of Energy	Discusses opportunities to reduce manufacturing costs for LEDs based on DOE research efforts.
05/2011	Bardsley Consulting, Navigant Consulting, Radcliffe Advisors, SB consulting, SSLS, Inc.	Solid-State Lighting Research and Development: Multi Year Program Plan	U.S. Department of Energy	Updates the Multi-Year Program Plan FY'09-FY'15 including plans, accomplishment, and projects through May 2011.
05/2011	D&R International, Ltd.	2011 Product Snapshot: LED Replacement Lamps	U.S. Department of Energy	Presents an analysis of the dataset underlying DOE Lighting Facts product list. Presents findings on LED replacement lamp market and its trajectory. Concludes that performance of LEDs remains highly variable for characteristics such as lamp life, CRI, CCT, light distribution, etc. Report also concludes that while available light output has been rising among replacement lamps, they will not improve enough to replace 100W lamps by 2012. Findings show that 75W replacement lamps are expected to reach the market between mid 2011 and 2013, with 100W replacements reaching the market between mid 2013 and mid 2015. The report presents findings on the US market and details differences between A-lamp, reflector, and linear lamp replacements.
04/2011	Pacific Northwest National Laboratory	CALiPER Special Summary Report: Retail Replacement Lamp Testing	U.S. Department of Energy	Identifies solid-state lighting (SSL) replacement lamp products that are available to the general public through retail stores and websites and presents test results.
04/2011	The Cadmus Group	What Will the Lighting Market Look Like Under EISA?		Presents likely scenarios and perspectives on the lighting market based on the introduction of EISA standards.
01/2011	D&R International, Ltd.	2011 Project Portfolio: Solid-State Lighting	U.S. Department of Energy	Provides an overview of SSL projects currently funded by DOE, and those completed from 2003 through 2010. The document lists projects, with full descriptions, based on LED and OLED categories. Gives a list of emerging technologies.
01/2011	Navigant Consulting	Energy Savings Estimates of Light Emitting Diodes in Niche Lighting Applications	U.S. Department of Energy	Discusses factors that motivate consumers to adopt LEDs and the energy savings that result from the use of LEDs.

Table 2-1 (continued)

Date	Author(s)	Study Title	Study Sponsor(s)	Study Overview
12/2010	Digitimes	LED Lighting Continues Growth to 10% Market Share in 2011		Presents LED market share data for LED lighting and High Brightness HB LEDs. Forecasts through 2013. (News article.)
09/2010	D&R International	2010 Product Snapshot: LED Replacement Lamps	U.S. Department of Energy	Outlines status of LED market and legislation that effects future of market. Presents data for current LED market diversity, with comparisons to CFL and Incandescent lamps. Presents multiple graphs showing LED market status compared to EISA benchmarks.
08/2010	Applied Proactive Technologies, Inc.	The U.S. Replacement Lamp Market, 2010-2015, and the Impact of Federal Regulation on Energy Efficiency Lighting Programs		Focuses on the current status and upcoming changes to the U.S. replacement lamp market. It is written with the intention of guiding EE lighting program planning. Concludes that it is essential for EE programs to continue to promote energy efficient lighting products not only prior to EISA (2007) but also throughout the transition years of 2012-14, and beyond.
05/2010	The Institute for Energy Efficiency, UC Santa Barbara	Fast-Tracking Widespread Adoption of LED Lighting		Summarizes ideas developed during a workshop hosted by the Institute for Energy Efficiency at UCSB. The workshop focused on: LED Research and Manufacturing, Lighting Applications and Systems, Commercialization, and Economics.
04/2010	International Energy Agency	Phase out of incandescent lamps		Discusses incandescent phase out regulatory developments by region.
02/2010	ASHRAE Journal	Solid-State Lighting, Part 2: Applications		Describes the potential for LED lights in certain niche sectors of the lighting industry. These niche sectors include: outdoor lighting, recessed downlights, troffers, and omni-directional replacement lamps.
02/2010	Consortium for energy Efficiency	Position Paper on Solid-State Lighting in Efficiency Programs		Presents information to support the energy efficiency program industry in its effort to effectively communicate with the SSL industry and responsibly identify and assess applications that appear ready for SSL promotion and market introduction.
02/2010	Navigant Consulting	Energy Savings Potential of Solid-State Lighting in General Illumination Applications 2010 to 2030	U.S. Department of Energy	Updates the previously published estimates of energy savings potential from SSL in general illumination applications published in 2006 (DOE, 2006), 2003 (DOE, 2003), and 2001 (DOE, 2001). This report presents an estimate of the national energy savings that could be realized through the market penetration of energy-efficient SSL if the technology achieves certain forecasted price and performance objectives. Provides forecasting data for lumens, price, lamp life, and lumen/Watt. Provides some market information: LED maximum penetration market potential, lumen hour demand. All data is at the national level.
01/2010	ASHRAE Journal	Solid-State Lighting, Part 1: Technology		Describes LED benefits, challenges, and market factors.
01/2010	Greentech Media	Four Solid-State Lighting Trends for 2010		Discusses four SSL trends expected for 2010.

Table 2-1 (continued)

Date	Author(s)	Study Title	Study Sponsor(s)	Study Overview
03/2009	Navigant Consulting, Radcliffe Advisors, SSLS, Inc.	Multi-Year Program Plan FY'09-FY'15	U.S. Department of Energy	Presents a Multi-Year Program Plan (MYPP) to guide SSL Core Technology Research and Product Development over the next few years and informs the development of annual SSL R&D funding opportunities. Outlines the current technology status of SSLs, DOE's current Portfolio and Funding opportunities, and Technology Research and development plans. Also describes R&D accomplishments to date. Main focus is on DOE LED R&D projects, plans, and past accomplishments. Includes some barriers to entry and market status analysis.
11/2008	Duke Center on Globalization Governance and Competitiveness	LED Lighting		Analyzes LED products within the global lighting industry. Describes the LED market, market players, and LED lighting value chain.

Once the above sources were identified and compiled, DNV KEMA staff then reviewed all of these sources and identified the following six key themes:

1) **Diversity** of LED lamps available to consumers in terms of characteristics such as lamp style (i.e., A-lamp, Reflector, etc.), lamp life, wattage, and lumen output;

2) **Availability** of medium screw-base (MSB) LED lamps[5] in retail channels that typically sell light bulbs, including the types of stores that sell LED lamps, the average number of LED lamps per store, and the number of LED lamps available compared to other lamp types;

3) **Pricing** of LED lamps currently available in the market and forecasts for LED pricing moving forward (including average prices and price ranges);

4) **Market Size** of LED lamps within the global and North American general lighting markets;

5) **Installed Base** of LED lamps in the United States and California, and;

6) **Barriers** to LED lamp adoption faced by consumers including high first cost, low lumen output, lamp performance issues, and lack of consumer education.

These themes provide the basis for organizing the results in this report.

2.2 In–Depth Interviews

The purpose of the in-depth interviews was to elicit information on the current status of the market for LED lamps. The interviews focused on California's LED lamp market as much as

[5] The purpose of this report is to characterize the market for LED replacement lamps. Data collected in support of the Fall 2011 California Lighting Retail Store Shelf Survey Report includes both Medium Screw Base (MSB) LED lamps and Non-Medium Screw Base Lamps (Non-MSB) so that MSB lamps (as the most common replacement lamp base type used in residential applications) could be isolated for analysis. Unless otherwise specified, analyses presented in this report refer to MSB LED lamps and the market for MSB LED lamps.

possible, however the majority of respondents were not able to differentiate between market conditions in California and the overall U.S. market.

Based on the information gathered through the Literature Review, the DNV KEMA team identified a list of possible in-depth interview participants. The participants fell into five groups:

1) LED manufacturers;
2) Brick-and-mortar retail stores targeting mass market customers;
3) Wholesale distributors and lighting showrooms targeting contractors and/or nonresidential customers;
4) Online retailers; and
5) Other lighting market experts.

DNV KEMA staff attempted to assign a higher priority to interviews with staff from larger manufacturers and retailers in the U.S., however, in the absence of information regarding manufacturing or sales volume from these entities; it is not possible to state the percentage of the LED lamp market represented by the interview respondents. LED manufacturer and retailer sales and market share data were unavailable and could not be obtained for this report.

In total, DNV KEMA staff completed 37 in-depth interviews with LED market actors in early 2012 (Table 2-2). These interviews helped to provide a robust picture of the U.S. and California market for LED lamps.[6]

[6] Some interview topics included in the research plan for this project were excluded from the report as a result of market actors limited knowledge on the topic, unwillingness to share details, or lack of meaningful responses that could be characterized and aggregated. Topics that were excluded include: availability and diversity of LED fixtures, typical market introduction process for LED lamps and fixtures, decision making around product distribution strategies, retailer decision making regarding new product selection and shelf space allocation, and retailer concerns and efforts to screen for quality.

Table 2-2
Number of Completed In-Depth Interviews by Market Actor Type, 2012

LED Market Actor Type	Number of Completed Interviews
Manufacturer	12
Distributor	8
Retailer – Brick and Mortar	9
Retailer – Online	6
Market Expert	2
Total Interviews	**37**

2.3 Fall 2011 California Lighting Retail Store Shelf Surveys

This report leverages data that was produced as part of the Fall 2011 California Lighting Retail Store Shelf Survey Report.[7] These data provide the foundation for assessments of LED lamp availability, diversity, and pricing in the California market as included in this report.

As part of the Shelf Survey study, field researchers conducted complete inventories (shelf surveys) of lighting products on California store shelves in September through November (Fall) of 2011. Researchers conducted these surveys in a variety of retail stores and collected detailed information on product characteristics and prices. The study includes data on lamp stock and prices across seven retail channels including discount, drug, grocery, hardware, large home improvement, mass merchandise, and membership club stores.

The Fall 2011 Shelf Survey database includes lamp inventories from 184 individual retail stores (Table 2-3) and contains nearly 26,000 records.[8] Each record includes key information regarding each store visited (such as the retail channel, store name, IOU service territory, and store address) as well as information specific to each package of lamps in the store, including model number, lamp type, base type, lamp style, manufacturer, wattage, and number of lamps

[7] DNV KEMA, 2012.
[8] Each record in the database represents a particular lamp model and packaging configuration in a specific store during a shelf survey visit. Researchers may have found the same lamp model in multiple stores. As such, the number of unique models represented by the database is lower than the total number of records.

in each package. Additionally, field staff recorded the number of packages, whether or not the lamps are 3-way or dimmable, the full price per package, the discounted price and discount provider (if relevant), lamp life, color temperature, lamp coating, lumens, wattages, and whether each model was 3-way, dimmable, and/or Energy Star labeled for each package of lamps.[9]

Table 2-3
Number of Stores by Retail Channel -
California Retail Lighting Store Shelf Surveys, Fall 2011

Retail Channel	Number of Stores Surveyed
Discount	27
Drug	27
Grocery	27
Hardware	27
Large home improvement	26
Mass merchandise	24
Membership	26
Total Stores	**184**

2.3.1 Pricing Analysis Methodology

As explained in the Fall 2011 California Lighting Retail Store Shelf Survey Report[10], average prices presented in this report are not sales-weighted because lamp sales data by channel are not yet available for the Fall 2011 time period. However, average prices presented in this report are bulb-weighted; analysts calculated average prices for each lamp type category by taking the following steps:

- First, we calculated the price per lamp for each record of data in the Shelf Survey database by dividing final package price by the number of lamps per package;

[9] For additional information regarding lighting retail store shelf survey methods – including sample design, overview of fieldwork conducted, and approach to data cleaning and analysis – please see the Fall 2011 California Lighting Retail Store Shelf Survey Report – DRAFT (DNV KEMA Energy & Sustainability, 2012).
[10] DNV KEMA, 2012.

- Next, we calculated the total number of lamps for each record in the Shelf Survey database by multiplying the number of packages by the number of lamps per pack;
- Then, we calculated the total lamp price in each record in the Shelf Survey database by multiplying the price per lamp by the total number of lamps; and
- Finally, we calculated the average price per lamp for each lamp type by dividing the sum of total lamp prices for a given lamp type by the sum of the total number of lamps represented by each lamp type.

3. Results

In the following sections, we present the results of our analyses using information from the literature review, in-depth market actor interviews, and the Fall 2011 California Lighting Retail Store Shelf Surveys for each of the six key themes identified in Section 2.1 above (diversity, availability, pricing, market size, installed base, and market barriers).

3.1 Diversity

This section of the report provides details on the LED lamps available to consumers in the U.S. and in California based on the following characteristics:

- Lamp style;
- Rated Life;
- Wattage; and
- Lumen Output and Efficacy.

3.1.1 Style

To provide context for the discussion of lamp diversity, Figure 3-1 displays different replacement lamp styles. See Appendix C for a more detailed depiction of replacement lamp styles.

Figure 3-1
Visual Representation of Lamp Styles

 A-lamp	 Globe	 Reflector
 Candelabra/torpedo	 Bug Light	 Night Light

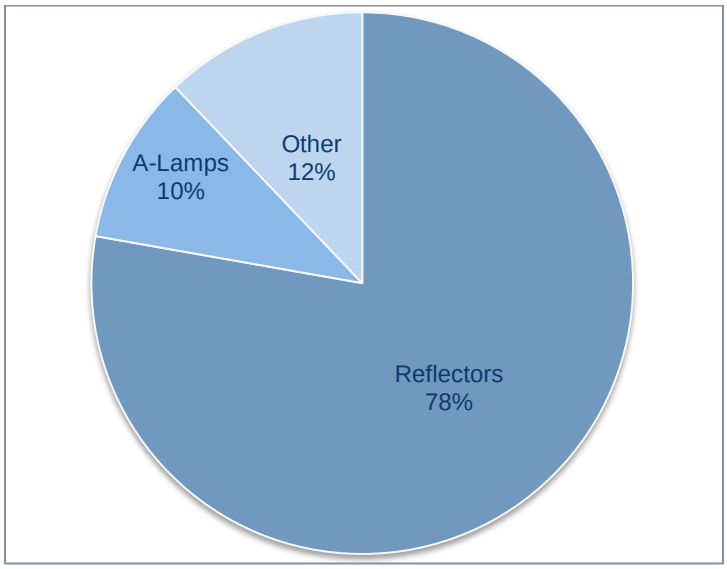
3.1.1.1 U. S. Market

The U.S. Department of Energy (DOE) showcases general purpose LED lamps from manufacturers that participate in specific product testing and reporting practices through its "LED Lighting Facts Program." The program also offers a Lighting Facts label for LED lamps that provides information to help consumers compare products in the marketplace.[11] While the program does not represent all LED replacement lamps available in the U.S., D&R International (which tracks Lighting Facts data for the DOE) suggests that these data represent a substantial and representative snapshot of the market for these products in the U.S.[12]

Data from the DOE Lighting Facts Program implies that although there was a diverse range of LED replacement lamp models available in 2012, these were largely dominated by reflector lamps. As shown in Figure 3-2, reflector lamps accounted for approximately 77 percent of the products reviewed by DOE through mid-May, 2012, while A-lamps accounted for only 10 percent of the lamp models that have been reviewed by the Lighting Facts Program. [13] These results make intuitive sense given that much of the initial focus on LED replacement lamps was on reflector products given that LEDs are a directional technology and reflectors are directional lamps (as opposed to A-lamps, globes, and many other lamp styles, which are omnidirectional).

[11] For more detail, visit www.lightingfacts.com.
[12] U.S DOE Lighting Facts Product List, May, 2012.
[13] *Ibid.*

Figure 3-2
LED Replacement Lamp Models by Lamp Style (All Base Types), 2012[14]



Source: U.S. DOE Lighting Facts Product List, May, 2012 (n=1,835).

Information gathered from DNV KEMA's in-depth interviews with LED lamp manufacturers, distributors, and retailers conducted by DNV KEMA staff[15] suggests that most manufacturers are producing not only reflectors but also A-lamps, and that most of the lighting retailers we interviewed were selling both of these LED lamp types throughout the U.S. as of late 2011 (Table 3-1). The greater presence of LED A-lamps in these results compared to the DOE results presented above may reflect the increasing focus of LED lamp manufacturers and retailers on A-lamps – indeed, manufacturer and retailer representatives who participated in the interviews reported that they are likely to increase their focus on producing and selling A-lamps moving forward because they perceive great market potential for LED A-lamps.

[14] This data was analyzed using the U.S. Department of Energy's Lighting Facts Product data from May 16, 2012. A maximum lumen output of 2,000 was used to provide a relevant data set of replacement LED lamps for this report. Some LED lamps from the DOE product list were outside of this range (streetlights and commercial lamps for example) and they were eliminated from the data set to avoid distortions. Linear replacement lamps were also excluded.

[15] DNV KEMA interviewers also asked interview participants to comment on the types of LED fixtures they manufacture and sell. See Appendix D for more information.

Table 3-1
Number of Market Actors Who Manufacture/Sell LED Lamps
by Lamp Style and Market Actor Group, 2011

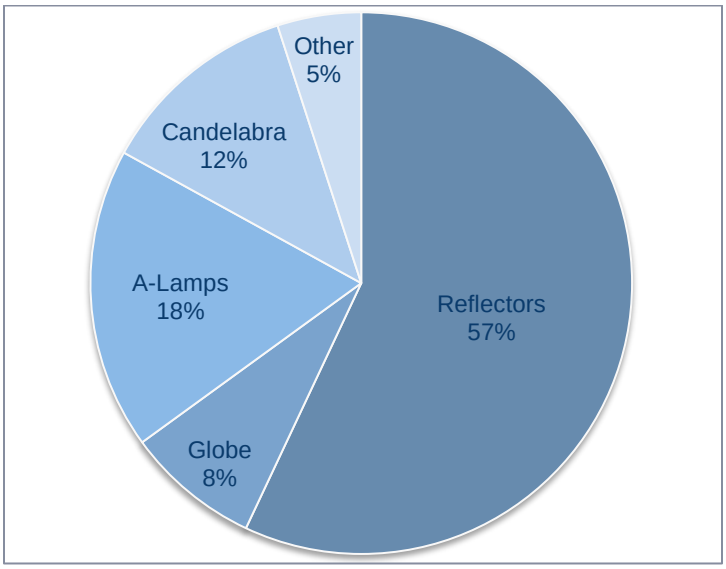
Market Actor Group	Number of Respondents	Number of Respondents Manufacturing/Selling LED Lamp Style					
		A-lamp	Reflector	Globe	Holiday & Nightlight	Candela-bra	Tube
Manufacturer	10	8	9	6	2	3	1
Distributor	8	4	7	4	3	5	2
Retailer - Brick and Mortar	9	7	8	4	5	7	0
Retailer - Online	6	5	5	4	3	4	3
Total Respondents	**33**	**24**	**29**	**18**	**13**	**19**	**6**

Source: In-depth interviews with LED market actors.

3.1.1.2 California Market

During the Fall 2011 California Lighting Retail Store Shelf Surveys, researchers gathered detailed information regarding the lamp model number for all lamps observed in 184 stores. Findings suggest that the LED lamp models observed among California retailers in Fall 2011 were largely comprised of reflectors and A-lamps (Figure 3-3). Fifty-seven percent of the lamps observed during the Fall 2011 shelf surveys were reflectors and 18 percent were A-lamps. These results are similar to those presented in Figure 3-2 above for the national market, and any differences between California and the national market can most likely be attributed to the fact that DOE Lighting Facts product data is cumulative and spans multiple years whereas the data collected as part of the shelf surveys in California was a snapshot of the products on the shelves of California retail stores in late 2011.

Figure 3-3
Percent of LED Lamp Models Observed by Lamp Style (All Base Types), Fall 2011*



Source: DNV KEMA, 2012; n=491 MSB LED Lamps models (all base types)[16] across 184 retail stores.
* "Other" consists of bug lights and recessed downlight lamps.

While reflector lamps made up the majority of unique models observed during the Fall 2011 Shelf Survey, LED A-lamps were the most prevalent MSB lamp style (actual counts of lamps rather than lamp models) accounting for 65% of all MSB lamps observed. Shelf survey results suggest that 80 percent of the available MSB LED lamps found at membership club stores in Fall 2011 were A-lamps (Table 3-2). Not only did membership club stores stock the largest proportion of A-lamps in 2011 compared to other retail channels in California, they also had over 11,000 MSB LED lamps available – nearly three times as many MSB LED lamps as any other store type. Results from DNV KEMA's in-depth interviews with LED suppliers suggest that manufacturers and retailers are likely to focus on A-lamps moving forward because the perceived market potential for those LED replacement lamps is large.

[16] "Other" MSB LED lamps consist of bug lights and recessed downlight lamps.

Table 3-2
Percent of MSB LED Lamps Observed by Lamp Style and Retail Channel, Fall 2011

LED Lamp Style	Retail Channel							Overall (n=184)
	Discount (n=27)	Drug (n=27)	Grocery (n=27)	Hardware (n=27)	Home Improv. (n=26)	Mass Merch. (n=24)	Memb. Club (n=26)	
A-lamp	-	-	65%	12%	33%	31%	80%	65%
Reflector/Flood	-	-	-	61%	54%	20%	18%	29%
Globe	-	-	-	14%	9%	24%	1%	4%
Candelabra/Torpedo	-	100%	35%	10%	4%	24%	-	2%
Other MSB Lamps[17]	-	-	-	3%	1%	-	-	<1%
Total Number of Lamps Observed	**0**	**8**	**62**	**368**	**4,434**	**221**	**11,431**	**16,524**

Source: DNV KEMA, 2012.

Based on observations from the Fall 2011 California Lighting Retail Store Shelf Surveys, LED A-lamps and reflector lamps were both available for purchase in 34 percent of the 184 stores visited during Fall 2011 (Table 3-3)[18]. While A-lamps and reflectors were only available in one-third of retail stores overall, they were both available in at least 85 percent of home improvement stores and membership clubs. Fall 2011 shelf survey results substantiate the market actor interview results in suggesting that LED reflector lamps and LED A-lamps have similar market availability.

[17] Other MSB Lamps include bug and recessed down light lamps.
[18] The availability of LED lamps compared to other lamp types is explained in further detail in Section 3.2

Table 3-3
Percent of Stores Stocking MSB LED Lamps by Lamp Style and Retail Channel, Fall 2011

Lamp Style	Retail Channel							Overall Stores (n=184)
	Discount (n=27)	Drug (n=27)	Grocery (n=27)	Hardware (n=27)	Home Improv. (n=26)	Mass Merch. (n=24)	Memb. Club (n=26)	
A-lamps	0%	0%	15%	22%	85%	25%	92%	34%
Reflector	0%	0%	0%	48%	88%	8%	96%	34%
Globe	0%	0%	0%	26%	85%	25%	15%	21%
Candelabra/Torpedo	0%	15%	15%	19%	46%	21%	0%	16%
Other[19]	0%	0%	0%	4%	8%	0%	0%	2%
Overall	**0%**	**15%**	**15%**	**52%**	**92%**	**29%**	**96%**	**43%**

Source: DNV KEMA, 2012.

3.1.2 Rated Life

3.1.2.1 U.S. Market

According to a 2012 DOE report, LED lamp life averaged 25,000 hours in 2010 and is expected to increase gradually over time.[20] As shown in Table 3-4, the average lamp life of LED lamps is projected to improve by more than 50 percent from 2010 to 2015 and will continue to improve as manufacturers strive to produce longer-lasting LED lamps. Even at current levels, based on manufacturers' claims, LED lamps last more than 20-times longer than traditional incandescent A-lamps (1,400 hours) and over 3-times as long as a general purpose CFL (10,000 hours).[21] However, according to Pacific Northwest National Laboratory, over half of the lamps tested are not expected to meet manufacturer-claimed lifetimes – so it is difficult to assess the accuracy of these projections.[22] However, comparing DOE projections for lamp life from 2010 and 2012 reports suggests that DOE has scaled back its earlier projections regarding the rate at which lamp life will increase between 2010 and 2015.

[19] "Other" MSB LED lamps consist of globe, torpedo/candelabra, bug light and recessed downlight lamps.
[20] Navigant Consulting, 2012a. Page 64.
[21] *Ibid,* Page 19.
[22] Pacific Northwest National Laboratory, 2011. Page 3.

Table 3-4
Average Rated LED Lamp Life in Hours, 2010 Actual and 2011-2015 Projected

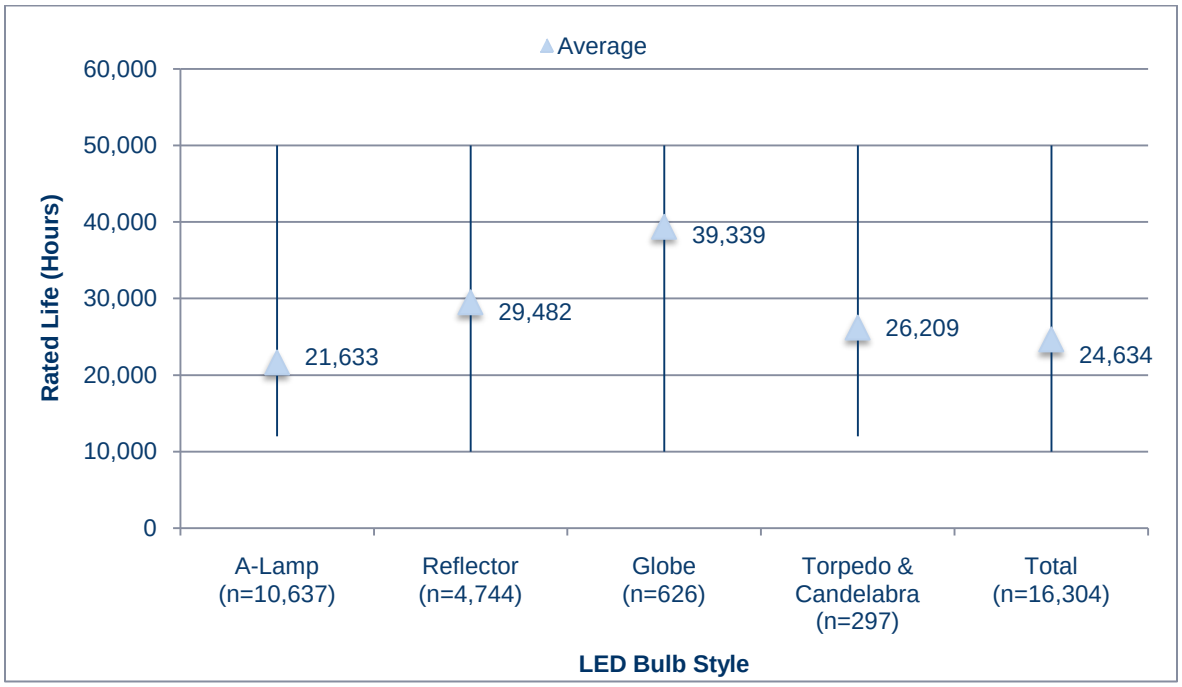
Year	Average Rated Life (in Hours)
2010	25,000
2011 (projected)	33,000
2012 (projected)	36,600
2013 (projected)	39,600
2014 (projected)	42,100
2015 (projected)	44,100

Source: Navigant Consulting, 2012a.

3.1.2.2 California Market

Average lamp life for LED lamps as reported by DOE (in Table 3-4 above) are in line with what DNV KEMA field researchers observed during the Fall 2011 California Lighting Retail Store Shelf Surveys. Researchers recorded the claimed product lifetimes shown on lamp packages, and as shown below in Figure 3-4, the average lamp life for LED lamps observed during the shelf surveys was 24,634 hours, slightly below the DOE average of 25,000 hours for 2010 but well below the projection of 33,000 hours for 2011. Results from the Fall 2011 shelf surveys suggest a range in claimed lamp life for MSB LED lamps of 10,000-50,000 hours.

Figure 3-4
Range and Average Rated Life of MSB LED Lamps by Lamp Style, Fall 2011



Source: DNV KEMA, 2012. n= 16,304 MSB LED lamps across 184 retail stores.[23]

3.1.3 Wattage

3.1.3.1 U.S. Market

DOE Lighting Facts Product data from May, 2012 (Table 3-5) indicates that LED replacement lamps for sale in the U.S. range from 1 to 30 watts and average 9.5 watts across all lamp styles.[24] Reflector lamps ranged from 1 to 29.8 watts, however, lower wattage lamps appear to be more prevalent as the average wattage for reflectors is 10.2 watts. A-lamps reviewed by

[23] Lamp life information was unavailable for a small sample of MSB LED lamps (n=220) and, as such, these lamps were not included in the analysis of lamp life.

[24] This data was analyzed using the U.S. Department of Energy's Lighting Facts Product data from May 16, 2012. A maximum lumen output of 2,000 was used to provide a relevant data set of replacement LED lamps for this report. Some LED lamps from the DOE product list were outside of this range (streetlights and commercial lamps for example) and they were eliminated from the data set to avoid distortions. Linear replacement lamps were also excluded.

DOE had a smaller wattage range than reflectors, 2 to 21.8 watts, and averaged 8.2 watts as of May, 2012.

Table 3-5
Wattage Diversity of LED Replacement Lamps by Lamp Style, 2012

Lamp Style	Wattage Range	Average Wattage	Number of Lamps Observed
A-lamp	2.0 – 21.8	8.2	190
Reflector	1.0 – 29.8	10.2	1,422
Other	.57 – 29.8	5.6	223
Overall	**.57 – 29.8**	**9.5**	**1,835**

Source: U.S. DOE Lighting Facts Product List, May, 2012

3.1.3.2 California Market

Results from the 2011 California Lighting Retail Store Shelf Surveys suggest that LED wattages observed in the 184 retail stores visited as part of the study closely resemble those reported for the national market from the DOE. Similar to the national-level data, the MSB LED reflector lamps observed 184 California retail stores in Fall 2011 had the highest average at 14 watts per lamp, while A-lamps had a much narrower range compared to the national data and averaged 5.6 watts per lamp (Table 3-6).

Table 3-6
Wattage Range and Average Wattage for MSB LED Lamps by Lamp Style, Fall 2011

Lamp Style	Wattage Range	Average Wattage	Number of Lamps Observed
A-lamp	0.6 – 13.0	5.6	10,802
Reflector	0.9 – 24.0	14.0	4,744
Globe	1.3 – 10.0	6.0	626
Candelabra / Torpedo	1.2 – 4.0	2.4	297
Other[25]	2 - 14.5	9.8	55
Overall	**0.6 – 24.0**	**8.0**	**16,524**

Source: DNV KEMA, 2012. n=16,524 MSB LED lamps across 184 retail stores.

[25] Other MSB Lamps include bug lights and recessed down light lamps.

3.1.4 Lumen Output and Efficacy (Lumens per Watt)

3.1.4.1 U.S. Market

According to DOE, LED replacement lamps had a limited range of available lumen options in the U.S. market during 2011. LED lamps matching 450 lumens and 800 lumens – roughly equivalent to 40 and 60-watt traditional incandescent lamps – were readily available to consumers in 2011.[26] LED lamps with lumen outputs of 1,100 (equivalent to 75W standard incandescent lamps) have begun to appear in the national market but were not widespread as of 2011, while DOE reports that 1,600 lumen replacement lamps (100W incandescent equivalent) are not expected to reach the market before 2013.[27]

While availability is limited for high-lumen LED lamps equivalent to some common incandescent lamps (e.g., 75 and 100 watts), LED lamps are already significantly more efficient than incandescent lamps[28]. Based DOE data (Table 3-7), LED lamps are projected to average 48.3 lumens per watt during 2011, which is approximately three times as efficient as a traditional 100 Watt incandescent lamp (which produce approximately 16 lumens per watt).[29] Projections based on these data suggest a tripling in LED lamp efficacy between 2010 and 2015, further widening the efficiency gap between LED lamps and traditional incandescent lamps.[30]

[26] D&R International, 2011a. Page 4.
[27] *Ibid.*
[28] Lumen output and efficiency (lumens/watt) varies by lamp style, size, and intended application.
[29] Navigant Consulting, 2012a.
[30] *Ibid.*

Table 3-7
Current and Projected LED Lamp Efficacy (Lumens per Watt),
2010 Actual and 2011-2015 Projected

Year	Efficacy (in Lumens/Watt)
2010	36.9
2011 (projected)	48.3
2012 (projected)	61.7
2013 (projected)	77.6
2014 (projected)	94.8
2015 (projected)	112.5

Source: Navigant Consulting, 2012a.

3.1.4.2 California Market

Average LED lamp efficacy observed during DNV KEMA's Fall 2011 California Lighting Retail Store Shelf Surveys is closely aligned with the national-level estimates from DOE shown above (in Table 3-7). The overall average observed for lumens per watt among LED lamps in the Fall 2011 shelf surveys (54.5 lumens per watt) is very close to the national average of 48.3 lumens per watt for 2011 (based on DOE estimates), the efficacy range for lamps observed in the Fall 2011 shelf surveys in California -- 3 to 136 lumens per watt -- is quite broad, suggesting a variety of light output options available in California during 2011 (Table 3-8).

Table 3-8
Efficacy Range and Average Efficacy for MSB LED Lamps by Lamp Style, Fall 2011

Lamp Style	Efficacy Range (in Lumens/Watt)	Average Efficacy (in Lumens/Watt)	Number of Lamps Observed
A-lamp	32 - 136.4	57.3	10,802
Reflector	4.5 – 110.0	49.1	4,744
Globe	3 - 106.3	50.1	626
Candelabra / Torpedo	30.0 – 65.0	45.5	297
Other[31]	44.8 – 135.0	70.5	55
Overall	**3.0 - 136.4**	**54.5**	**16,524**

Source: DNV KEMA, 2012.

[31] Other MSB Lamps include bug lights and recessed down light lamps.

3.2 Availability

Availability refers to the proportion of stores by retail channel that stock LED lamps, the average number of LED lamps stocked per store, and the number of LED lamps available compared to other lamp types. The availability of LED lamps by retail channel was only available for California where DNV KEMA researchers conducted the Fall 2011 California Lighting Retailer Store Shelf Survey at 184 retail locations throughout the state. Comparable national data were not available for inclusion in this report.

3.2.1 California Market

Percent of Stores Carrying LEDs. As mentioned above in Section 3.1.1.2, a diverse range of LED products were observed in 184 California retail stores during Fall 2011. Table 3-9 summarizes these results for the MSB LED products observed in these stores compared to their incandescent and CFL equivalents. As shown, field researchers observed LED A-lamps, reflectors, and/or globes in six of the seven retail channels, with these LED lamps absent only from discount stores.

More than 90 percent of membership club stores and home improvement stores included in the 2011 shelf surveys carried at least one MSB LED lamp model. On the opposite end of the spectrum were discount stores (in which researchers observed no LED lamps) and grocery stores, in which researchers observed LED lamps in only 15 percent of the stores visited during Fall 2011. As a point of comparison, researchers observed CFLs in almost three-quarters of the stores visited within each of the seven retail channels included in the Fall 2011 shelf surveys.

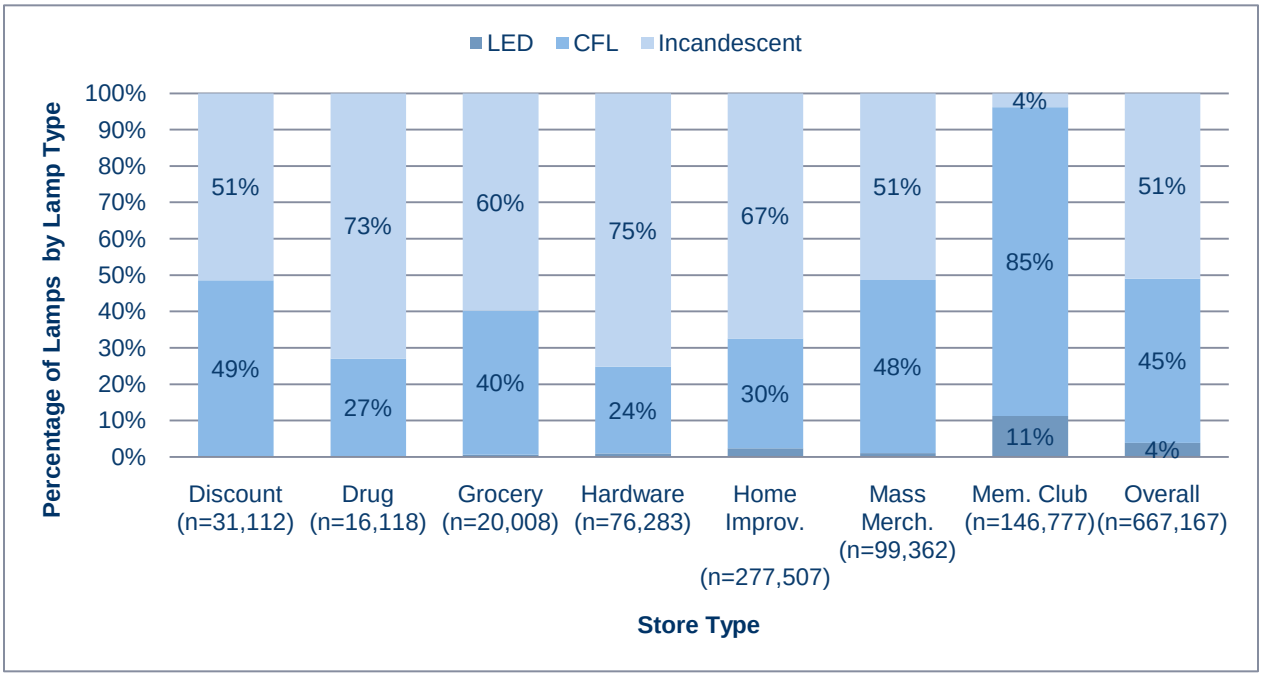
Table 3-9
Percent of Stores Carrying MSB Lamps by Lamp Type and Lamp Style, Fall 2011

MSB Lamp Type/Style	Retail Channel							Overall (n=184)
	Discount (n=27)	Drug (n=27)	Grocery (n=27)	Hardware (n=27)	Home Improv. (n=26)	Mass Merch. (n=24)	Memb. Club (n=26)	
MSB Twister CFLs								
CFL	74%	100%	78%	96%	100%	96%	100%	92%
MSB A-lamp								
LED	0%	0%	15%	22%	85%	25%	92%	34%
CFL	30%	93%	44%	78%	100%	92%	46%	68%
Incandescent	93%	85%	93%	100%	100%	96%	15%	83%
MSB Reflector/Flood								
LED	0%	0%	0%	48%	88%	8%	96%	34%
CFL	22%	93%	33%	96%	100%	71%	88%	72%
Incandescent	48%	85%	59%	96%	100%	83%	4%	68%
MSB Globe								
LED	0%	0%	0%	26%	85%	25%	15%	21%
CFL	15%	74%	22%	74%	96%	83%	92%	65%
Incandescent	70%	85%	48%	89%	100%	71%	0%	66%
All MSB LED Styles	**0%**	**15%**	**15%**	**52%**	**92%**	**29%**	**96%**	**43%**

Source: DNV KEMA, 2012.

Share of Observed Lamps by Lamp Type. As shown in Figure 3-5, LED lamps represented less than 4 percent of the total lamps observed in the 184 stores visited during the Fall 2011 California Lighting Retail Store Shelf Surveys. Traditional incandescent lamps represented 51 percent of the lamps observed across all store types, while CFLs represented 45 percent of the lamps observed. LED lamps comprised more than 10 percent of the total lamps observed in membership clubs in our sample, far more than in any other retail channel.

Figure 3-5
Percentage of Total Lamps Observed by Lamp Type and Retail Channel (All Base Types), Fall 2011

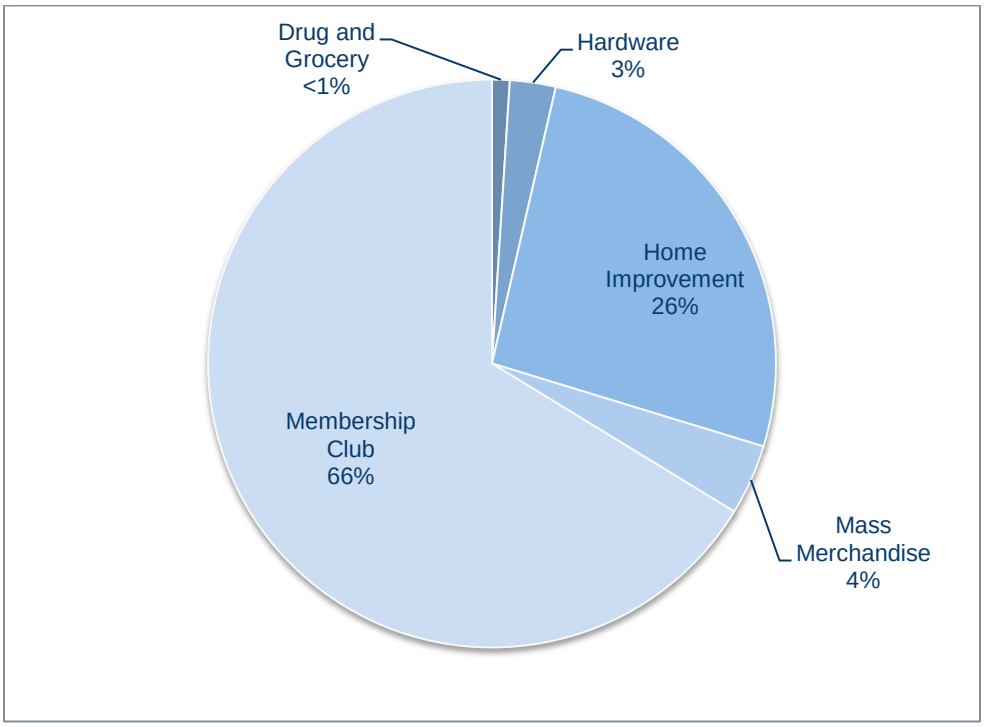


Source: DNV KEMA, 2012. Sample included 184 retail stores.

Share of Observed LED Lamps by Retail Channel. Of the 24,807 LED lamps observed during the Fall 2011 California Shelf Surveys (across all base types), the majority of the lamps were available at either home improvement or membership club stores. As shown in Figure 3-6, membership club stores accounted for 66 percent of all LED lamps observed during the Shelf Surveys (roughly 16,500 LED lamps). The high numbers of LEDs at membership clubs in California are likely due to the decision by some membership clubs to stop stocking traditional incandescent lamps in favor of more efficient CFL, LED and EISA-compliant incandescent/halogen lamps, and also the fact that chains in this channel tend to carry larger packaging sizes (multi-packs).[32, 33]

[32] DNV KEMA staff obtained this information through in-depth interviews conducted with membership club representatives in 2010 in support of several different studies (e.g., NMR Group, Inc., KEMA, Inc., Cadmus Group, Inc., and Tetra Tech, 2011 and KEMA Inc. and ECONorthwest, 2010).

Figure 3-6
Share of All LED Lamps Observed by Retail Channel (All Base Types), Fall 2011

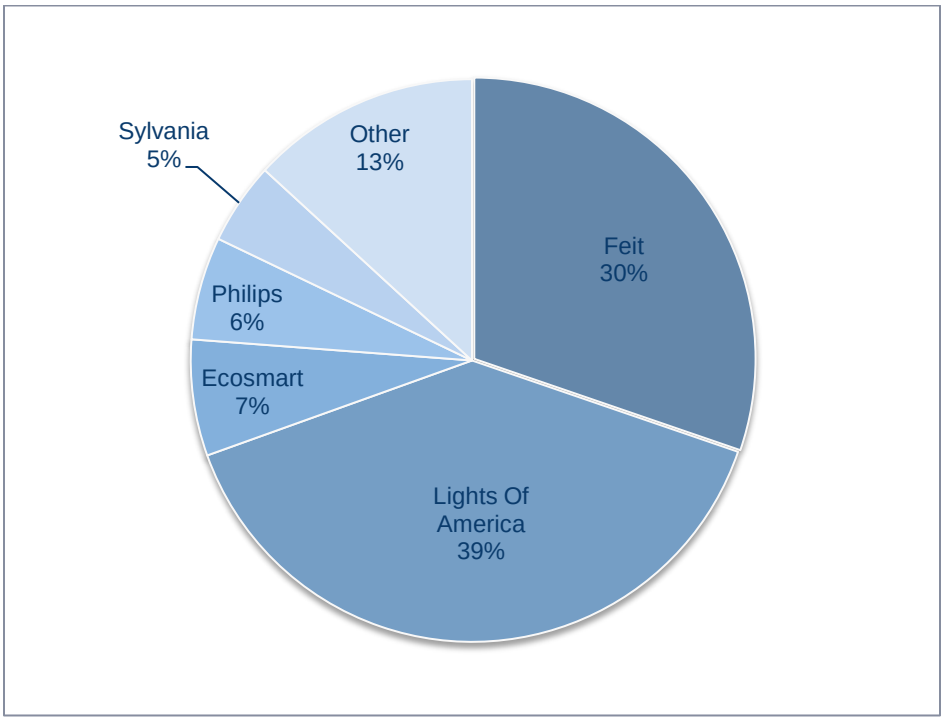


Source: DNV KEMA, 2012. n= 24,807 LED lamps (all base types) across 184 retail stores.

Share of Observed LED Lamps by Manufacturer. Figure 3-7 shows the share of all of the LED lamps observed during the Fall 2011 California shelf surveys by lamp manufacturer. This data suggests that two manufacturers -- Feit and Lights of America – accounted for more than two-thirds of all lamps observed in the 184 stores visited in California during Fall 2011. Only three other manufacturers – Ecosmart, Sylvania, and Utilitech – accounted for at least 5 percent of the observed lamps, respectively. A number of smaller players (24 manufacturers in total) comprise the remaining 13 percent of lamps observed in Fall 2011.

[33] Less than 4 percent of the total lamps observed in Membership Clubs were incandescent lamps, all of which were EISA-compliant products.

Figure 3-7
Share of All LED Lamps Observed by Manufacturer (All Base Types), Fall 2011



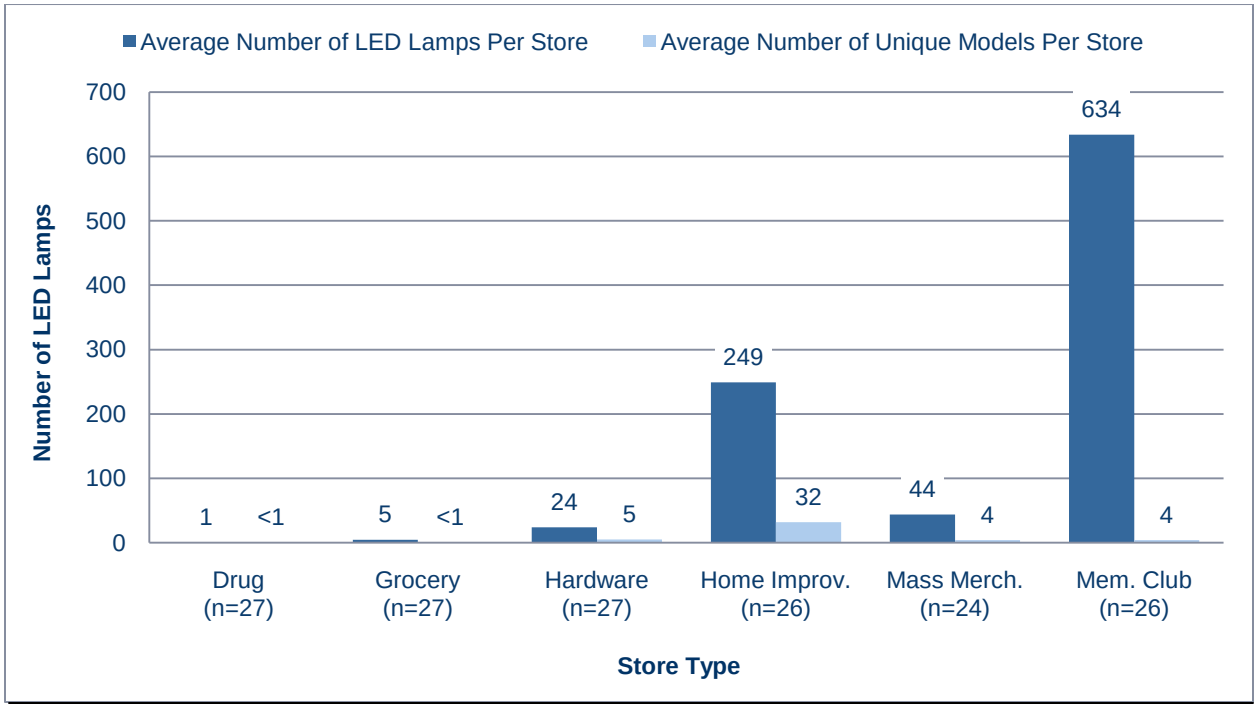
Source: DNV KEMA, 2012. n= 24,807 LED Lamps (all base types) across 184 retail stores.

Average Number of LED Lamps and Unique LED Models Observed per Store. During the Fall 2011 California Lighting Retail Store Shelf Surveys, field researchers counted all of the lamp packages observed in each store. To determine the total number of lamps per store, analysts multiplied the number of packages by the number of lamps in each package. For LED lamps, field staff observed an average of 26 LED lamps per store during the Fall 2011 shelf surveys. As shown in Figure 3-8, the average number of lamps per store varied widely by retail channel. Grocery and drug stores averaged less than 10 LED lamps per store visited in 2011 while hardware and mass merchandise stores averaged 57 and 44 LED lamps per store, respectively. At the opposite end of the spectrum, home improvement stores averaged 249 LED lamps per store visited in 2011 and membership club stores carried by far the most LEDs, with an average of 634 LED lamps per store.

While membership club stores averaged more than twice as many LED lamps per store as home improvement stores, they averaged only approximately 4 unique models per store compared to 32 unique models per home improvement store. These data suggest that while

membership club stores stock a larger number of lamps compared to other channels, they do not offer as much product diversity as home improvement or hardware stores.

Figure 3-8
Average Number of LED Lamps and Unique LED Models Observed per Store by Retail Channel (All Base Types), Fall 2011[34]



Source: DNV KEMA, 2012. n= 24,807 LED Lamps (all base types)

3.3 Pricing

This section presents a summary of LED pricing data available from the national studies examined as part of the literature review task as well as comparative pricing data for various lighting products observed in California retail stores during Fall 2011.

[34] For details regarding the total number of lamps observed across all stores within each retail channel, please refer to Table D-3 in Appendix D.

3.3.1 U.S. Market

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 3-10).[35] In 2008, DOE estimated the average cost of LED A-lamps (specifically the A19 size) to be $170 per kilolumen,[36] 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 by DOE.[37] 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.[38]

Table 3-10
Cost of Light Sources ($/kilolumen), 2010

Replacement Lamp Types	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, Navigant Consulting, Radcliffe Advisors, SB consulting, SSLS, Inc., 2011a.

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.[39] 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

[35] Bardsley Consulting, Navigant Consulting, Radcliffe Advisors, SB consulting, SSLS, Inc., 2011a, Page 38.
[36] Navigant Consulting, 2010. Page 69.
[37] Bardsley Consulting, Navigant Consulting, Radcliffe Advisors, SB consulting, SSLS, Inc., 2011a, Page 38.
[38] Navigant Consulting, 2012a, Page 64.
[39] Bardsley Consulting, Navigant Consulting, Radcliffe Advisors, SB consulting, SSLS, Inc., 2011a, Page 39.

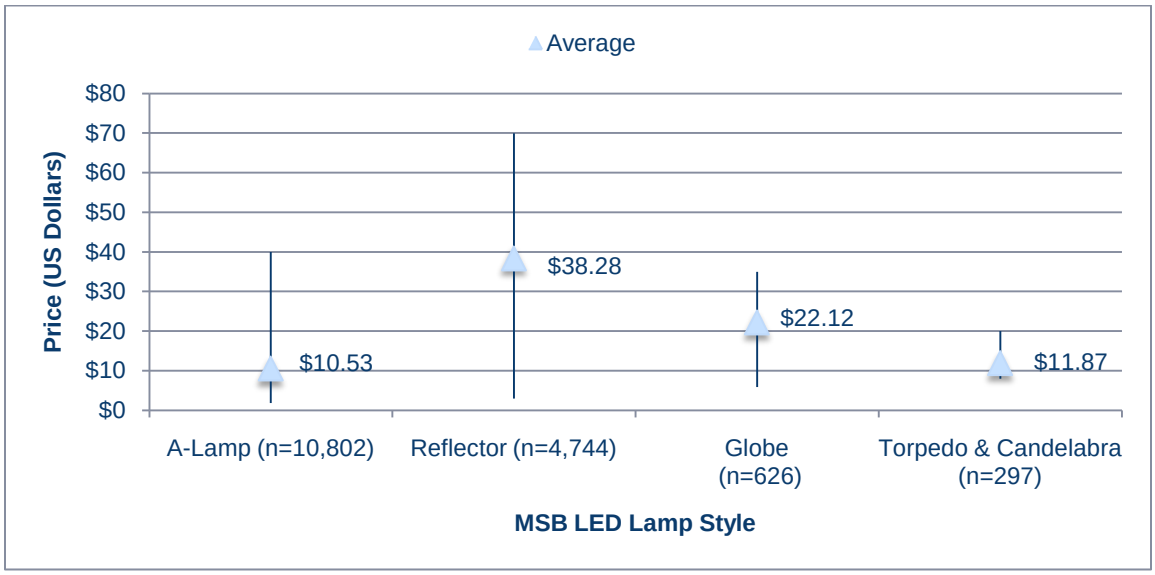
and $60 for a 17 to 18 watt PAR 38 lamp (750-850 lumens).[40] Overall, the DOE found retail prices for LED lamps were around $36 on average, roughly 30 times higher than the initial cost of incandescent lamps and 9 times higher than the initial cost of CFLs in 2010.[41]

3.3.2 California Market

California lamp prices discussed in this section are based on data derived from DNV KEMA's Fall 2011 California Lighting Retail Store Shelf Surveys using the weighting methods discussed in Section 2.3.1. Data gathered during the Fall 2011 Shelf Survey suggests an overall average price per LED lamp of just over $15 (see Table D-2 in Appendix D for average price per lamp type by channel). The Fall 2011 Shelf Survey data suggests price ranges for MSB LED lamps across four lamp styles in a sample of 184 retail stores. Researchers observed the broadest range of prices for reflector lamps ($3-$70) and the smallest range for torpedo and candelabra lamps ($8-$20), but price ranges were fairly broad overall (Figure 3-9). Based on these data, the average lamp price for most LED lamp styles was typically in the middle to lower end of the price range.

[40] *Ibid.*
[41] Bardsley Consulting, Navigant Consulting, Radcliffe Advisors, SB consulting, SSLS, Inc., 2011a. Section 3.5.

Figure 3-9
MSB LED Lamp Price Ranges by Lamp Style, Fall 2011



Source: DNV KEMA, 2012.

The lamp prices recorded by field staff during the Fall 2011 Shelf Surveys included the discounted and non-discounted prices for CFLs. In this case, "discounted" refers to the purchase after any discount was applied, and "non-discounted" refers to lamps for which no discounts were available at the time of the shelf surveys.[42] When average LED lamp prices from the Fall 2011 shelf surveys are compared with those for both discounted and non-discounted CFLs as well as incandescent lamps, LED prices are higher (Table 3-11). As shown:

- LED A-lamps averaged three times the price of non-discounted CFL A-lamps and about 10 times the price of discounted CFL A-lamps and traditional incandescent A-lamps. It should also be noted that based on findings from the Fall 2011 shelf surveys, the average LED A-lamp in California is priced well below the DOE average ($20-40 less depending on lumen output).

- LED reflector lamps observed by California shelf survey researchers were more than seven times as expensive as the average incandescent and discounted CFL reflector

[42] Discounts included those from the California IOUs and other sources.

lamp and more than 10 times as expensive as the average discounted CFL reflector lamp. Average prices for LED reflector lamps in California appear to be in line with the national averages estimated by DOE.

Table 3-11
Average MSB Lamp Price by Lamp Type and Lamp Style (All Base Types), Fall 2011

Lamp Style	Lamp Type			
	CFL		LED	Incandescent/ Halogen
	Discounted*	Non-Discounted		
MSB lamps				
Basic twister CFLs (≤30 watts)	$0.97	$2.29	-	-
A-lamp	$1.05	$3.60	$10.53	$1.25
Reflector/flood	$1.83	$4.82	$38.28	$5.06
Globe	$1.23	$3.24	$22.12	$2.12
Candelabra & torpedo shape	-	$5.88	$11.87	$1.45
Other MSB lamps[43]	-	$1.83	$35.22	$2.83
Total Lamps	**95,103**	**178,927**	**16,524**	**254,385**

Source: DNV KEMA, 2012.
* "Discounted CFLs" refer to the CFL purchase price after any discounts (provided by IOUs or others) were applied.

While the price of LED A-lamps observed during the Fall 2011 California Retail Store Shelf Survey averaged $10.53, below the average price estimated by DOE, it is important to understand how brightness (lumen output) affects the price of A-lamps. Table 3-12 breaks out the price of A-lamps observed in California using the lumen bins defined by EISA[44] and shows that bright lamps with a higher lumen output are significantly more expensive than the average price. "Medium low brightness" A-lamps with a lumen out roughly equivalent to a 60 watt incandescent lamp averaged over $30 per lamp, which is in-line with DOE estimates. The vast majority of A-lamps observed in California were cheap, low lumen output lamps found at membership club stores. No A-lamps were observed in the "medium high" or "high" brightness categories, roughly equivalent to 75 watt and 100 watt incandescent lamps, respectively.

[43] "Other" MSB LED lamps consist of bug lights and recessed downlight lamps.
[44] The "very low brightness" category (0-309 lumens) is not regulated by EISA but was included in the analysis because of the large number of A-lamps observed in that category.

Table 3-12
Average Price and Price Range of MSB LED A-lamp by Lamp Brightness, Fall 2011

Lamp Brightness (Lumens)	Observed Lamps	Low Range	High Range	Average Price
Very Low Brightness (0-309)	4,631	$4.97	$34.99	$6.55
Low Brightness (310-749)	5,817	$1.86	$39.88	$12.58
Medium Low Brightness (750-1049)	354	$16.98	$39.98	$31.22
Medium High Brightness (1050-1489)	-	-	-	-
High Brightness (1490-2600)	-	-	-	-
Overall	**10,802**	**$1.86**	**$39.98**	**$10.53**

Source: DNV KEMA, 2012.

3.4 Market Size

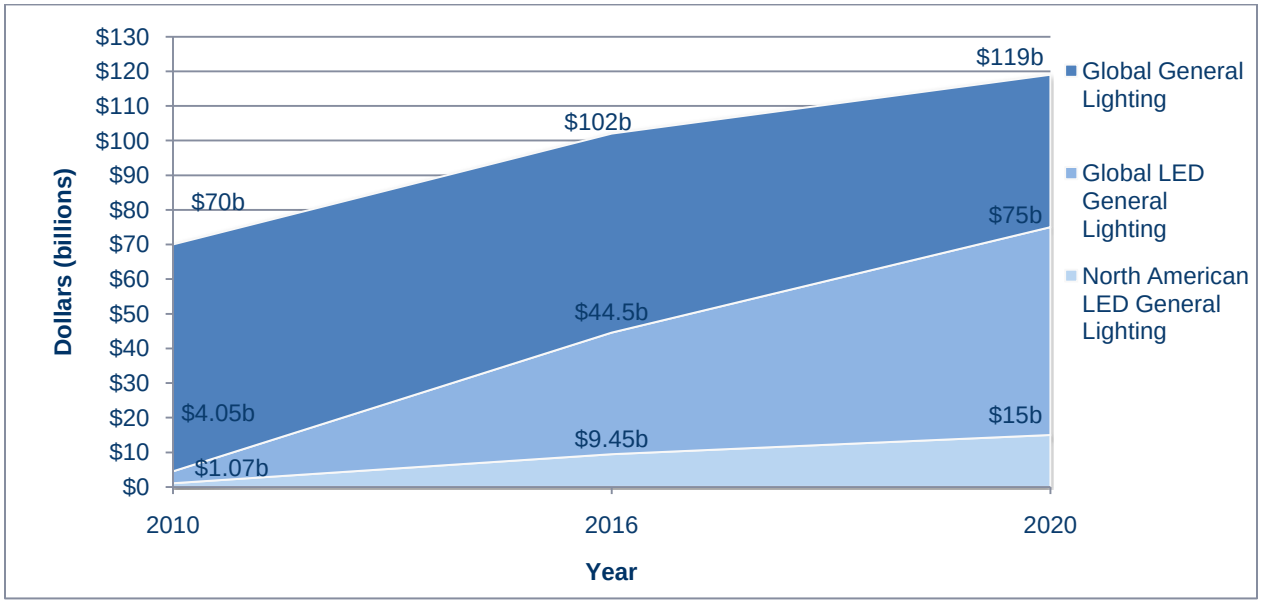
DNV KEMA staff collected information on the size of the global and North American LED market through the literature review process described in Section 2.1. Comparable data was not available for California.

A 2011 McKinsey & Company report provides detailed data on the size of the global lighting market and forecasts market size going forward. [45] The study provides data for "general lighting," which includes both replacement lamps and new installations across all lamp technologies (i.e. incandescent, CFL, LED, etc.) in the residential, office, industrial, shop, outdoor, hospitality, and architectural sectors. The data also includes an equivalent "LED general lighting" category which is a subset of the overall general lighting market. As shown in Figure 3-10, the estimated value of the global general lighting market – which includes all lamp types in the sectors described above – was $70 billion in 2010, and is expected to increase to $119 billion by 2020. The global LED general lighting market was valued at $4.05 billion in 2010, accounting for approximately 6 percent of the global general lighting market value. [46] The study authors project that the value of the global LED general lighting market will grow by a

[45] McKinsey & Company, 2011. Exhibit 1.
[46] McKinsey & Company, 2011. Exhibit 8.

factor of sixteen over the next ten years, and is projected to be worth $75 billion by 2020.[47] It is also estimated that by 2020, global LED general lighting will represent 63 percent of the global general lighting market (up from 6% in 2010).[48] It should be noted that most of the exponential growth in the LED market is expected to occur in the next several years, with the global LED market increasing in size by over 1,000 percent from 2010 to 2016. Growth projections slow after 2016 as more longer-life LEDs penetrate the market, reducing the demand for replacement lamps.

Figure 3-10
Overall Global General Lighting and LED General Lighting Market Size, 2010-2020



Source: McKinsey & Company, 2011.

The North American LED general lighting market was worth approximately $1.07 billion in 2010 (Figure 3-10 above) according to McKinsey & Company.[49] The same source predicts that the value of the North American LED general lighting market will reach $15 billion in 2020, a fifteen-fold increase compared to the current market value.[50] Similar to the global LED market, most of

[47] *Ibid.*
[48] *Ibid.*
[49] McKinsey & Company, 2011. Page 56.
[50] McKinsey & Company, 2011. Page 52.

the exponential growth in the North American market is expected to occur in the 2010 to 2016 time period. While McKinsey forecasts significant growth in the North American LED market, most of the growth in the global LED market will occur in lighting markets outside of North America - suggesting that factors outside of the North American market may ultimately drive trends such as price and quality.

Projections of rapid and exponential growth for the LED market were also a common theme amongst the various market actors with whom DNV KEMA conducted in-depth interviews: all twelve of the lighting manufacturers reported that they expect the U.S. LED market to grow significantly over the next few years, with one of the larger manufacturers projecting 60 to 70 percent annual growth in the U.S. from 2011 to 2012 and some of the smaller players projecting 200 to 1,000 percent annual growth over the same time period. Representatives of LED retailers and distributors we interviewed (n = 15 and 8, respectively) were also in unanimous agreement regarding the expectation for significant growth of the LED market over the next few years.

3.5 Installed Base of LED Lamps

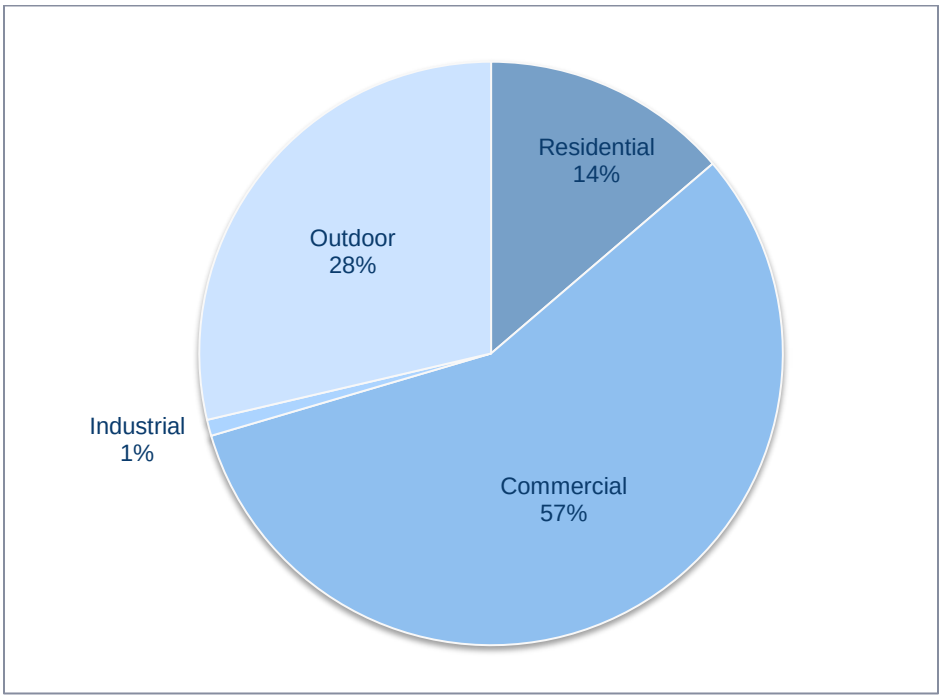
In this section we discuss the installed base of LED lamps in the U.S. and California markets. Installed base refers to the number of LED lamps in light sockets and the percentage of LED lamps installed in light sockets compared to other lamp types.

3.5.1 United States

According to a 2012 report, there were 67 million LED lamps installed in the United States in 2010, which represented less than 1 percent of the total installed lamp base in the U.S.[51] As shown in Figure 3-11, the majority of LED lamps are installed in the commercial sector. According to the same source, there were roughly 9 million LED lamps installed in the residential sector in 2010, accounting for only 14 percent of the total LED lamps installed.

[51] Navigant, 2012b. Page 22.

Figure 3-11
Estimated Inventory of LED Lamps Installed in the U.S. by End-Use Sector, 2010



Source: Navigant, 2012b.

The U.S. installed base of reflector lamps during 2010 is shown in Table 3-13. LED reflector lamps represented only 0.2 percent of all directional lamps installed in 2010, or approximately 900,000 of the estimated 534 million total directional lamps installed as of 2010.[52]

[52] Navigant Consulting, 2011.

Table 3-13
U.S. Reflector Lamp Installed Base, 2010

Lamp Style	Percentage	Number of Lamps (000's)		
		Residential	Commercial	Total Lamps
PAR20 (halogen)	9.8%	33,900	19,300	53,200
PAR30 (halogen)	11.1%	38,700	20,200	58,900
PAR38 (halogen)	16.8%	60,800	28,900	89,700
BR30 (incandescent)	37.9%	180,000	21,800	202,000
BR40 (incandescent)	8.2%	38,800	4,700	43,500
R20 (incandescent)	10.0%	48,300	5,010	53,300
CFL Reflector	6.0%	32,000	-	32,000
LED Reflector	0.2%	-	900	900
Total	**100%**	**433,000**	**101,000**	**534,000**

Source: Navigant Consulting, 2011.

3.5.2 California

During 2008 and 2009, field researchers conducted comprehensive inventories of lamps installed in more than 63,000 light sockets in 1,200 California households as part of the Residential Lighting Metering Study.[53] KEMA, Inc. conducted the Metering Study as part of an evaluation of the California investor-owned utilities' 2006-2008 Upstream Lighting Program.[54] Results suggest that less than one percent of residential light sockets in California were filled with LED lamps as of 2008-2009.While it is acknowledged that data from 2008-09 is quite old in relation to the rapidly changing LED market, this is the only data currently available on the installed base of lamps in California. This data will be updated in late 2012 or early 2013 as part of the California Lighting and Appliance Saturation Survey (CLASS).

3.6 Market Barriers

Based on findings from the literature review and interviews with representatives of LED lamp suppliers and LED market experts, DNV KEMA researchers compiled a list of the primary barriers for LED lamp adoption by consumers. While the literature review sources addressed

[53] KEMA, Inc., PA Consulting Group, Jai J. Mitchell Analytics, The Cadmus Group, and Itron, 2010b.
[54] KEMA, Inc., PA Consulting Group, Jai J. Mitchell Analytics, The Cadmus Group, and Itron, 2010a.

several other barriers, researchers focused on the four most prevalent barriers in these sources, including:

- High first cost;
- Low lumen output;
- Performance issues; and
- Lack of education.

3.6.1 High First Cost

Among the barriers identified for LED lamps, high first cost was most frequently cited by literature review sources as the largest obstacle to LED lamp adoption by consumers. This perspective was reiterated participants in the in-depth interviews with LED market actors conducted in early 2012, including 9 of the 12 manufacturers and all 15 of the retailers we interviewed (brick-and-mortar and online). In a 2011 report, DOE documented retail prices of 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.[55] Retail pricing of LED lamps observed during the Fall 2011 California Retail Store Shelf Survey also suggest that high first cost of LEDs presents a significant barrier to consumer adoption with the average cost of LED A-lamps, the most common household replacement lamp style, over three times more expensive than non-discounted CFLs and almost ten times more expensive than discounted CFL and incandescent A-lamps.

3.6.2 Low Lumen Output

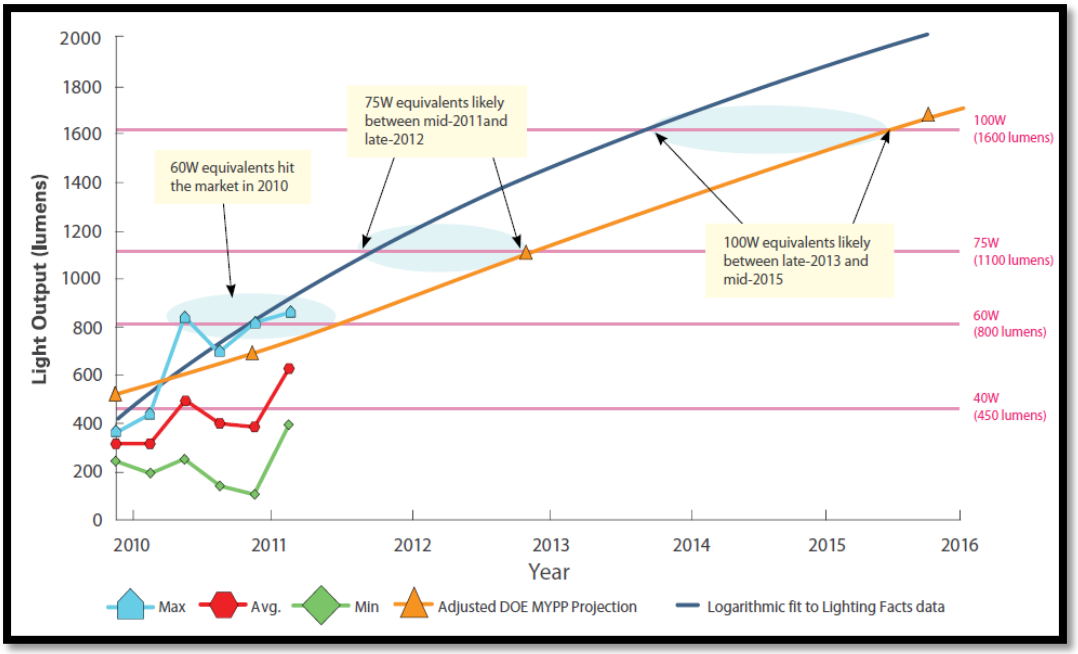
Currently, high-lumen LED lamp options are limited in the market and LED equivalents do not exist for some common high-lumen lamps, presenting a barrier to widespread LED adoption. With the current level of lumen output available, LEDs are not able to compete in the markets for 1,100 lumen and 1,600 lumen replacement lamps (roughly equivalent to standard 75 watt and 100 watt incandescent lamps, respectively). Figure 3-12 shows the trends in lumen output improvements over the past year and an average of 650 lumens for LED lamps in 2011 based

[55] Bardsley Consulting, Navigant Consulting, Radcliffe Advisors, SB consulting, SSLS, Inc., 2011a. Section 3.5.

on DOE data.[56] According to DOE projections, LED lamps will begin to enter the 75 watt equivalency (1,100 lumens) market in 2012 and the 100 watt equivalency (1,600 lumens) market between 2013 and 2015.[57]

Both DOE and industry analysts expect lumen output to improve over time. This continuous upward trend is likely to be driven by upcoming lighting standards for manufacturers and improvements in LED technology. By 2015, it is likely that the lumen output barrier will be significantly reduced and the diversity in LED lumens will have increased.

Figure 3-12
Non-Directional LED Lamp Performance Trends and Projections, 2011



Source: D&R International, 2011a.

3.6.3 Performance Issues

The literature review revealed a number of sources that discussed poor performance claims, and most of these sources cited analyses conducted by DOE's Commercially Available LED

[56] D&R International, 2011a. Page 11.
[57] *Ibid.*

Product Evaluation and Reporting (CALiPER) program.[58] Since 2006, the U.S. DOE has conducted at least two rounds annually of CALiPER studies and tests of SSL products to verify product claims in the LED replacement lamp market. The purpose of these efforts is to avoid duplicating some of the poor consumer experiences encountered during the introductory stages of CFLs to the consumer market – such as exaggerated manufacturer lifetime claims, flickering, poor color, and so on -- which are widely cited as having had negative effects on the rate of CFL adoption.[59]

Through the process of evaluating SSL products, the CALiPER program found that a number of LED lamp performance claims were inaccurate, and that consistency at the manufacturing and retail levels can vary widely. Our analyses identified three major categories that were evaluated by CALiPER[60] where inconsistent product information was provided to consumers, including:

- **Lumen output.** Few products met or came close to their claimed lumen output. For almost all lamp styles, less than 50 percent of the lamps tested met the average light output of their claimed incandescent equivalents.[61] [62]
- **Lamp life.** Over half of the lamps tested are not expected to meet manufacturer-claimed lifetimes[63]
- **Correlated Color Temperature (CCT).** Of the packaging claims tested (primarily rated lumens, CCT, and life) many of the measured values for the products were close to, but not completely, accurate. All incandescent equivalency claims were inaccurate.[64]

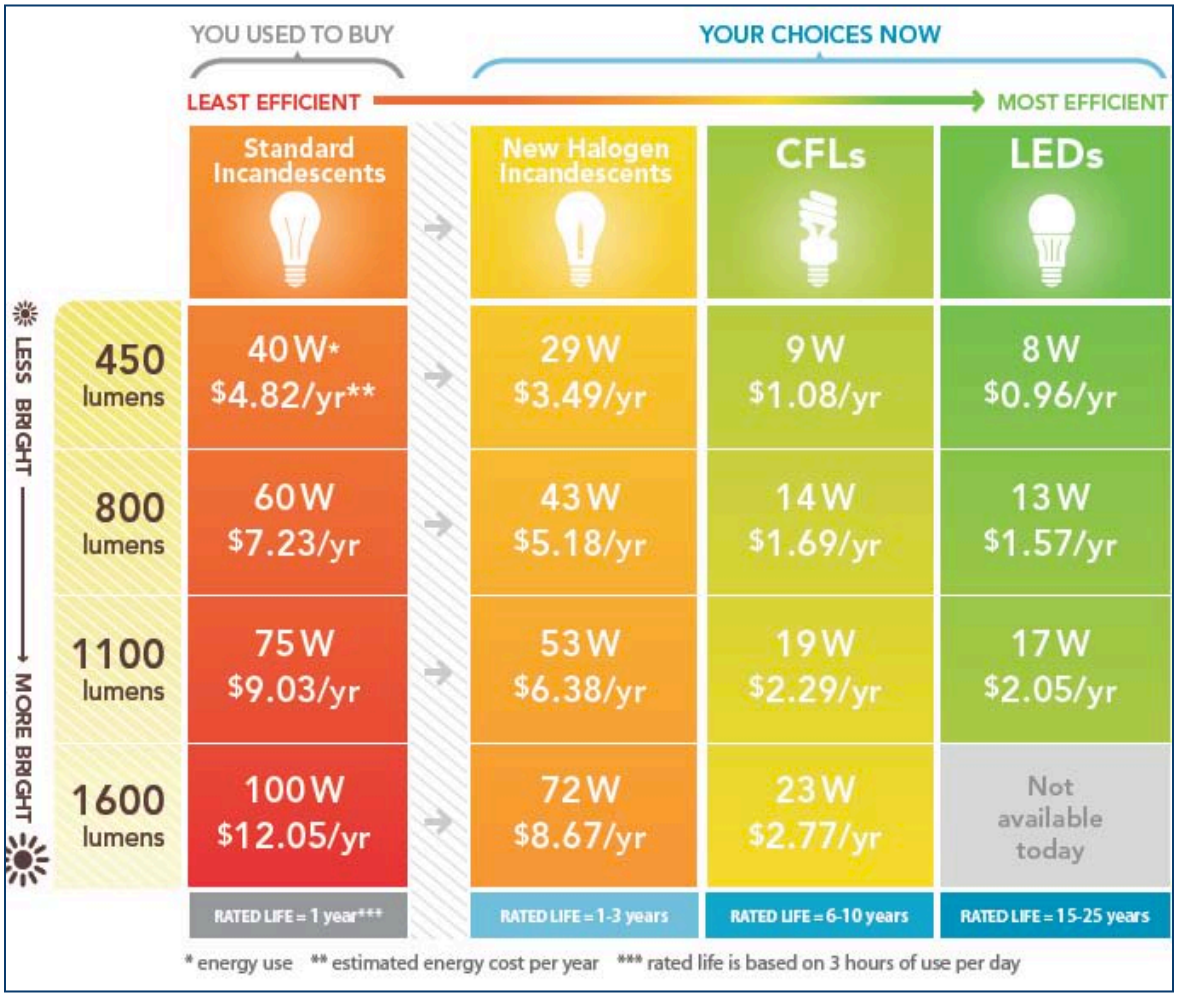
[58] Because most sources in the literature review cited this particular source, KEMA relied on DOE CALiPER findings for this subsection.
[59] See, e.g., page 2 of Pacific Northwest National Laboratory, 2011.
[60] The results of the CALiPER evaluation referenced are based on 33 different LED lamps from 10 different manufacturers purchased from 8 different retail stores in June and August of 2010.
[61] 2 of 5 A-lamps tested almost met incandescent equivalents, 1 of 4 B-10 lamps met claims, 4 of 11 MR16/PAR16 lamps came close to meeting claims, 0 of 4 PAR20 SSL lamps met claims, 3 of 7 SSL PAR30 came close to meeting claims.
[62] Pacific Northwest National Laboratory, 2011. Page 3.
[63] *Ibid.*
[64] *Ibid.*

3.6.4 Lack of Consumer Education

The market for general purpose lighting is changing as AB 1109 general purpose lighting efficiency standards have been in place in California since 2011 and EISA standards have begun to take effect nationally (starting in January 2012). These new regulations coupled with a rapidly evolving market for LED lamps and other efficient lighting products makes consumer education crucial. After high first cost, consumer education was the second most frequently-cited barrier to LED adoption by market actors interviewed by DNV KEMA researchers in early 2012.

As traditional incandescent lamps are phased out over the next couple of years by AB1109 and EISA, consumers will be faced with a different set of lamp choices than they have had in the past. As a result, several initiatives have been launched to address consumer understanding of these technologies. For example, the Natural Resources Defense Council (NRDC) has proposed a consumer education campaign geared at increasing awareness of the lifetime costs of different lamp options rather than only focusing on initial costs (see Figure 3-13). NRDC presents the perspective that while LED lamps have the highest initial cost of any of the lamp options currently available, they also have the lowest annual operating expenses.

Figure 3-13
Consumer Lamp Buying Guide



Source: Ecos Consulting, 2011.

4. Findings and Conclusions

Below we summarize the findings and present conclusions regarding the LED replacement lamp market for each of the six key themes revealed in the literature review (diversity, availability, pricing, market size, installed base, and barriers to consumer adoption of LED lamps).

4.1 Diversity

Below we summarize the findings and present conclusions regarding LED replacement lamp diversity, including lamp style, lamp life, wattage, and efficiency.

- **Style.** Reflector lamps continue to dominate the national LED replacement lamp market as of mid-May 2012 with respect to the number of unique lamp models available, and in Fall 2011, the LED lamp models observed during the shelf surveys suggest the same was true in California. Because LED technology is inherently directional, these results may reflect the initial market focus on reflectors (which are directional lamps) versus other lamp types (such as omnidirectional A-lamps).

  While reflector lamps will continue to comprise a large component of the LED replacement lamp market, manufacturer and retailer representatives perceive great market potential for LED A-lamps and have begun focusing on these products in addition to LED reflector lamps. There may be some early evidence of this in California, as A-lamps comprised a greater proportion of all LED replacement lamp models observed in the Fall 2011 shelf surveys in California (approximately 18%) than of LED lamp models available throughout the U.S. (about 10% according to DOE data). The differences between California and the national market can most likely be attributed to the fact that DOE Lighting Facts product data is cumulative and spans multiple years whereas the data collected as part of the shelf surveys in California was a snapshot of the products on the shelves of California retail stores in late 2011.

- **Lamp life.** A 2012 DOE report suggests that the average LED lamp life was 25,000 hours in 2010 and is projected to increase to 33,000 hours in 2011. These estimates align with those produced from data collected in California during the Fall 2011 California Lighting Retail Store Shelf Surveys. Manufacturers suggest that rated LED lamp life will increase in the future and DOE predicts that this will be true at least through 2015 (the last year for which rated lamp life projections are currently available). Interestingly, DOE

has recently scaled back its earlier projections regarding the rate at which lamp life will increase between 2010 and 2015.

- **Wattage.** DOE data from May, 2012 suggests that LED replacement lamps for sale in the U.S. range from 1 to 30 watts and average 9.5 watts across all lamp styles. Reflector lamps had the widest wattage range (from 1 -30 watts) and an average wattage of 10.2 watts, while A-lamps had a narrower wattage range (2-22 watts) and lower average wattage (8.2 watts) in May, 2012. Fall 2011 data from California suggests a narrower wattage range for A-lamps (0.6-13 watts) and lower average wattage than nationally (5.6 watts), while reflector lamps have a narrower wattage range than nationally (0.9-24 watts) but a higher average wattage (14 watts). Reasons for the differences between national and California data are unclear but are likely related to the fact that the California data is lamp weighted whereas the DOE data is reflective of cumulative lamp models reviewed by the Lighting Facts Program.

- **Lumen Output and Efficacy (lumens per watt).** DOE data suggest that LED replacement lamps had a limited range of available lumen options in the U.S. market during 2011, with the majority of lamps in the lower lumen ranges (roughly equivalent to the lumen output of traditional 40 and 60-watt incandescent lamps). LED lamps with lumen outputs equivalent to traditional 75W have begun to appear in the national market but were not widespread as of 2011, and higher output lamps are not expected to reach the market until 2013 or later. DOE data suggest efficacy levels averaging approximately 48 lumens per watt for LED replacement lamps in 2011, approximately three times as efficient as a traditional 100 watt incandescent lamp.

  The average LED lamp efficacy observed during DNV KEMA's Fall 2011 California Lighting Retail Store Shelf Surveys is closely aligned with the national-level estimates from DOE for 2011. The overall average observed for lumens per watt among LED lamps in the Fall 2011 shelf surveys (54.5 lumens per watt) is very close to the national average for 2011 based on DOE estimates, the efficacy range for lamps observed in the Fall 2011 shelf surveys in California -- 3 to 136.4 lumens per watt -- is fairly broad, suggesting a variety of light output options available in California during 2011.

4.2 Availability

Findings in California suggest that LED replacement lamps were widely available in the home improvement and membership club channels and, to a lesser extent, in hardware stores as of

Fall 2011. In most channels, the range of product options is slim, with only a handful of models available in all channels except home improvement stores (in which field researchers observed an average of 32 models per store during Fall 2011). Researchers observed no LED lamps in discount stores (which is logical given that the price point for LEDs is typically higher than discount stores tend to stock).

California's membership clubs and home improvement stores collectively accounted for almost 90 percent of all LED lamps (across all base types) observed in the California market during Fall 2011. All together, however, LED lamps represented a small fraction of lamps observed in California during the Fall 2011 shelf surveys (less than 4% of all observed lamps), while incandescent lamps represented 51 percent of observed lamps and CFLs represented 45 percent. Comparable data for the national market are not available.

4.3 Pricing

California data from late 2011 (based on the Fall 2011 California Lighting Retail Store Shelf Surveys) suggest somewhat lower average prices and broader price ranges than reported by DOE in 2010. Based on DOE data, the average retail price for an LED replacement lamp averaged approximately $36 in 2010, with average prices in the $20-40 range for A-lamps and in the $20-60 range for reflector lamps. Based on the Fall 2011 California Lighting Retail Store Shelf Surveys, average California LED lamp prices were just over $15 per lamp with a range of $2-40 for A-lamps (averaging $10.53) and $3-70 for reflectors (averaging $38.28). The majority of LED A-lamps observed in California were lower priced, low lumen output A-lamps at membership clubs, which may explain why the average California A-lamp price observed during the Fall 2011 shelf surveys is lower than the average price range reported by DOE for A-lamps in the national market in 2010. LED A-lamps with lumen output roughly equivalent to a 75 watt incandescent lamp had an average price of $31.22 in California.

4.4 Market Size

As of 2010, LED replacement lamps represent a small percentage of the overall global and North American general lighting markets (less than 10% of each), but these shares are expected to increase exponentially over the next ten years, and by 2020 LEDs are projected to be the dominate technology in the lighting market. A 2010 report projects that the value of the global LED general lighting market will increase sixteen-fold between 2010 and 2020 to reach a market value of $75 billion, while the value of the North American LED general lighting market is

expected to grow fifteen-fold to $15 billion in 2020. Comparable data for California are not available.

4.5 Installed Base

In 2010, LED lamps represented less than 1 percent of the total lamps installed across the U.S., the majority of which were installed in the commercial sector. In California households, data collected during 2008 and 2009 suggest that less than one percent of residential light sockets in California were filled with LED lamps.

4.6 Market Barriers

The literature review and interviews with representatives of LED lamp suppliers and LED market experts suggested that four barriers are most prevalent to increased consumer adoption of LEDs, including high first cost, relatively low lumen output, poor performance claims, and lack of consumer education.

- **High first cost.** Among the barriers identified for LED lamps, high first cost was most frequently cited by literature review sources as the largest obstacle to LED lamp adoption by consumers. This perspective was reiterated by LED market actors who participated in the in-depth interviews conducted in support of this study in early 2012. Retail pricing of LED lamps observed during the Fall 2011 California Retail Store Shelf Survey suggests that the average cost of LED A-lamps, the most common household replacement lamp style, is over three times more expensive than non-discounted CFL A-lamps and almost ten times more expensive than discounted CFL and incandescent A-lamps. It is widely anticipated by market actors, however, that high first cost will become less of an issue over the next few years as LED lamp price continues to decline rapidly due to increased economies of scale, manufacturing technology improvements (i.e. enhanced automation), and pressure from competition.

- **Low lumen output.** There are currently few LED replacement lamps on the market with lumen output in the range of traditional 75 watt and 100 watt incandescent lamps. LED product offerings are continuing to expand – including products with higher lumen output – driven by upcoming lighting standards for manufacturers and improvements in LED technology.

- **Performance issues.** The literature review sources (primarily those from DOE's CALiPER program) suggest that poor performance (such as inaccurate and/or exaggerated manufacturer regarding lumen output or lamp life, flickering, poor color, and so on) present barriers to consumer adoptions of LED lamps. If these barriers are not addressed, these claims could lead to consumer dissatisfaction and slower rate of market growth compared to projections.

- **Lack of consumer education.** As traditional incandescent lamps are phased out over the next couple of years by AB1109 and EISA, consumers will be faced with a different set of lamp choices than they have had in the past. Literature review sources and interview results suggest a need for improved consumer education regarding the costs and benefits of LED lamps.

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B. Appendix B: Available For-Purchase Sources

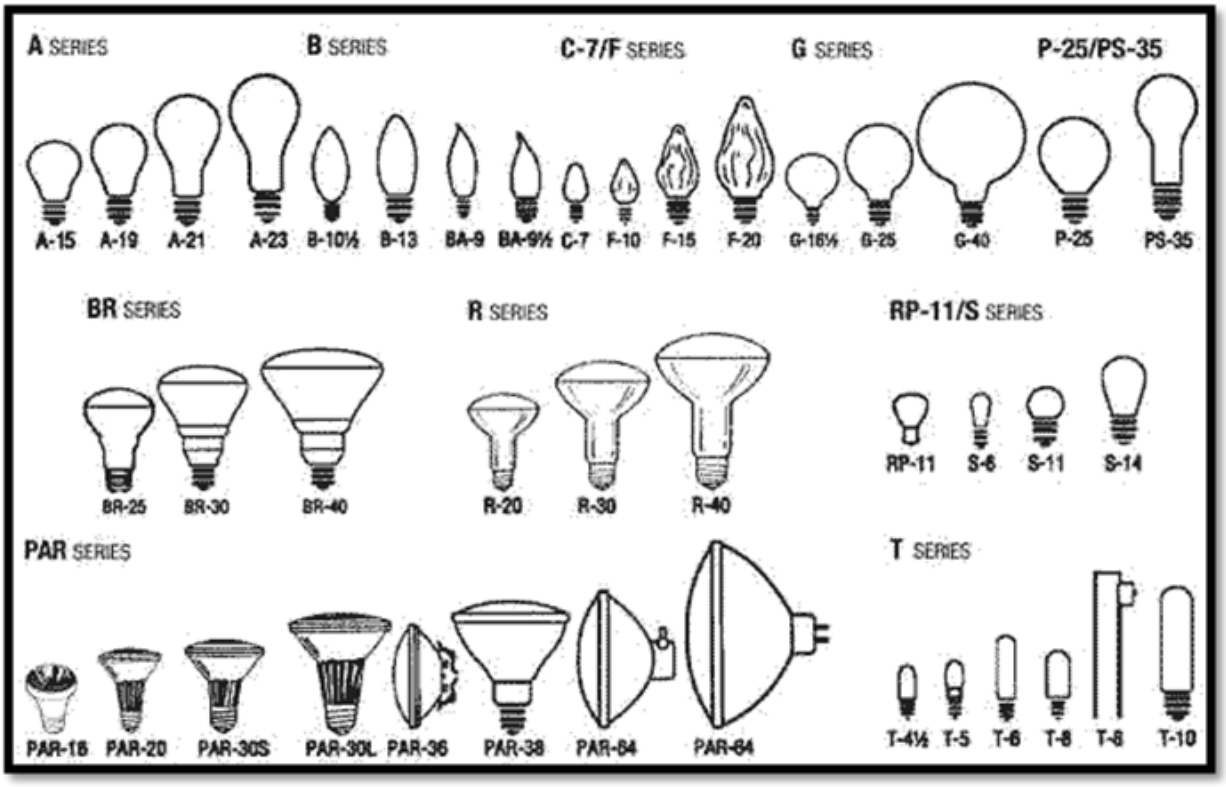
An additional four relevant sources were identified that could provide information on pricing, market share, sales data, availability, and diversity for the national or global LED market (Table B-1). Each of these sources required a license purchase ranging from $1,495 to $7,480. Each of the following sources provides a table of contents prior to purchase to detail the data provided and a list of all relevant tables and charts pertaining to the report.

Table B-1
For-Purchase LED Market Studies

Date	Title	Overview	Author(s)	Price
12/10	Enterprise LED Lighting: Commercial and Industrial Market Trends, Opportunities & Leading Companies	This report examines today's products for these market applications, and produces a summary review of the current market dynamics, its customers, the technology and the leading companies. The study also profiles the top fifty LED fixture manufacturers and ten LED component providers, naming BetaLED, Cree, Lighting Science Group and Philips as LED market leaders for 2011. Additional report elements include: • LED market size and price forecasts through 2015 for the U.S. • Comprehensive LED technology and application overview • Analysis of industry trends promoting LED adoption • LED's value in reducing energy and maintenance costs • Profiles of top 50 enterprise LED players and top 10 LED component suppliers • Survey of large-scale LED adopters, uncovering reasons for and challenges of LED implementation	GTM Research	$1,495 (single)
04/10	LED: A Global Strategic Business Report	This report analyzes the Global market for Light Emitting Diodes (LED) in Million Units, and US$ Million by the following end use segments: Automotive, Phones, Portable PCs (Netbooks, & Netbooks), LCD TV, and Lighting & Others. Annual estimates and forecasts are provided for the period 2006 through 2015. The report profiles 46 companies. Market data and analytics are derived from primary and secondary research. Company profiles are mostly extracted from URL research and reported select online sources.	Global Industry Analysts, Inc.	$3,950
Quarterly	GaN LED Supply and Demand Report - Quarterly	• Detailed coverage of the metal organic chemical vapor deposition MOCVD market featuring historical units, revenues, ASPs and share by supplier, region, wafer size and model. • Rolling 4-quarter forecast of MOCVD shipments by region, customer and wafer size through surveys by local personnel. • Exhaustive examination of >70 LED manufacturers' capacity expressed in 2" equivalents, 4" equivalents, area, actual wafers, die capacity, yielded die capacity and binned die capacity. • Provides quarterly LCD shipments by panel supplier, application, size, resolution, refresh rate and backlight type along with # of LEDs per panel. • Provides forecasts for all LED applications including backlighting, lighting, automotive, signage and more. • Includes historical and forecasted LED pricing by die size/package/application and sapphire pricing. • Provides tier 1 and average yields and bin rates by application.	IMS Research	$7,480 (single)
02/11	LED Luminaires Market Analysis and Forecast 2011	Comprehensive report that looks at the demand of the high-brightness LED lighting luminaire market. The report includes an application analysis, worldwide market review, five-year market forecast and an appendix of LED Luminaire manufacturers. This second edition report, LED Luminaires Market Analysis and Forecast is the most recent edition in a series of reports published on the LED industry by Strategies Unlimited, the leading market research firm covering HB LEDs and other optoelectronic devices.	Strategies Unlimited	$4,950

C. Appendix C: Lamp Style

Figure C-1
Replacement Lamp Style Guide



Source: Bulborama, 2011.

Table C-1
LED Replacement Lamp Style Equivalents

Lamp Series/Size	Lamp Style
A15, A19, A21, A23	A-lamp
B10½, B13, BA9, BA9½, F10, F15, F20	Torpedo/Bullet
S8, S11, S14	Straight Shaped Bulbs (unique to LEDs)
BR25, BR30, BR40, R20, R30, R40, PAR15, PAR20, PAR30S, PAR30L, PAR38	Reflector (see Figure C-1 above for more detail)
G16½, G25, G40, P25, PS35	Globe
T 4½, T5, T6, T8, T10	Tube
C7	Night Light

Source: DNV KEMA, 2012.

D. Appendix D: Additional Shelf Survey Information

Table D-1

Number of Lamps by Lamp Type and Lamp Style (All Base Types), Fall 2011

Lamp Style	Lamp Type		
	CFL	LED	Incandescent/ Halogen
MSB Lamps			
Basic Twister CFLs (≤30 Watts)	177,120	-	-
A-lamp	16,112	10,802	139348
Reflector/Flood	28,728	4,744	60431
Globe	16,045	626	24552
Candelabra & Torpedo Shape (MSB)	803	297	18358
Other MSB Lamps *	20,774	55	4082
Specialty MSB Lamps			
Specialty MSB CFLs: Dimmable	12,399	0	-
Specialty MSB: 3-way	2,049	0	7614
Other Non-MSB Lamps			
Candelabra Base	14,762	1,429	70684
GU Base	1,392	1,370	7790
Pin Base	8,125	102	5634
Candelabra Base with MSB Adaptor	2,173	5,371	4
Other Base Lamps †	152	11	533
Total Lamps	**300,634**	**24,807**	**339,030**

Source: DNV KEMA, 2012.
* Other MSB Lamps include bug and recessed down light lamps.
† Other Base Lamps include large base and wedge base lamps.

Table D-2
Average Price per Lamp by Lamp Type and Channel, 2011*

Lamp Type	Channel							
	Discount	Drug	Grocery	Hardware	Home Improv.	Mass Merch.	Memb. Club	Overall
ADVANCED	**$1.09**	**$7.49**	**$6.74**	**$7.38**	**$9.97**	**$3.60**	**$4.87**	**$5.78**
Advanced CFLs	$1.09	$7.43	$6.50	$6.55	$5.86	$3.45	$2.60	$3.82
LEDs	–	$11.61	$8.01	$17.95	$26.28	$8.42	$11.91	$15.67
Hybrid CFL/LEDs	–	–	–	–	$7.33	$7.57	–	$7.34
Cold Cathodes	–	–	–	–	$6.26	–	–	$6.26
NON-ADVANCED	**$0.62**	**$2.70**	**$1.64**	**$3.10**	**$2.27**	**$2.04**	**$1.40**	**$2.11**
Basic CFLs (≤30 Watts)	$0.83	$3.86	$1.37	$2.38	$2.16	$2.88	$1.40	$1.80
Incandescent/Halogens	$0.45	$2.44	$1.80	$3.05	$2.13	$1.84	$1.41	$2.15
HID Lamps	–	–	–	$19.88	$21.39	$10.97	–	$20.92
Number of Lamps	**31,112**	**16,118**	**20,008**	**76,283**	**277,507**	**99,362**	**146,777**	**667,167**

Source: DNV KEMA, 2012