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MEMORANDUM

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LITERATURE REVIEW OF CUSTOMER LIGHTING PREFERENCES

Like many utilities, Pacific Gas & Electric (PG&E) has achieved a large fraction of its energy and demand savings through lighting programs. These have included a variety of program types, including those targeting residential and nonresidential customers; upstream and downstream programs; and programs incentivizing readily available technologies (e.g., through deemed programs) and emerging technologies. For the 2010-2012 program cycle, lighting measures represented more than one third of PG&E's electric portfolio savings claim.

However, the lighting market is quickly evolving as LEDs become more prevalent and efficient, advanced controls become more sophisticated, some (although far from all) of the inefficient base technologies (e.g., incandescent lamps and T12s) have been replaced, and new regulations set higher efficacy requirements for lighting. This evolution of lighting is reflected in many changes in end-user behavior such as CFL spiral bulbs achieving a saturation level exceeding 50% of sockets in homes in the PG&E service territory in 2012 and the introduction of utility-rebated lamps by online retailers. Utility programs must also evolve if they will continue to provide the level of energy and demand savings delivered in the past.

The purpose of this review is to inform future program design and implementation, so that PG&E's lighting programs can continue to serve the current market, anticipate future needs, provide energy and demand savings, and educate customers and trade allies. This memo also serves a California Public Utility Commission (CPUC) Lighting Action Plan (LAP) initiative. The LAP is a key component of the California Long Term Energy Efficiency Strategic Plan that was adopted by the CPUC in 2008.[1] The purpose of the memo is detailed in the Purpose, Scope, and Limitations section. We present the findings of this literature review in the memo below.

Introduction

Below, we describe the purpose and scope of this memo, the approach we used to identify literature for review, the structure of the memo (i.e., how information is organized), and the terminology used.

[1] California Public Utilities Commission Energy Division (2013). *California Energy Efficiency Strategic Plan – Lighting Action Plan 2013-2015*. Retrieved from: http://www.cpuc.ca.gov/NR/rdonlyres/81B1D776-D00B-4423-ABF2-B34F814CA749/0/LAP_20131107_Distribute.pdf.

Purpose, Scope, and Limitations

Purpose

This project serves two purposes. First, the literature review is intended to provide PG&E lighting program staff with information regarding customer preferences to inform market intervention strategies, such as lighting program design, implementation, and marketing. Secondly, the literature review is intended to fulfill the following action under the CPUC LAP Initiative 6-1:

> ***Initiative 6-1:*** *Institute a statewide study to assess end user wants, needs, and desirability of currently-installed lighting technologies; publicize results to help tailor product marketing and messaging.*
>
> ***Key Action:*** *Review and synthesize results of completed residential and non-residential studies to identify and document end user wants and needs.*

In developing this memo, TRC focused on summarizing research related to customer lighting wants or preferences, because customer preferences (rather than needs) could be influenced through incentives, education, or other market interventions.

TRC developed recommendations for PG&E and the other California utilities, but many of the findings may be applicable to other utilities or program administrators because they are drawn from a variety of studies conducted across the country.

TRC delivered a draft memo to PG&E on December 19, 2013. PG&E distributed the draft memo to the LAP champions for comment. TRC incorporated feedback from this comment period into the final memo.

Scope

Overall, TRC reviewed 60 studies, of which 28 were reviewed and integrated into this memo. The remaining 32 studies are listed in Appendix B: List of Studies Excluded from Review. In general, the studies that were excluded from review were outside of the scope of this project.

Literature Included: In general, we focused on reviewing literature that collected or summarized data on residential and nonresidential customers' preferences for lighting in buildings. But we also included studies on related topics, as described below.

We included literature that discussed the science of choice, because this affects customer decision making, even if customers may not realize that such factors (e.g., previous purchase patterns) influence their choices. These decision making processes could be considered customers' subconscious wants. In addition, because program staff represented an important audience for this memo, we included studies that discussed how to translate customer preferences into program-related actions. These actions include program design structures, marketing messages to customers, and energy efficient product placement in stores (for upstream lighting programs).

While we defined "customers" as end use customers, in the nonresidential market, other market actors (e.g., contractors, distributors, electrical engineers) influence customers' decisions. Consequently, we included literature that studied the barriers and motivations for these nonresidential market actors in selling, installing, or specifying high efficacy lighting products, even though they are not direct end use customers.

Literature Excluded: Because this was a technical literature review, we excluded documents expressing individual opinions that were not supported by data, such as thought-pieces, editorials, blog posts, and company websites.

This would become a publicly available document; therefore, we also excluded confidential studies, unless the study author had granted permission for its inclusion.

This review also excluded studies of energy savings or parameters affecting savings (e.g., hours of use, effective useful life, wattage per bulb, etc.). While this is important information, it was outside the scope of this project.

If a topic was not addressed in available literature, it was not included. For example, Light emitting diodes (LEDs) and other solid state lighting (e.g., organic light emitting diodes – OLEDs) present a paradigm shift. They can be used in traditional applications (e.g., residential and nonresidential sockets and fixtures, holiday and decorative lighting, display and promotional lighting), but also in new applications, such as under cabinet lighting. However, we did not find published studies that focused on these new applications. (We found and included a few results on installation patterns, but not studies that focused on this topic.) Thus, there could be issues relating to customer needs or preferences that are not addressed in the current literature.

Recommendations: While the primary focus of this project was to review existing literature, we also compiled recommendations for programs and other market intervention strategies. These recommendations include both suggestions that TRC developed based on the literature findings, and recommendations taken directly from the literature (including the study citations). We provided the recommendations with the intention of making the literature review findings more actionable, but these recommendations are not intended to be comprehensive, and readers are encouraged to draw their own conclusions from the results of the literature review.

Limitations

This literature review presents a limited "point in time" review of lighting research. TRC developed the literature review over a relatively short time-frame (2 months) for a draft deliverable in December 2013, to inform program development at the beginning of 2014. While we attempted to be comprehensive, because of the large quantity of lighting literature available, there may have been some studies that we missed. In addition, because lighting studies are continuously being released, studies released after fall 2013 were not included. Ideally, this literature review can be updated periodically, as new studies are released.

One important development that is not reflected in current literature is the release of the LED specification by the California Energy Commission (CEC). The California LED Lamp Quality Specification is a voluntary lamp performance specification that the program administrators have agreed to adopt as part of their incentive programs. Only LED products that meet the specification will be available to receive incentives. However, non-compliant lamps can still be offered for sale in retail locations. The efficacy requirements match the EPA's ENERGY STAR criteria. However, the quality requirements are higher than ENERGY STAR criteria, and require a specific color temperature range, color consistency and quality, dimming capability, lamp life, and light distribution performance. The CEC specification should ensure high efficacy and quality for incentivized products, and encourage the development of products that will meet customers' preferences.

Literature Review Approach

To identify literature to review, TRC worked with PG&E to identify the most relevant resources. These included a residential customer survey conducted specifically for PG&E by Optimal Strategix Group (OSG 2011) and an existing lighting literature review by D&R (the California Lighting Critical Synthetic Literature Review – i.e., D&R 2012a).

TRC then used the lighting study workbook we had developed previously for PG&E to identify additional studies relevant to this topic. TRC developed this workbook at the end of 2012 based on a review of CALMAC, American Council for an Energy Efficient Economy (ACEEE) publications, lighting journal publications, utility and energy

efficiency organization websites, and by contacting staff at energy efficiency organizations to inquire about current or recently published studies. TRC originally developed the workbook to inform future lighting research plans. As part of the literature review conducted here, we re-contacted staff at energy efficiency organizations to ask about the status of studies that were projected to be released in 2013.

After identifying studies that would include findings related to customers' lighting preferences, we reviewed each study and summarized or excerpted pertinent information. (We did not review older studies that were already included in the D&R (2012a) literature review, as this appeared to be a redundant task.) We present the full findings of our review in the Appendix A: Annotated Bibliography.

TRC then synthesized the findings from the various studies, to develop the main body of this memo.

Memo Structure

We have organized the memo as follows:

The main body of this memo presents a synthesis of our findings from the reviewed literature. We have organized these findings as:

- **General Findings** applicable to both the residential and nonresidential sectors. This section presents findings on the general science of choice; findings on LEDs that are applicable to both sectors; human factors and health impacts of lighting; and recommendations that apply to both the residential and nonresidential sectors on these topics.
- **Residential Findings**. This section presents residential customer preferences; market segments; upstream program findings; CFL findings; and recommendations for residential programs. The recommendations include LED recommendations that are specific to the residential sector.
- **Nonresidential Findings**. This section presents nonresidential market actors and their motivations for participating in programs (or purchasing high efficiency lighting); innovative program designs and emerging technologies; and recommendations for nonresidential programs.

In support of the main body of the memo, we also provide an:

- **Appendix A: Annotated Bibliography** – The body of this memo references studies supporting our findings. In the Appendix, we provide for each study a full citation, link (if available), and relevant findings, including figures.
- **Appendix B: List of Studies Excluded from Review** – We provide a list of studies that we did not include in this review, and why we excluded each study. Common reasons include that it did not include information directly relevant to customer preferences, was summarized in a previous literature review, or was too old.

Terminology

The lighting field has various terms that are technically incorrect, but that are often used in common language. We have used the following technically correct terms in the main body of the memo.

- Lamp (not bulb): Technically speaking, a bulb is the glass or plastic part that surrounds the light-emitting device (filament, in an incandescent lamp), while a lamp is the assembly, including the socket, bulb, and other parts, depending on the lamp. (What the layperson refers to as a "bulb" is technically a lamp.)

- High Efficacy (not efficient) lighting: Lighting that provides high lumens per watt is technically described as "high efficacy", rather than efficient.

However, in the Appendix A: Annotated Bibliography, we generally quote the study directly, including whatever terminology the study used.

General Findings (Applicable to both Residential and Nonresidential)

This section presents overall findings on the science of choice (related to consumer purchasing choices); human factors (e.g., occupant well-being); and LEDs, which are increasingly penetrating both the residential and nonresidential markets.

This memo provides further information on these topics in the following sections:

- "In-Store Strategies to Increase Sales" describes how residential upstream programs can use the science of choice to encourage the purchase of high efficacy lighting.
- "Residential Findings" presents findings on LEDs that specifically relate to residential customers.

Science of Choice

As described by D&R (2012a), "Most decisions are automatic and primarily influenced by immediate situational factors." The following figure from this study illustrates how people make choices, in order of importance.

How do people make choices?	
Several situational factors have been shown to very strongly influence decision making. These factors are listed roughly in order of their importance and strength. The more factors present, the stronger the effect. Text in parentheses represents the corresponding scientific terminology for these effects.	
1.	The default condition (status quo bias)
2.	What we see other people doing (social norms/social proof)
3.	Urgency, often due to limited supply or limited time (scarcity effect)
4.	Whatever is readily at hand (status quo bias)
5.	Reminders, prompts, and other attention-getter (prompts)
6.	Relative cost/comparative value (contrast effect/anchoring and adjustment)
7.	The number of things to choose among (choice overload/option paralysis)
8.	Recommendations from similar people (homophilicity)
9.	Familiarity, confidence, and emotional associations (available heuristic)

Figure 1 – Primary Reasons for Decision Making (D&R 2012b)

As described by D&R (2012a), incentives that are directed at lowering prices should be used with care, as they have the potential to distort the market and customer perceptions of cost and value.

Human Factors and Health Impacts of Lighting

The science behind lighting impacts on humans is not fully resolved at this point, but there is growing evidence that the quality, quantity, and color of light can have an impact on the physical and psychological well-being of the occupant (NRC 2001). Lighting is also known to positively or negatively affect productivity and other metrics of subject efficiency (absenteeism, error avoidance, quality metrics, student evaluation performance, etc.) (NRC 2010, UMCH 2012, LBNL 2004, UTUM 2012). Studies have shown that lighting does not rise to the level of conscious awareness for most consumers, but they can positively respond both consciously and subconsciously to the lighting in the space (RPI 2009). The research is ongoing to help establish metrics for lighting that can directly inform this aspect of the impacts of lighting on humans, but there is a clear understanding that sufficient light, delivered in a low-glare manner, is preferable in most circumstances. In addition, studies have found that having user control of the lighting conditions and amounts in the workspace typically produce more satisfied and productive occupants (NRC 2010). Research is being done to further understand how this information may be collected and communicated to consumers so that they are able to play an active role in the application of appropriate lighting strategies to improve their surrounding environment (RPI 2009). This research presents findings that could be used

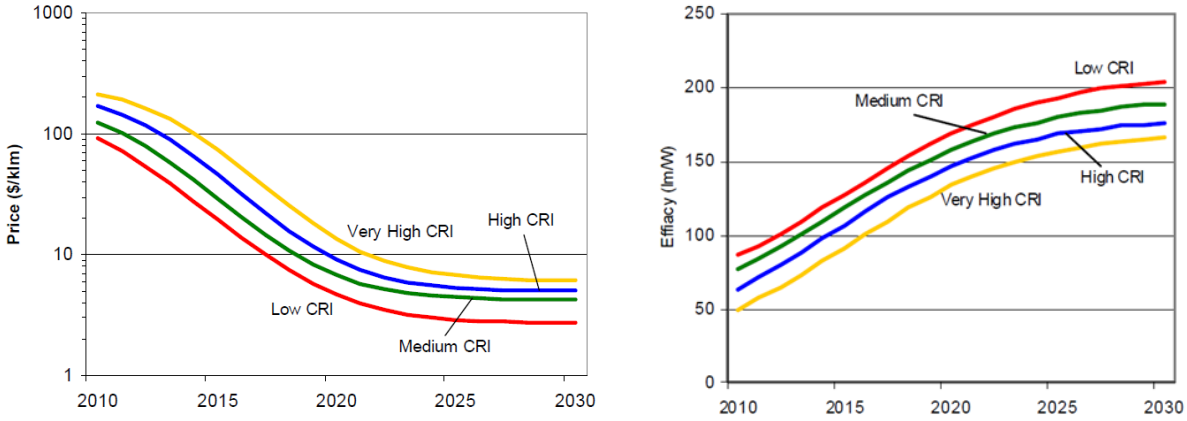
to influence customers to pay more to purchase LEDs over traditional lighting sources that may not be able to provide the same health benefits. However, customers are generally not currently aware of these health effects.

LEDs

As ERS (2013) describes, "LEDs offer the prospect of transforming the commercial and residential electric lighting market in a way unprecedented since the introduction of the ballasted fluorescent lamp in 1938." This shift in lighting is expected to be profound in both technology (lighting devices, controls devices), and in the philosophical purpose of lighting in the lives of people at home, work, clinical applications, and other arenas.

There are indications that the transformation has begun in some portions of the lighting industry, including street-lighting, entertainment lighting, and certain specific applications that are ideally suited for the application of LED. The market for LEDs holds great opportunity, and the speed of market adoption will be influenced by cost (first cost and lifetime cost), and product features.

In addition, LEDs have yet to reach their full potential in terms of energy efficiency or their lowest price. As ERS (2013) describes, "While most other types of lamps are approaching their maximum theoretical efficacy, the best performing white-light LED products are only half way to their theoretical potential. At the same time, production costs and market pricing for LED lighting systems are dropping and are expected to continue to decrease in both cost per lumen and cost per lamp." Navigant (2010) developed the following price and efficacy projections that support this notion:



LED Price Projection *LED Efficacy Projection*

Figure 2 – LED Price and Efficacy Projections (Navigant 2010)

Unfortunately, based on interviews conducted for Massachusetts Program Administrators, lighting manufacturers and retail buyers reported that emerging LED technologies are more likely to take market share away from specialty CFLs than from standard spiral CFLs (NMR 2013). Reasons included CFLs' poor dimming capability and start-up time, and that the price difference between LEDs and specialty CFLs is currently smaller than it is between LEDs and standard spiral CFLs (NMR 2013). If studies verify that some LED product types largely replace CFLs rather than less efficient base technologies, it will continue to be difficult for these LEDs to pass cost effective tests.

Motivations and Barriers

Both residential and nonresidential customers have expressed great interest in LEDs. They provide many of the features that CFLs or other types of fluorescents lack, including better light quality, no mercury content, and short start-up time. LEDs can also provide smooth dimming, another feature desired by customers, if matched with compatible dimmers.

Price is by far the major barrier for customers to adopt LEDs (ODC 2012, KEMA 2012). Although many program administrators would like to encourage market adoption by incentivizing LEDs, many LEDs do not pass cost effectiveness tests.

However, LED lamp price continues to decline rapidly due to increased economies of scale, manufacturing technology improvements, and competition (KEMA 2012). The section "Residential Customer Preferences" includes detail on acceptable LED price points for residential customers. In summary, customers are generally unwilling to spend more than $20 on any type of lamp, and $5.99 or less is the ideal price point. As LED technology continues to improve and the market matures, it is likely that the lumens achieved per watt will increase, the price of the lamp will come down, and consumers will become convinced of the lamp's long life. At that point, more of them may be willing to pay the higher price for LEDs over halogens or CFLs (NMR 2012b).

A Southern California Edison (SCE) study of lighting customer preferences found that LED lamp sales in high-income areas were 4.1 times higher than sales in low-income areas and 1.9 times higher than sales in medium-income areas. LED lamp sales in medium-income areas were 2.2 times higher than low-income areas, although region did not affect sales (ODC 2012).

Numerous studies cited that customers are leery of LED technologies due to little to no direct experience with the technology, and negative past experiences with CFLs. Customers are concerned about lighting quality (including color), ability to dim without flicker, and realization of longevity claims (ODC 2012, KEMA 2012). Customers are overwhelmingly satisfied with LED light quality and prefer it to CFLs once they have experienced them (ODC, 2012).

Residential customers have cited poor CFL brightness as a reason for not purchasing CFLs, and KEMA (2012) noted in its shelf survey that 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, which suggest brightness limitations similar to CFLs. However, product offerings continue to expand (KEMA, 2012).

A survey of Massachusetts store managers found that, of those not selling LEDs, reasons included that the lamps were too expensive for their customers (19%), their corporate offices made the purchasing decisions (16%), they lacked an LED supplier (14%), and the LEDs did not fit in well with the rest of their product line (14%) (NMR 2013). High prices of LEDs also deterred retailers from promoting them (NMR 2013).

Customers' Use of LEDs

There are few studies that have included large on-site inventories of LEDs (i.e., inventories of the number and type of LEDs installed in homes or commercial buildings). However, based on an on-site lighting inventory of 150 homes in Massachusetts in 2012, 7% of the households used LEDs at the time of the onsite, and they collectively used 92 LEDs. Most of these LEDs did not have the A-shaped profile and were instead used as track or under cabinet lighting. One household accounted for 29 of the LEDs, and the mean number of LEDs was 0.6 for all households. Only two LEDs were found in storage. (NMR 2012c).

For commercial applications, based on a forum of market actors active in the Northeast, LEDs are currently replacing exterior incandescent and high-intensity discharge (HID) lighting as well as special display lighting and

incandescent and halogen lighting for retail applications (ERS 2013). Flat panel LED lighting is showing promise as general space lighting (ERS 2013).

General (Residential and Nonresidential) Recommendations

We compiled the following recommendations from the literature, or developed our own recommendations based on our review. These recommendations relate to the science of choice and to LEDs, and are applicable to both Residential and Nonresidential programs. We provide sector-specific recommendations in the "Residential Program Recommendations" and "Nonresidential Program Recommendations" sections.

Science of Choice

The science of choice drives all market actors involved in lighting programs (e.g., distributors, contractors, residential and nonresidential customers). When developing programs, program administrators should refer to Figure 1 – Primary Reasons for Decision Making (D&R 2012b), and consider how the program could be designed or implemented to encourage each market actor to choose the high efficiency option. Programs should also continue to use other strategies besides incentives (such as education, demonstrations, and ensuring high efficacy lighting choices are available in customer venues), because these can complement incentives, and because incentives have the potential to distort the market.

LEDs

Program administrators should consider incentivizing a limited number of LED product types in the short-term because the price of LEDs is rapidly decreasing while quality increases, and because many types of LEDs do not pass the cost effectiveness test under current assumptions. In the long-term, prices will fall, and some customers will have tried LEDs and presumably been satisfied with the product, which will encourage them to purchase more. However, TRC acknowledges that there are challenges to both sides of this recommendation. The market's natural interest in LEDs (and price as their main obstacle) suggests that program administrators encourage their adoption through broader LED incentives. On the other hand, the new CEC specification for LEDs limits the types of LEDs that the program administrators can incentivize.

In the short-term, program administrators should consider targeting LEDs that will perform better in cost effectiveness tests, including LEDs that:

- Are typically installed in areas with high hours of use
- Typically replace low efficacy technologies (e.g., incandescent as the base technology)
- Are lower in price (so that the rebated price is below $20)

Customers have expressed a need for dimmable lighting products, and LEDs have the capability of providing this feature if matched with compatible dimmers. As described by KEMA (2013b), program administrators can provide more education on the performance of LEDs and on LED interactions with dimmer switches, and encourage distributors, manufacturers, and contractors to do the same. For example, they can provide lists of recommended dimmers and general information on the technical challenges of LEDs on dimmers, including minimum load ratings. (KEMA 2013b). (This recommendation was made for the Massachusetts Program Administrators for an upstream nonresidential program, but TRC believes the recommendation also applies to PG&E and its residential and nonresidential programs.) PG&E and IOUs can also use their demonstration sites to allow customer to test various lamps to see the actual color, light level, dimming capabilities, and other features of LEDs.

In its customer education, program administrators should emphasize that LEDs, have similar (or more optimal) features than traditional lighting (OSG 2011).

Residential Findings

Below we provide our findings for residential customer preferences and residential programs.

Residential Customer Preferences

Based on a 2012 phone survey of 604 Massachusetts households, customers generally buy CFLs or LEDs for energy savings and long lamp lifetime, and incandescent (or other lamp types) for light color or brightness (NMR 2012a). A study for SCE generally confirmed these findings (ODC 2012). When asked what types of information they look for on packaging, 96% of respondents report that they consider wattage, 92% consider price, and 70% consider wattage equivalency; other characteristics considered by more than one-half of the respondents include lamp life, color appearance, the ENERGY STAR label, and lamp shape (NMR 2012a).

We provide more findings on these preferences below. Many of these findings are from a survey by Optimal Strategix Group (OSG) of over 1,000 PG&E residential customers.

- Brighter lamps: Customers generally prefer over 40-watt lamps (OSG, 2011), and ideally 100-watt equivalent lamps (ODC 2012). Other studies have found that a common consumer complaint of CFLs is that they are not bright enough (KEMA 2013a, NMR 2012a, NMR 2013).
- Price and Energy Savings: Studies have shown that customers are motivated by both price and money from energy savings, but price is more critical (OSG 2011). A customer survey for Southern California Edison (SCE) by ODC (2012) found that products with prices $20 or less sold the best in all categories, and that sales at prices above $40 were virtually non-existent. Customers indicated that they would pay as much but no more than $10 for LED A-Lines and $30 for LED Reflectors (ODC 2012). Other surveys generally support the main ODC price point: Massachusetts customers reported that they wanted to move to LEDs as their preferred lighting source, but were hesitant to spend over $20 for a light bulb (NMR 2012b). OSG (2011) found a significant increase in customer adoption when the price dropped below $20, although they recommend $5.99 as the ideal LED price. While the study did not break out the price point findings by market segment, early adopters are generally less dependent on price and more respondent to marketing than imitators and late adopters.
- Lamp life: Many surveys have found that customers cite long lifetime as a major reason to purchase CFLs and LEDs. However, customers' preference for a lamp rises considerably as its lifetime increases from 1 year to 5 years with minimal gains for a lamp that lasts longer than 5 years (OSG 2011). Also, customers see value in a 1-year warranty, but warranties longer than 1 year have a relatively minor impact (OSG 2011).
- Wattage Equivalency: While a majority of Massachusetts customers had heard of lumens (55% - NMR 2012a), various studies confirm that customers are more comfortable with "wattage" and "wattage equivalent" and make purchasing decisions based on these (OSG 2011, NMR 2012a).
- Lamp color: Medium white color temperature is vastly preferred over cool white or warm white temperature (OSG 2011). Two-thirds of Massachusetts customers reported to understand the terms warm white and cool white (NMR 2012a). However, TRC notes that there is no firm definition of "warm white" and "medium white", and that this definition varies by manufacturer. In general, customers gravitate towards a medium color. (Thus, it is difficult to develop an actionable program recommendation from this finding.)

- Customers would much rather purchase a lamp with an energy saving label than one without a label, but there is little difference in preference between an ENERGY STAR and "Eco-Friendly" label (OSG 2011).
- Customers prefer smooth dimming (ODC 2012), and the inability of CFLs to deliver this is a complaint by customers.

Regarding the phase out of traditional incandescent bulbs, and how consumers plan to adapt to it: KRC (2013) found that, when aided, most American consumers are aware of the phase out of traditional incandescent bulbs. As a result, roughly half (46%) will switch to CFLs, a quarter (24%) to LEDs, 13% to halogens, and 16% are not sure (KRC 2013). As part of their survey with Massachusetts consumers, NMR asked consumers about their awareness of upcoming Energy Independence and Security Act (EISA) regulations, explained EISA to those who were not aware, and asked all consumers whether they planned to stockpile incandescent lamps. About one-fourth of the Massachusetts consumers surveyed reported they are likely to stockpile incandescent lamps; of those who were already aware of EISA, 30% reported they are likely to stockpile them (NMR 2012a). This agrees with findings at the national level by KRC (2013), which found that 3 in 10 consumers plan to stockpile incandescent bulbs.

Market Segments

The OSG (2011) study identified the following residential market segments and their preferences:

- Early Adopters (13% of OSG's sampled customers) are aligned with energy efficiency. They have already adopted CFLs and are moving to other technologies, such as LEDs. But as with all customers, price is a barrier. Early Adopters are the segment most receptive to branding, efficiency messaging, and product recommendations. They tend to be younger, well-educated, higher income, more likely to rent, and be more likely to be Asian or Hispanic.
- Imitators (51% of OSG's sampled customers) have the highest use of CFLs, but driving additional adoption for these and other high efficacy products will require effective messaging regarding energy savings and color quality. They tend to be older than Early Adopters but younger than Late Adopters, and have similar education levels and incomes as Early Adopters.
- Late Adopters (36% of OSG's sampled customers) tend to be older, less educated, poorer, and more likely to own a home that Early Adopters. They are concerned with value (price, dollar savings, and durability) and light quality. They could be convinced through demonstrations that high efficacy lighting products are similar (e.g. in light quality) to incandescent, and through dollar savings messaging.

Upstream Program Findings and Strategies

PG&E and other utilities have used an upstream (or midstream) program strategy for incentivizing lighting products. TRC identified the following findings relevant to this type of program.

In-Store Strategies to Increase Sales

In general, while price impacts sales, there are other factors impacting consumer purchasing decisions. As much as possible, program administrators should work with retailers to design "choice architecture" that helps make high efficacy lighting choices the default purchasing option, particularly for impulse purchases. ("Choice architecture" refers to the collection of situational factors that influence a specific choice and that often, unintentionally, drives people to a particular decision [D&R 2012a]). D&R has conducted studies investigating how different retail

strategies can influence program lamp sales. As they point out, one retailer chain can generate as much as 10 times the sales lift from incentives as another in the same channel (D&R 2012b).

Recommendations for increasing program lamp sales include:

- Increase their shelf space (D&R 2012a).
- Place them at prime eye-level positions (D&R 2012a).
- Install in-aisle, end-cap, and "catch the season" displays, and place lamps outside the lighting department. These methods catch additional shoppers and encourage them to purchase high efficacy lighting through impulse buys (D&R 2012b). Simplify choices with these displays, ideally to one lamp option (D&R 2012a).
- Match program lamps to their baseline replacements. Walmart placed CFLs on shelves directly above the incandescent lamps they replaced, enabling people to find the right CFL without needing to learn what a lumen was or noticing differing wattage (D&R, 2012a).
- Emphasize dollar savings (D&R 2012b).

D&R (2012b) summarized the key components of Walmart's 18 Seconds campaign for CFLs as shown below:

Strategy	Examples
Improved packaging and package messaging	Had GE redesign packaging to be visually cleaner and simpler
	Rebranded the lamps as "Energy Smart"
	Made "Saves $38 in energy" the primary message
Installed an in-shelf display in the lighting aisle	Showed 10 types of CFL and incandescent lamps side by side
	Incorporated messaging comparing lifetime costs and highlighting savings
Lowered the actual and perceived product price and promoted purchase of multipacks	Dropped the price of a 3-pack from $9.58 to $7.58, which decreased the per-bulb price from $3.19 to $2.52
	"Saves $38 in energy" made $7.58 seem even smaller in contrast
Placed CFLs in more prominent locations	Increased CFL shelf space by 40%
	Replaced a portion of incandescent product shelf space with CFLs
	Demoted incandescent lamps to lower shelves and placed CFLs at eye level and within easy reach
	Retained sections of lighting set previously devoted to CFLs
	Placed stack-outs in the grocery section of the store and periodically featured the product on the "Catch of the Season" wall at the front of the store
Increased advertising and PR	Advertised CFLs in weekly circulars
	GE ran a complementary print advertising campaign
	Campaign was covered in national newspaper and magazine stories

Figure 3 – Key Components of Walmart's 18 Seconds Campaign for CFLs (D&R 2012b)

A KEMA study for the Northwest Energy Efficiency Alliance (NEEA) which included a shelf survey, found that nearly two-thirds of urban stores displayed promotional materials for replacement lamps compared to less than 10% of

rural stores (KEMA 2013). If this pattern holds true for PG&E territory (PG&E program staff and Account Representatives may be able to provide information on this), PG&E could work with rural retailers to provide more customer education.

Purchasing Locations and Retailer Chains

OSG (2011) found that PG&E residential customers most often purchase lamps at mass merchandiser and home improvement stores. Customers reported using online purchasing for only 4% of lamps, and that these customers are more likely to be early adopters. (TRC notes the use of online purchasing may have changed – probably increased - since the report was published.) This information is summarized in the figure below from OSG (2011).

Q08, MSB Purchase Locations (all and most often)	All Locations	Most Often
Mass merchandiser like Target, K-Mart, or Wal-Mart	62.1%	27.9%
Home improvement store like Home Depot, Lowes or OSH	61.3%	24.4%
Hardware store like Ace or True Value	39.9%	9.1%
Drug Store like CVS, Rite Aid, or Walgreen's	38.4%	8.0%
Grocery store like Safeway or Lucky's	36.5%	8.1%
Club store like Costco or Sam's Clubs	29.4%	9.1%
Discount/99 Cent Store	24.3%	7.7%
Lighting store	9.2%	0.9%
Furniture store like IKEA	8.4%	0.6%
Electronic store like Best Buy or Fry's	7.7%	1.3%
Department store like Sears	6.2%	0.5%
Specialty store like Bed Bath and Beyond	5.4%	0.5%
Over the Internet	4.3%	1.0%
Mail-order catalog	1.7%	0.2%
Other	1.6%	0.8%

Q08. In the first column of the grid below, please select all the locations where you have purchased light bulbs, and in the second column please select the one location where you purchase light bulbs most often. (select multiple locations in the first column and one location in the second.)

Figure 4 – Self-Reported Store Type for PG&E Residential Customers' Lighting Purchases (OSG 2011)

CFLs

In general, because the majority of California residential sockets still hold incandescent lamps, CFLs will continue to be an important component of residential programs in the short term. However, the best long-term opportunities are with LEDs. We provide more detail in the section below.

CFL Market Penetration

Based on a national CFL market profile (D&R 2010), CFLs still have the potential to deliver considerable energy savings to the residential sector. Most light sockets still hold incandescent lamps. California has the highest socket saturation of all states evaluated by D&R, but California's mean and median CFL socket saturation is only about 30% and 27%, respectively[2]. In states without CFL programs, CFL saturation averages as low as 1 in 20 (D&R 2010). In addition, 5 out of 6 lamp shipments are still incandescent at the national level (D&R 2010). Based on findings from Navigant (2013), the socket penetration of CFL varies considerably by lamp type. For example, based on projections using the U.S. DOE forecast model the study found that CFLs comprised 43% of total A-type lamps installed in the U.S. in 2012 (up from 34% in 2010), but only 11% of directional lamps in 2012 (down from 15% in 2010).

The D&R (2010) findings suggest that many California consumers are still purchasing incandescent lamps instead of CFLs, and that the CFL programs in California (and other states) are helping to shift the balance towards CFLs, compared to states without CFL programs. D&R (2010) also states that EISA is not enough to transform the market; many specialty lighting products are exempt, and manufacturers have developed minimally compliant incandescent lamps.

CFL Consumer Preferences

A national survey found that Americans are most familiar with halogens as an alternative to incandescent bulbs, but a majority are also aware of LEDs and CFLs (KRC 2013). A phone survey of 604 Massachusetts households found that the majority of consumers are generally aware (89% for 2012), but not very familiar with CFLs (27%) (NMR 2012a). These results are similar, but slightly lower, to what NMR found in similar surveys they conducted 2009-2011.

Several studies found that, while CFLs are accepted by many customers, there is some dissatisfaction with them. Several studies also found declining satisfaction with CFLs (e.g., KEMA 2013a, NMR 2012c). Customers reported energy savings and long lifetimes as the best features of CFLs, and consumers generally appear to be aware of these features (KEMA 2013a). Customers complain that CFLs are not bright enough, that they "take too long to light up", and have poor dimming capabilities (KEMA 2013a, NMR 2012a, NMR 2013, EPA 2011, KRC 2013). OSG (2011) found that PG&E customers also cited the mercury content of CFLs as a deterrent, as did EPA (2011) at the national level.

In its survey of PG&E residential customers, OSG (2011) found that most customers prefer CFLs with a price of $1.99 or less. This price point was much lower than the ideal price point for LEDs ($5.99), and TRC hypothesizes that this is because customers believe that LEDs have better features than CFLs.

[2] Based on results shown graphically in D&R (2010),p. 17. Because TRC took these values from a graph (not a table), these mean and median values may be off by 1 to 2 percent.

Residential Program Recommendations

Below, we have compiled program recommendations from the literature reviewed. We have also developed a few additional recommendations, based on our synthesis of the findings.

In general, program administrators could:

- Continue to offer rebates to help overcome price -- the biggest barrier to high efficacy lighting purchases (OSG 2011) -- but consider waiting to incentivize certain types of lighting products until their quality improves, and/or their price drops. NMR (2013c) recommends: Dimmable, three-way, and candelabra CFLs and LEDs are among the products that the Massachusetts Program Administrators should consider not supporting until the technology improves to meet standards desired by consumers. (See TRC's recommendation on dimmable products below.)
- Show the lifetime value (cost / energy savings) to the customer from higher efficacy lamps (OSG 2011).
- Promote only the highest quality energy-efficiency lamps, particularly for dimmable applications (NMR 2012a). (The CEC specification should help guide selection for LEDs.) For upstream programs, TRC recommends that program administrators encourage participating retailers to sell compatible dimmers right next to the lamps, and provide an educational panel that explains lights / dimmer compatibility.
- Target Early Adopters for new high efficacy lighting (OSG 2011). (This could include LEDs.) Consider targeting early-adopting segments through online channels in the short term before prices drop enough to entice other segments (ODC, 2012).
- Raise consumer awareness and understanding of lumens, color temperature, and color rendering (KEMA 2013a). Help consumers make the transition from thinking about watts to thinking about lumens (NMR 2012a).

Upstream program recommendations include:

- Provide options that encourage the participation of stores in frequently visited retail channels (D&R 2012b, OSG 2011). A Massachusetts study recommends discount stores and small grocery stores for making CFLs more accessible to hard-to-reach customers (NMR 2013).
- Support and monitor retailers (using utility staff or implementers) to make sure promotions are executed as agreed, including requiring stores to maintain a particular choice architecture, and provide feedback to retailers on their performance relative to the incentive (D&R 2012b). NMR (2013) echoed the need to conduct face-to-face outreach with participating store managers to discuss how a program works, collect feedback on the program, and work with managers to bring LEDs into the program.
- Work with partnering retailers to place a consumer education campaign that helps consumers make more informed lamp choices, rather than simply defaulting to their usual incandescent lamp purchases. Also, work with retailers to avoid "get them while you can" incandescent lamp promotions (NMR 2012a).
- Provide flexibility on pricing for retailers and manufacturers so they can maximize top line sales revenue (D&R 2012b).

Program administrators should continue to promote CFLs in the short-term, and in particular:

- Incentivize CFLs with improved product features, such as those with low mercury, dimmability, very short warm up time, and high quality light output (OSG 2011). Encourage manufacturers to improve CFLs with these features (OSG 2011, ODC 2012), such as providing higher incentives for them.

- Continue to communicate the long lifetimes of high efficacy lamps and their savings potential (OSG 2011).
- Provide rebates for a net price of $1.99 or less (OSG 2011).

We provide most LED findings, and some general LED recommendations in "General Findings (Applicable to both Residential and Nonresidential)" because LEDs will be used in both applications. However, we provide a few recommendations specific to the residential sector below:

- Provide LED rebates to drive long-term PG&E objectives, as they have higher efficacy, are more environmentally friendly, and have many of the features desired by customers.
  - Provide rebates for a net price of $20 or less, and ideally for $5.99 or less.
  - Because customers' preferences plateau for products with lifetimes longer than 5 years, and because future LEDs should have higher efficacy, consider providing incentives for lower cost, shorter-lived LEDs.
  - Where possible, incentivize products with a warranty of at least 1-year. (Warranties influence consumers, although a warranty term beyond a year make little difference to consumers [OSG 2011].)
- Several studies recommend improved consumer education regarding the benefits of LEDs, such as more point-of-purchase signage and more mass advertising. In particular, educate customers about LED characteristics, like energy savings, long lifetime, dimmability, high light quality, and mercury free composition (OSG 2011, ODC, 2012, KEMA 2013a).

Nonresidential Findings

We summarize our findings on nonresidential customers and programs below.

Market Actors and Product Flows

For good program design and implementation support, it is important to identify key market actors, and understand their barriers and motivations.

The following product flow map was created by Xenergy in 2000. (Xenergy created multiple product flow maps, which D&R 2012 combined into the single figure below.) While it is over a decade old, the market actors and business models have generally not changed since 2000, based on TRC's understanding of the lighting market. However, market actors' expectations about digital performance have changed considerably, due to the increased sophistication of controls, integration with mobile applications, digital recording devices, and smart meter data.

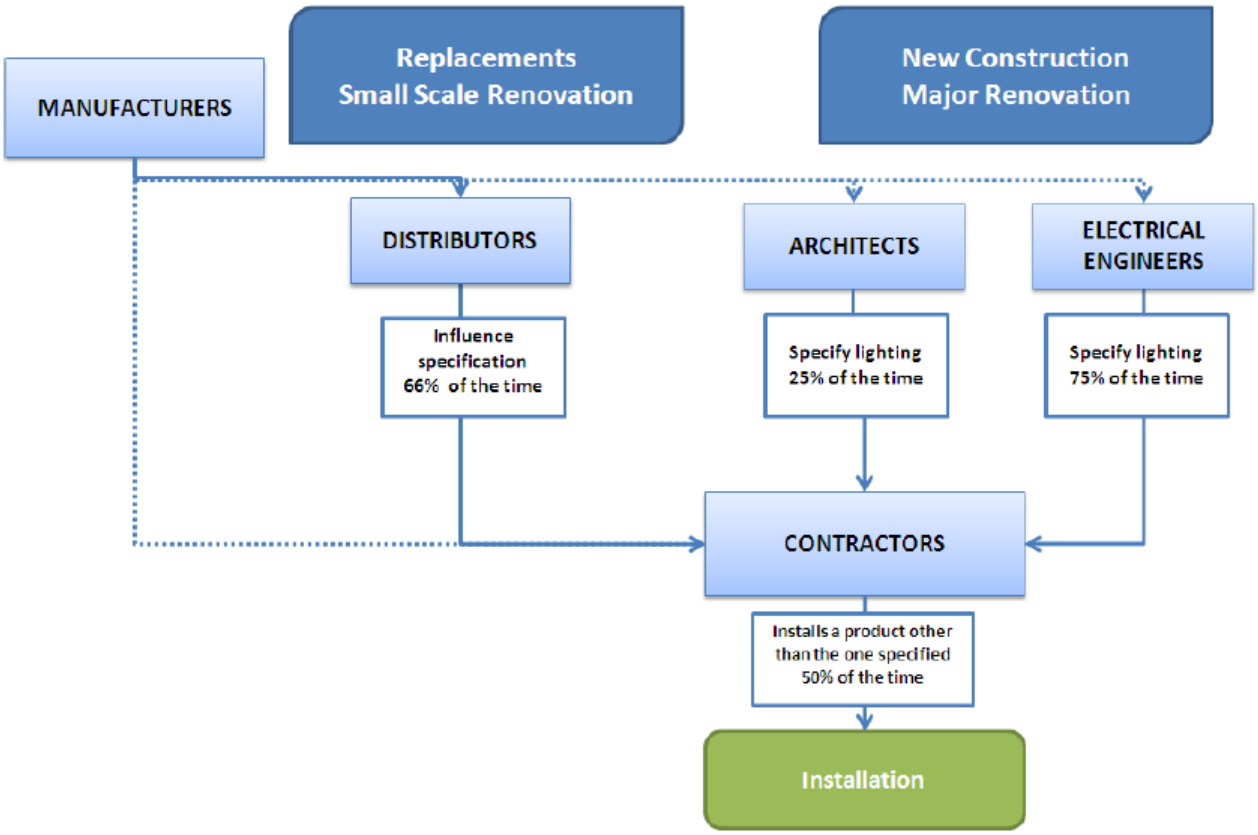


Figure 5 - Nonresidential Lighting Product Flow and Key Market Actors (Source: Xenergy, 2000 – presented in D&R 2012a)

As shown in the figure above, key market actors in the lighting retrofit market are manufacturers (including manufacturer representatives), lighting distributors, and contractors. Among these market actors, contractors have the greatest influence on what lighting commercial end users chose to install, and are frequently the only lighting professional to interact directly with the end user (Evergreen Economics, 2013). Distributors sometimes sell directly to building owners or managers who install the replacement products themselves (D&R, 2012). But frequently, distributors sell to contractors who are hired to install products, particularly when a fixture or ballast is being replaced. It is important to encourage distributors to stock higher quantities of high efficacy products at reduced cost, thereby indirectly encouraging contractors to use high efficacy products.

As shown in the figure above, for new construction and major renovation projects, lighting is specified by electrical engineers about 75% of the time, and architects about 25% of the time. Electrical engineers tend to favor familiar products and solutions to avoid uncompensated redesigns (D&R International, 2012). Half the time, contractors install a product other than the one specified. Lighting is installed at the end of the construction phase, and contractors will often install a lower efficiency system to stay within budget.

The figure below from D&R (2012) summarizes the motivations of the critical market actors.

Market Actors	Motivator
Manufacturers	• Promote products with highest profit • Highly competitive market
Architects	• Prefer to design creative, artistic space • If T&M contract, prefer expensive materials • If fixed price, will cut costs
Electrical Engineers	• Rely on familiar techniques to reduce callbacks • Seek to please architects to earn repeat business • Typical job is fixed priced – cost cutting and familiarity
Distributors	• Typically paid on commission, based on products sold
Contractors	• Rely on familiar techniques to reduce callbacks • Often fixed price – rely on familiar technologies • Choice is driven by availability and price • Rely heavily on distributors for advice and guidance

Figure 6 – Nonresidential Market Actors and Their Motivations (Source: D&R, 2012)

A KEMA study (KEMA 2013b) evaluated an upstream commercial program in Massachusetts. (TRC notes that, while upstream programs are common for residential lighting programs, they are less common for nonresidential.) Based on interviews, distributors participated to increase or make sales (45%), due to the incentive levels (35%), or other reasons, as shown below.

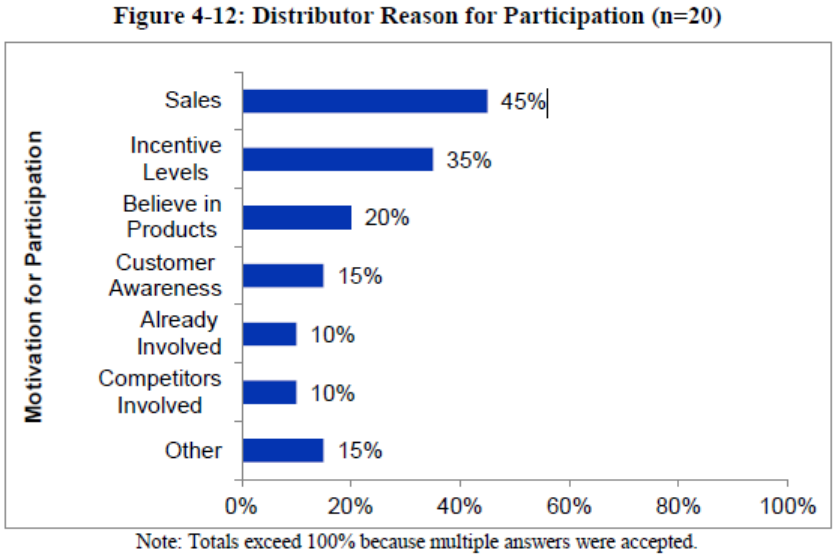


Figure 7 - Massachusetts Nonresidential Distributors' Reasons for Participating in Upstream Program (KEMA 2013b)

Based on interviews with Massachusetts nonresidential contractors, price is the number one factor in deciding which product to buy, as shown in the figure below.

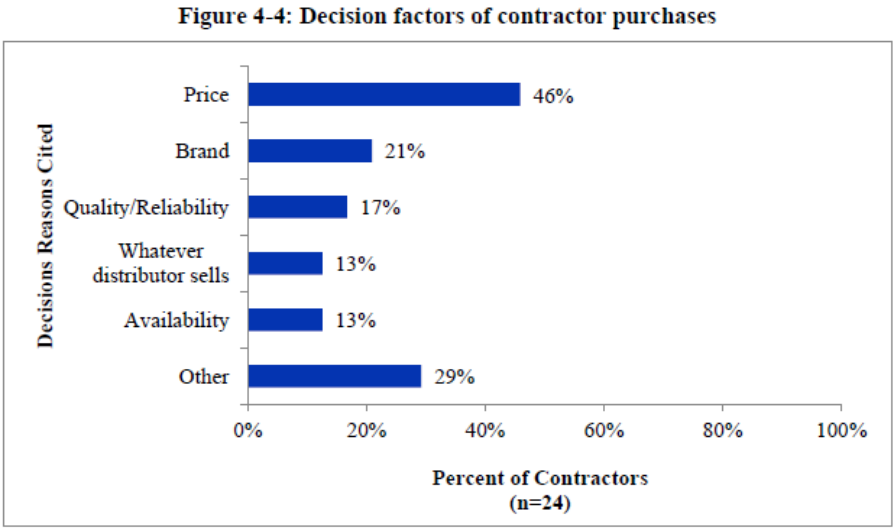


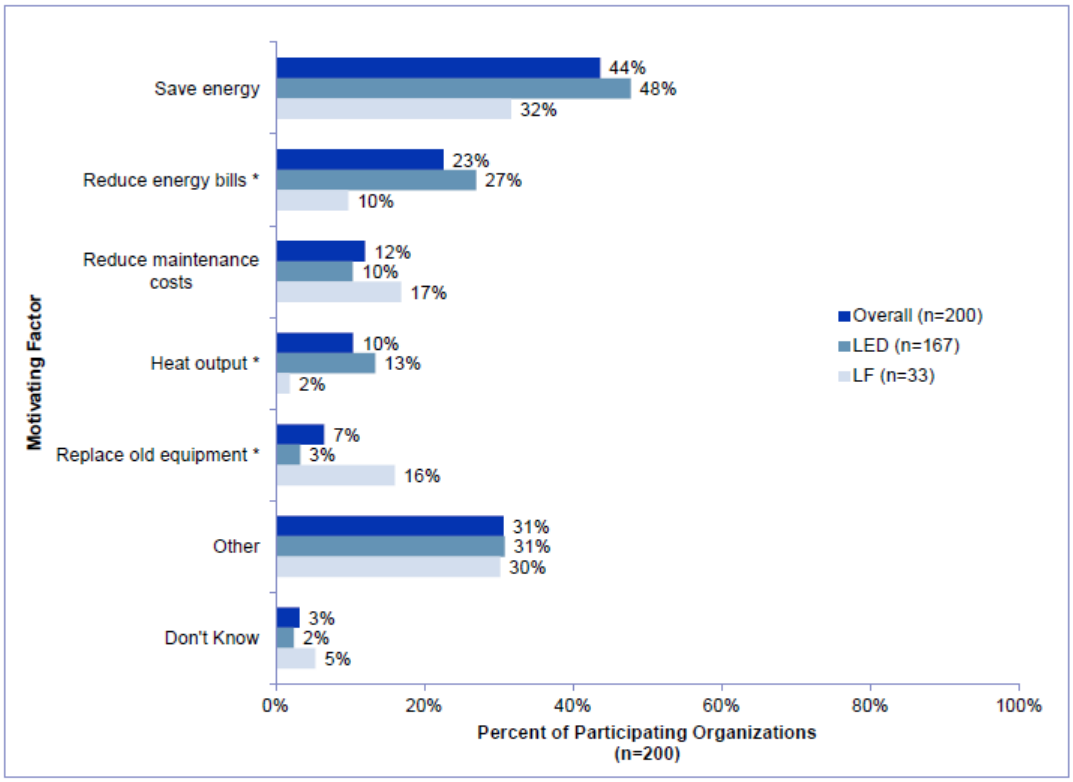
Figure 8 – Massachusetts Nonresidential Contractors' Purchasing Decision Factors (KEMA 2013b)

Customer Motivations

End use customers in nonresidential program represent a diverse group, in terms of building types, ownership (e.g., tenants, owners, and institutional facilities), size, and other factors. The ownership issue can lead to split incentive problems (i.e., the lighting decision maker does not always reap the rewards from higher efficacy lighting), which can act as a barrier to making high efficacy lighting decisions. As an illustration of the split incentive challenge, based on a survey of nonresidential customers in Massachusetts, LED end users who owned all of their space were more likely than those who leased some space to say that their decision factors involved energy savings (KEMA 2013b). LED end users in the retail or office sectors were more likely than those in any other sectors to say their decision factors involved the quality of the light (KEMA 2013b).

The KEMA study of the upstream program in Massachusetts surveyed 200 end users. The most common reasons that they provided for participating in the program were to save energy (44%) and to reduce their utility bills (23%). The results are provided in the figure below.

Figure 4-10: Motivations to Participate



* Difference between LED and linear fluorescent is statistically significant at 90% confidence level.

Note: Totals exceed 100% because multiple answers were accepted.

Other included the following, each mentioned by less than 5% of the respondents: get incentives, pro-environmental corporate policies, longevity, old equipment failed, quality of light, installer/contractor recommendation, old equipment working poorly, distributor/salesperson recommendation, recommendation of pa staff, the technical assistance offered through the program, recommendation of internal staff, past experience with program, and unspecified other reasons.

Figure 9 – Massachusetts Nonresidential Customers' Motivation to Participate in a Program by Lamp Type (LED v. Linear Fluorescent) (KEMA 2013b)

The Massachusetts upstream program provided linear fluorescents and LEDs. The KEMA (2013b) study found that over 90% of both the LED participants and the linear fluorescent participants were satisfied (4 or 5 on a 5-point satisfaction scale) with the program-discounted lamps. However, the participating end users were less satisfied (72% of respondents) with the performance of the lamps when connected to dimmer switches.

Philips Research (2013) conducted a study of three Department of Defense buildings that underwent advanced controls retrofits. In both pre- and post-retrofit surveys, the most common desired improvements listed were:

- fixtures that emit less light,
- to change the color appearance of the lighting fixtures,
- to have the ability to control the light output of the overhead light fixtures, and
- better access to windows and daylight.

Several post-retrofit comments from open office occupants expressed frustration with the lights being too bright, lack of ability to dim the lights, and inconsistent system operation. Based on this feedback, Philips developed a

software upgrade that stores the user preferred dimming level as the new defaults, which is expected to improve occupant satisfaction (Philips Research 2013).

TRC (previously, as Heschong Mahone Group[3]) conducted an evaluation project for a comprehensive commercial lighting initiative (CCLI) for the Northwest Energy Efficiency Alliance (NEEA). The evaluation included a survey of building owners and facility managers. These customers reported that their primary motivations for conducting comprehensive retrofits were increased energy savings and improved lighting quality (HMG 2013).

Innovative Program Designs and Emerging Technologies

The nonresidential lighting market continues to evolve. There are fewer opportunities for simple change-outs (e.g., T12 to T8 replacements) and the level of sophistication continues to grow, as controls, LED products, smart meter integration, and other technologies become more advanced. Consequently, utilities and other energy efficiency entities are testing new types of technologies and program structures.

Program Designs

This section provides examples of different program designs than the traditional one-for-one replacement incentive programs or deemed programs incentivizing high efficacy lighting products.

As noted by a forum of market actors active in the Northeast, lighting efficiency programs have generally focused on the adoption of advancing technologies as replacements for existing equipment or as substitutes for baseline, while ASHRAE 90.1-based codes are based on lighting load metrics (e.g., lighting power density) (ERS 2013). Several of the Northeast forum member organizations have implemented LPD-based lighting design programs (ERS 2013).

Massachusetts Program Administrators developed the upstream Bright Opportunities program, which provides incentives directly to distributors of specific lighting technologies (LEDs and linear fluorescent lamps), with the assumption that the discounts will be passed down the supply chain (KEMA 2013b). While the program was generally successful, including high satisfaction rates from end use customers and contractors, many contractors expressed dissatisfaction with the program's marketing, reporting that marketing is not reaching end users.

NEEA developed a pilot initiative to encourage a comprehensive approach to lighting retrofits. Through the CCLI, NEEA's partnering utilities provided higher incentives than projects would have received compared with traditional deemed (one-for-one replacement) programs, and NEEA's implementer provided contractor training. The pilot was successful in incentivizing projects to achieve deep energy savings, and owners reported satisfaction with the improved light quality. However, contractors reported that the additional paperwork and longer wait times to receive incentives were barriers. Many utility program managers reported challenges developing an appropriate incentive structure for comprehensive lighting retrofits that was distinct enough from traditional incentive offerings and balanced with the added effort required by trade allies, while still maintaining program cost-effectiveness (HMG 2013).

New York City developed lease language to attempt to address the split incentive program. The energy-aligned lease language bases owners' cost recovery on predicted savings, but limits owners' capital expense pass-through to 80% of these predicted savings; the additional 20% "performance buffer" was designed to protect tenants from underperformance of the system (PlaNYC 2011). The lease language has been used in at least two large office spaces (PlaNYC 2011).

[3] Heschong Mahone Group was acquired by TRC on January 1, 2013.

Emerging Technologies

One type of advanced controls system that is emerging in the market is called Local Luminaire Lighting Controls (LLLC), which locates sensors and the lighting controller at the luminaire level. Thus, there is an individual lighting controller at each luminaire location using this approach. NEEA is particularly interested in this system, and plans to launch an initiative to incentivize this type of advanced lighting controls system for simple lighting retrofits. NBI (2013) conducted a study on four pilot sites. After installation of the LLLC, occupants generally experienced increased comfort and satisfaction with the light levels and with their ability to control those levels. However, most thought the system was an improvement, but that it was too dim to complete high-light tasks, such as reading or filing (NBI 2013).

Within the realm of lighting controls, many manufacturers are developing products at price points that make them viable for consideration in applications that were never possible before. Many products include wireless communication capabilities, load measurement and sophisticated reporting, and integration of multiple control inputs and strategies. As a result, there are many opportunities to employ these control systems in an effective system to reduce the lighting load in lower demand situations.

Nonresidential Program Recommendations

We compiled the following recommendations from the literature, or developed our own recommendations based on our review. There are additional LED recommendations in General (Residential and Nonresidential) Recommendations.

- Continue to work with the various market actors identified in the Market Actors and Product Flows section, particularly based on the barriers and motivations noted in this section.
- According to Evergreen Economics (2013), distributors may offer a unique opportunity for commercial lighting programs in California. They can special order almost any available lighting product, and what the distributor carries influences the product awareness and choices made by contractors. Programs should work to reduce distributors' risk in carrying high efficacy products as follows (Evergreen Economics, 2013):
  - Provide contractors the tools to learn about and market advanced lighting, to both accelerate their knowledge and increase their ability to sell advanced lighting retrofits.
  - Test programs that provide incentives to distributors (i.e., a midstream program), reducing the cost and risk to distributors to stock high efficacy products.
  - Use manufacturer rebate (i.e., upstream) programs and other approaches to improving manufacturer and distributor sale agreements.
- Investigate other types of program designs for nonresidential lighting programs, such as those described in the Innovative Program Designs and Emerging Technologies section. The program staff for these programs may be willing to provide guidance and information on strategies that did and did not work.
- Studies have found controls to affect occupant satisfaction (e.g., Philips Research 2013). Consequently, TRC recommends that program administrators consider providing incentives for products that provide luminaire-level control, or provide a method to combine incentives on lighting and controls products that provide additional benefits, like local luminaire dimming.
- Consider providing tiered incentives for proven emerging technologies (Evergreen Economics 2013).

APPENDIX A: ANNOTATED BIBLIOGRAPHY

Below, we present important findings on customer preferences from the studies we reviewed. We list these studies in rough order of their importance and relevance to this topic. We categorized this information as: General (applies to both Residential and Nonresidential), Residential, and Nonresidential. Some studies did not have pertinent information in all three categories.

In many cases, we excerpted text or figures directly from these studies. If we added text for clarification within these excerpts, we present it in [brackets]. We generally present the terminologies used in these studies, even if these terminologies are technically inaccurate (e.g., bulbs instead of lamps, high efficiency instead of high efficacy).

In the body of the memo, we re-created excerpted tables (i.e., copied the information into a new table) for formatting consistency. But in the section below, we copied and pasted a screen shot of the table, so that a reader can better identify the original table in the study.

OSG 2011: PG&E Lighting Conjoint Study ASEMAP

Primary Author: Optimal Strategix Group (OSG)

Client: PG&E

Publication Date and Report Type: April 20, 2011 - Presentation

Link (if available): not available. PG&E commissioned study, not published publicly

Excerpts and Relevant Findings:

Residential

This study surveyed 1,031 PG&E residential customers to understand customer preferences in the lighting category, how PG&E can optimize its lighting programs, and how customers can be educated to encourage them to make energy efficient lighting purchases. The study focused on Medium Screw Based (MSB) lamps, which can screw into most residential sockets, and are thus the majority of lamps purchased by residential customers.

Summary:

Findings from the Executive Summary include the following:

- Early Adopters (13% of sampled customers) are aligned with energy efficiency. They have already adopted CFLs and are moving to other technologies (LEDs). But as with all customers, price is a barrier. Early Adopters are the segment most receptive to branding, efficiency messaging, and product recommendations. They tend to be younger, well-educated, higher income, more likely to rent, and be more likely to be Asian or Hispanic.
- Imitators (51% of sampled customers) have the highest use of CFLs, but driving additional adoption for these and other types of MSBs will require effective messaging regarding energy savings and color quality. They tend to be older than Early Adopters but younger than Late Adopters, and have similar education levels and incomes as Early Adopters.
- Late Adopters (36% of sampled customers) tend to be older, less educated, and poorer, and more likely to own. They are concerned with value (price, dollar savings, and durability) and light quality. They could be

convinced through demonstrations that efficient lighting products are similar (e.g. in light quality) with incandescent, and through dollar savings messaging.

- PG&E can encourage efficiency lighting adoption by:
  - Offering rebates and other targeted offers to help overcome price (the biggest barrier)
  - Showing the lifetime value (cost / energy savings) to the customer from the more efficient bulbs
  - Emphasizing that efficiency lighting, especially LEDs, have similar (or more optimal) features than traditional lighting
  - Continuing to partner with retailers to provide more locations at which energy efficient bulbs can be purchased and recycled.

Short term: PG&E should continue to incentivize CFLs. Rebating CFLs will accelerate the 87% of the market who are slower to adopt them in advance of legislation. To increase CFL adoption:

- Incentivize CFLs with improved product feature changes, such as no mercury (and thus easy to recycle), dimmability, and immediate warm up time. Also, encourage manufacturers to advance CFLs with dimmable capability and recyclability.
- Continue to communicate the longevity of the bulb and the savings potential.
- Eliminating mercury and improving light quality would have the greatest impact on customers' perceived value.
- Provide rebates for a net price of $1.99 or less.

Long term: LEDs represent energy savings opportunities long term, but their price is prohibitive to most customers. (Price is the only issue.) To increase adoption:

- Provide LED rebates to drive long-term PG&E objectives, as they are more energy efficient, environmentally friendly, and have many of the features desired by customers. Ideally, provide rebates for a net price of $5.99 or less.
- Educate customers about the existing features and benefits of LEDs: Long lifetime, Energy savings (immediate and over lifetime), warranty (1 year sufficient), dimmable, mercury free, easy disposal.

Other Overall Marketing Recommendations:

- Target Early Adopters for new efficiency lighting.
- Highlight the benefits that are important to other segments.
- Highlight that alternatives to incandescent bulbs offer equal lighting conditions
- Educate consumers that the life-time savings will overcome higher prices
- "Ladder" lighting program onto other efforts (e.g., low income energy) to increase awareness.
- Offer rebates to more channels where consumers shop.

Other findings:

- It will be challenging to convince customers that lower wattage bulbs provide the same light quality as a 100-watt (incandescent) bulb.

- CFL bulbs are the most appealing medium screw base (MSB) type, followed by LED bulbs, although high efficiency incandescent are close third to LEDs. (Halogens and incandescent are least preferable.) [TRC notes, the LED information may be out of date by now.]
- Customers' preference for a bulb rises considerably as its lifetime increases from 1 year to 5 years with minimal gains in preference for a bulb that lasts longer than 5 years.

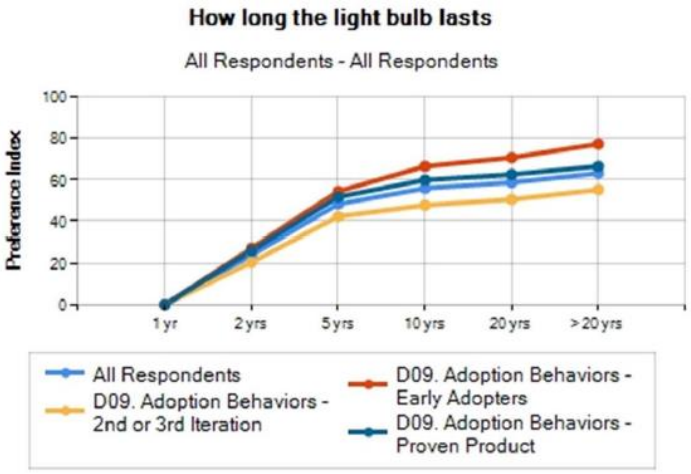


Figure 10. Customer Preference for Light Bulb Lifetime (Source: OSG, p. 21)

- Customers would much rather purchase a bulb with an energy saving label than one without a label. There appears to be little difference in preference between an Energy Star and "Eco-Friendly" label.
- Bulbs without any mercury are vastly preferred over those that contain mercury.
- The price of the bulb is more important than the money saved from energy savings. Providing any energy savings at all (in terms of dollars or percentages) causes a substantial boost in preference, with diminishing returns coming into play for each additional level of savings.
- Customers generally prefer bulbs with higher wattages over 40-watt bulbs.
- Customers tend to be indifferent towards whether the bulb is A-line or twister shape.
- A 1-year warranty provides added value, but warranties longer than 1 year have a relatively minor impact on customers' preferences.
- Medium white color temperature is vastly preferred over cool white or warm white temperature.
- Customers understand the term "wattage" more than "lumens".
- Mass merchandiser and home improvement stores are the most common locations for MSB bulb purchases. Customers report using online purchasing for only 4% of bulbs [TRC notes this may have changed since the report was published]; these customers are more likely to be early adopters.

Q08. MSB Purchase Locations (all and most often)	All Locations	Most Often
Mass merchandiser like Target, K-Mart, or Wal-Mart	62.1%	27.9%
Home improvement store like Home Depot, Lowes, or OSH	61.3%	24.4%
Hardware store like Ace or True Value	39.9%	9.1%
Drug store like CVS, Rite Aid, or Walgreen`s	38.4%	8.0%
Grocery store like Safeway or Lucky`s	36.5%	8.1%
Club store like Costco or Sam`s Clubs	29.4%	9.1%
Discount / 99 Cent Store	24.3%	7.7%
Lighting store	9.2%	0.9%
Furniture store like IKEA	8.4%	0.6%
Electronic store like Best Buy or Fry`s	7.7%	1.3%
Department store like Sears	6.2%	0.5%
Specialty store like Bed Bath and Beyond	5.4%	0.5%
Over the Internet	4.3%	1.0%
Mail-order catalog	1.7%	0.2%
Other	1.6%	0.8%
©2011 Optimal Strategix Group, Inc.		

Q08. In the first column of the grid below, please select all the locations where you have purchased light bulbs, and in the second column please select the one location where you purchase light bulbs most often. (Select multiple locations in the first column and one location in the second)

Figure 11 – Self-Reported Store Type for PG&E Residential Customers' Lighting Purchases (OSG 2011)

D&R 2012a: California Lighting Critical Synthetic Literature Review

Primary Author: D&R International

Client: Southern California Edison and Pacific Gas & Electric

Publication Date and Report Type: March 23, 2012, Final Report

Link: The literature review was part of a larger study, and is in the report Appendix (begins on pdf page 6): http://www.calmac.org/publications/SCE0307.02_-_SCE_and_PGandE_Lighting_Report_Appendices.pdf

D&R conducted a literature review of the residential and nonresidential lighting markets in California to develop detailed lighting program strategies to define priority areas for primary market research.

Excerpts and Relevant Findings:

General

Science of Choice: "Residential and non-residential lighting choices are shaped by existing choice architectures. […] A choice architecture is the collection of situational factors that influence a specific choice and typically, often unintentionally, drive most people to a particular decision." To influence choices, you must understand the current choice architecture and choose which tools will best enable you to reshape it to favor the choices you want people to make. "Most decisions are automatic and primarily influenced by immediate situational factors."

"Incentives that are directed at lowering prices should be used with care, as they have the potential to distort the market and customer perceptions of cost and value. If incentives lower the product price below that which manufacturers can meet in the absence of the incentive, it can create a permanent dependence, such that removal of the incentive creates a contrast effect that works to the detriment of the program. In this case, the new price would necessarily be higher than the incentivized price and would be perceived by customers as expensive relative to their established expectations, thereby lowering sales. Incentives to market actors that encourage them to use other methods to boost sales do not suffer from this particular drawback, though they can still create dependence, making it difficult for the program sponsor to withdraw them."

Residential

Recommended program strategies: The study recommended strategies for various program types, including the following that are particularly relevant to upstream programs, from strongest to weakest:

- Defaults/slanted odds: "First, the increase in shelf space, promotion of CFLs to prime eye-level positions, and installation of in-aisle and "catch the season" displays made CFLs the default for impulse light bulb purchasers. With 75% of purchasing decisions made in-store, these changes alone would have dramatically shifted sales in favor of CFLs."
- Prompts: Improve the quality of and multiply the number of prompts to purchase CFLs. "Every package is a prompt and the improved packaging made each one much more effective. Increasing CFL shelf space by 40% increased the number of packages and thus the number of prompts. The additional placements outside the lighting department prompted a whole group of shoppers who might not have passed the lighting department to buy light bulbs."
- Clear mappings: "Efficient lighting products by definition have wattages that are much lower than those of the incandescents they replace…. By placing the CFLs on shelves directly above the incandescents they replaced, Walmart created a masterfully intuitive, visual mapping that enabled people to find the right CFL without needing to learn what a lumen was or noticing the differing wattage."
- Choice: "If choice is too extensive, people will revert to the status quo or not act at all. It is imperative that program managers ensure that customers who are offered a choice of efficient products are presented with a limited set of choices rather than an extensive one."
- Reduced uncertainties and effort: Simplify choice to the ultimate extent with the displays in grocery aisles and on the "catch the season" wall: there was just one bulb option. Walmart's educational display intended to reduce doubt and uncertainty about the performance and light quality of the new product for the many customers who were not familiar with CFLs.
- Contrast effects: "Essentially all human judgments are relative. We judge whether something is big or small, expensive or cheap, by comparing it with something else…. Hence, discount stores' frequent use of "Their price: $500. Our price: $199" on price tags."

"Behavioral research and research on retail sales and promotion indicate that for products such as light bulbs, in-store factors are generally more important than those outside the store."

Nonresidential

Product flow and critical market actors: There are two general types of nonresidential lighting installations: replacements/small-scale renovations, which typically involve distributors and electrical contractors; and new construction/large-scale renovations, which typically involve architects or electrical engineers and electrical contractors. The product flow and critical market actors for each is shown in the figure below, which was taken from a NEEA/ Xenergy report (2000)[4].

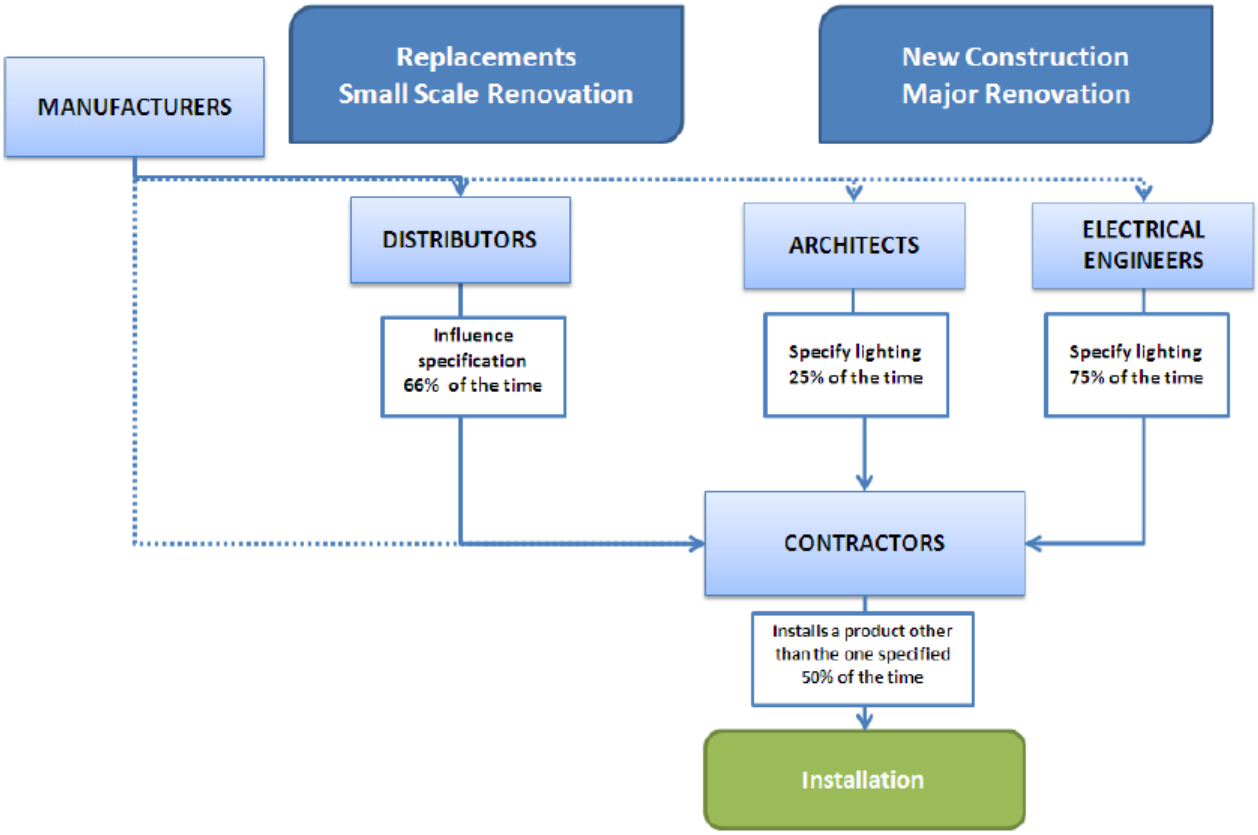


Figure 12 – Nonresidential Lighting Product Flow and Key Market Actors (Source: Xenergy, 2000)

Further excerpts from the study include the following:

Distributors sometimes sell directly to building owners or managers who install the replacement products themselves. But frequently, distributors sell to contractors who are hired to install products, particularly when a fixture or ballast is being replaced. "Distributors are typically paid on commission based on product sold. In the short-term, interventions that increase their margin per unit sold will be attractive. In the long-term, longer lived

[4] Xenergy, Inc. "Commercial and Industrial Lighting Study". Prepared for the Northwest Energy Efficiency Alliance. 2000.

products will lower their sales volumes and may necessitate developing new business models, such as retaining ownership of the installed fixtures and lamps and providing lighting as a service."

"Electrical contractors' role remains significant because they typically have latitude to substitute products or lighting solutions and will often do so if a less expensive option is available or if the specified product cannot be procured easily." […] "Half the time, contractors install a product other than the one specified. It is critical to encourage contractors to seek efficient products in all installations, but it is equally important to encourage distributors to stock higher quantities of efficient products at reduce cost, thereby indirectly encouraging contractors to use efficient products." […] "The tendency for electrical contractors to reverse decisions made by others earlier in the chain is most likely when neither they nor their distributors have been involved in developing the lighting design or specifications, i.e., for major renovations and new construction."

"Architects may be able to induce engineers to try out new approaches because electrical engineers seek to please architects to earn their repeat business. Absent this motivation, electrical engineers are under pressure to keep costs low. Thus, measures that reduce the cost of products/solutions will also make those solutions more attractive to electrical engineers."

"For new construction and major renovation projects, lighting is specified by architects about 25% of the time and by electrical engineers about 75% of the time. Again, the contractor may not adhere to an architect or engineer's lighting specification if the specified product is not readily available or a less expensive model is available.

While lighting may be the first priority of energy efficiency program managers, it is usually one of the lowest priorities for electrical engineers and architects, and one of the last items installed during the renovation and construction. This means designers will turn to tried and true solutions and lighting is more likely to be a target for cost cutting or simplification, particularly if projects run over budget or behind schedule." Electrical engineers tend to favor familiar products and solutions to avoid uncompensated redesigns.

Market Actors	Motivator
Manufacturers	• Promote products with highest profit • Highly competitive market
Architects	• Prefer to design creative, artistic space • If T&M contract, prefer expensive materials • If fixed price, will cut costs
Electrical Engineers	• Rely on familiar techniques to reduce callbacks • Seek to please architects to earn repeat business • Typical job is fixed priced – cost cutting and familiarity
Distributors	• Typically paid on commission, based on products sold
Contractors	• Rely on familiar techniques to reduce callbacks • Often fixed price – rely on familiar technologies • Choice is driven by availability and price • Rely heavily on distributors for advice and guidance.

Figure 13 – Nonresidential Market Actors and Their Motivations (Source: D&R, 2012)

Evergreen Economics 2013: Basic/Advanced/LMT Program Process Evaluation: Commercial Lighting Retrofits – Targeted Research

Primary Author: Evergreen Economics

Client: Southern California Edison and Pacific Gas & Electric

Publication Date and Report Type: October 11, 2013, Final Report

Link: http://www.calmac.org/publications/SCE0307.01_-_SCE_and_PGandE_Lighting_Final_Report.pdf

This study included the D&R California Lighting Critical Synthetic Literature Review.

"The Evergreen team's primary goal was to conduct research to inform the following commercial lighting areas of inquiry, within SCE and PG&E territory:

- The supply side structure of the commercial lighting market for advanced lighting technologies;
- The key drivers of the commercial advanced lighting market;
- The motivations of market actors and end users; and,
- How and why certain end users go "above and beyond" the typical lighting retrofit to install commercial advanced lighting."

The study consisted of three research tasks. First, the analysis team conducted a broad residential and commercial literature review. Then, the team conducted in-depth interviews to collect information on market structure and market actor motivations. Finally, the team conducted a telephone survey on commercial reasons for installing advanced lighting technologies.

Excerpts and Relevant Findings:

Nonresidential

"Commercial lighting market actors strongly influence the choice of lighting products among end users. This stream of influence – the midstream and upstream market actors – is where programs should look to influence choice architecture."

"Market barriers to advanced lighting retrofits are typical for new products in general, and include:

- High initial cost, exacerbated by availability of lower cost efficient options
- Knowledge and product awareness gaps among market actors
- Risk associated with product uncertainty and high initial cost"

Key market actors in the lighting retrofit market are manufacturer representatives, lighting distributors, contractors, and lighting designers. "Among these market actors, contractors have the greatest influence on what lighting commercial end users chose to install, and are frequently the only lighting professional to interact directly with the end user. However, contractor influence on end user choice does not happen in a bubble. Rather, the knowledge, available choices, and decisions of other market actors in the supply chain affect what contractors recommend to end users. Evidence from our primary and secondary research supports this theory and suggests that distributors may offer a unique opportunity for commercial lighting programs in California. Distributors can special order almost any available lighting product, but evidence suggests that what the distributor carries influences the product awareness and choices made by contractors. While contractors influence end user decisions,

our research suggests that the influence they impart on end users is affected by the relationships and motivations of market actors further upstream. Therefore, one important commercial end user "want and need" is for a reduction in distributor risk related to actively stocking and promoting advanced lighting technologies, discussed in more detail below."

Recommendations:

- "Reduce distributor risk: Market actors reported that distributors seek to meet, but not exceed, demand as a way of minimizing their risk. This can potentially constrain the choices presented to end users by reducing the likelihood that all options are equally presented. In order to affect the choice architecture presented to contractors, and ultimately to commercial end users," reduce distributor risk by:
  - "Accelerating contractor awareness and knowledge to increase demand of advanced lighting technologies. […] Providing contractors the tools to learn about and market advanced lighting may both accelerate their knowledge and increase their ability to sell advanced lighting retrofits."
  - "Testing midstream buy-down strategies to reduce the amount of capital a distributor must risk to stock advanced lighting products. Program administrators would assume part of the distributor risk by lowering the cost and risk of stocking."
  - "Leveraging relationships with manufacturers, possibly in the form of upstream buy-downs, to positively impact terms of sale agreements with their distributors."
- Tiered support for advanced technologies: Incentive programs will be offering 'premium' incentives for emerging technologies that are proven but not widely employed in the markets for which they are intended.

ODC 2012: The Southern California Edison (SCE) Advanced Light Emitting Diode (LED) Ambient Lighting Program Customer Preference and Market Pricing Trial

Primary Author: Opinion Dynamics Corporation (ODC)

Client: Southern California Edison

Publication Date and Report Type: December 2012, Final Report

Link: http://www.calmac.org/publications/SCE0324.01.pdf

"Initiated in May 2011, this study was conducted through December 2012 and focused on two ambient lighting categories: A-Lines and Reflectors. Within the Reflector category includes the sub-categories R, BR, PAR (screw-in Reflectors), and decorative recessed can retrofit lamps (Clip and Rim type)." The report focuses on SCE territory and presents the LED Market Pricing Trial Study (SCE Trial). The SCE Trial included the following data collection activities: (1) Market Pricing Trial (Pricing Trial), (2) Latent Class Discrete Choice (LCDC) Study and Segmentation Analysis, (3) In-home Customer Lamp Trial (Lamp Trial) among SCE Customers, (4) An Installation Survey of Lamp Trial Customers, (5) In-depth Interviews with Lamp Trial Customers (IDIs), and (6) Preliminary Focus Groups with SCE Customers (Focus Groups).

Excerpts and Relevant Findings:

Residential

"Pricing Trial: While no ideal "sweet spot" was identified for specific incentive levels or prices to increase sales, several discoveries emerged from the Pricing Trial that could help the SCE optimize incentives in their programs (Pricing Trial).

- Reflectors and A-lines showed different reactions to price reduction. Reflectors gained the greatest return on sales, selling at almost five times the rate of A-lines. For every 1% decrease in price, there is a 3.25% increase in Reflector sales, compared to a 1.14% increase in A-Line sales.
- LEDs sold much better when their prices were relatively close to the price of an equivalent CFL of the same type. Products with prices $20 or less sold the best in all categories."
- High prices are unacceptable to customers: Irrespective of product type, income level, or other test factors, sales at prices above $40 were virtually non-existent."
- "On average, LED lamp sales in high-income areas were 4.1 times higher than sales in low-income areas and 1.9 times higher than stores in medium-income areas. LED lamp sales in medium-income areas were 2.2 times higher than low-income areas."
- "Our data suggest significant retailer effects on sales. This test verifies that the choice of retailer is important because some sell LED products significantly faster and in higher quantities than others."
- Region (central vs. remote in the Los Angeles basin) had no statistically significant effect on sales.

Customer Willingness to Pay: The study included "qualitative and quantitative efforts to understand customers' willingness to pay for LEDs."

- "Customers are extremely price sensitive," and "price is the number one purchase decision for lighting."
- "Customers will accept LED lamps priced comparably to Compact Florescent Lamps (CFLs)."
- "Notably, customers indicate they will pay a premium for LED Reflectors, even though our Pricing Trial indicates high sensitivity to price for this category. Specifically, customers indicated that they would pay as much but no more than $10 for LED A-Lines and $30 for LED Reflectors (IDIs). This indicates that customers are receptive to LED technologies for this particular category."

Customer Perception and Awareness of Ambient LEDs:

- Focus Groups: "Customers are leery of LED technologies due to (1) little to no direct experience with the technology, and (2) negative past experiences with CFLs. Due to low levels of self-reported exposure to ambient LEDs, customers tend to expect similar drawbacks to new LED technologies that were indicative of the early rollout of CFLs. Primarily, customers are concerned about lighting quality, ability to dim smoothly, flickers, and realization of longevity claims. Other concerns include disposability and safety."
- In-Depth Interviews with Lamp Trial Customers: "Once experiencing LEDs, customers prefer the lighting quality of LEDs but skepticism lingers about unobservable attributes such as longevity. Customers are overwhelmingly satisfied with LED light quality and prefer it to CFLs once they have had the opportunity to directly experience the product."

Customer Attribute and Design Preferences:

- "After price, customers select products for purchase based on different attributes depending on whether they are selecting A-Lines or Reflectors. Specifically, energy savings, product type (CFL vs. LEDs), and long-

term savings drove A-Line selection. For Reflectors, product type, the purchase location or outlet, and brightness drove product selection. (LCDC)

- Customers who tried LEDs in their homes expressed clear preferences for product attributes. Specifically, customers are looking for warmer color temperatures; smooth, linear dimming; 100-watt equivalent lamps; and wider beam angles (115 degrees or more) for Reflectors.
- Notably, customers are more receptive to LED technologies for Reflector purchases. Our data suggest that customers are more interested in LEDs for Reflector technology. This is backed up by our Lamp Trial as well as our LCDC results. (LCDC, Lamp Trial and IDIs)"

Recommendations:

- "SCE should use its incentives to foster and "approve" higher quality products that will satisfy customers' expectations.
- SCE should stock and incentivize more wide-angled Reflector lamps and consider in-store education on beam angle and applications. Most customers did not/do not consider beam angle when purchasing lighting; however, their satisfaction with LED Reflector technology was highly affected by the beam angle of the lamps."
- "SCE should work with manufacturers to improve dimming quality of Reflector lamps and/or incentivize those that meet a minimum dim-ability standard."
- "Consider developing different marketing strategies for each product category, targeting the key selling points unique to each product category."
- "SCE should consider targeting early-adopting segments through online channels in the short term before prices drop enough to entice other segments. These segments (Tech Seekers and Product Explorers) are willing to pay more for new technologies, express high interest in LEDs, and look to make their purchases online.
- Target the Reflector market first to gain LED market penetration: Customers are substantially more receptive to LEDs when shopping for Reflectors."
- Educate customers on LED lamp longevity, disposal, safety, and functional quality. Focus group respondents were concerned that LEDs might also be hazardous or require special disposal the way that CFLs do. Customers noted that longevity claims cannot be trusted due to past experiences with CFLs. With the high cost of LEDs, a lack of trust in longevity claims may present an additional barrier to purchase.

KEMA 2012: California LED Lamp Market Characterization Report

Primary Author: DNV KEMA Energy & Sustainability

Client: California Public Utilities Commission Energy Division

Publication Date and Report Type: June 12, 2012, Final Report

Link: http://www.calmac.org/publications/LED_Market_Characterization_Report_-_Final.pdf

This study "provides 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." "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."

Excerpts and Relevant Findings:

General

"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."

D&R 2012b: Residential Lighting Market Profile

Primary Author: D&R International, Ltd.

Client: None

Publication Date and Report Type: 2012, Final Report

Link: None

D&R completed a profile of the residential lighting market, intended to serve as a reference for energy efficiency stakeholders.

Excerpts and Relevant Findings:

Residential

Upstream Program Recommendations

"Unfortunately, the short and medium term outlook for energy efficient residential lighting is not good.… Seven out of every eight lamps sold are incandescent. LED lamp prices, while falling, are likely to still be too high to generate really big sales volumes and for energy efficient programs to subsidize at reasonable cost."

"Walmart sold 137 million CFLs in 2007 by making changes in its stores that radically reshaped the choice architecture for both planned and impulse purchasers of light bulbs. It put CFLs at eye level, demoted incandescents to lower shelves, and placed stack-outs of CFLs in grocery aisles and on its Catch the Season wall at the front of the store. Programs in California, Vermont and the Northwest aggressively recruited retailers so a large fraction of people in their regions would encounter CFLs at eye-opening low prices in the places they shopped most frequently. Both types of changes matter because impulse and reminder purchase choices can account for up to 74% of in-store decisions. Although price reductions were an important factor for some programs, they were not the whole story; California and Vermont steeply discounted the price of CFLs, while Walmart did not."

"The trick for program administrators is inducing retailers and the manufacturers who supply them to optimize the choice architectures using strategies described in this Market Profile. Current program models don't do this consistently; one retailer chain can generate as much as 10 times the sales lift from incentives as another in the same channel. To obtain consistently high levels of performance from retail and manufacturer partners, administrators should consider modifying their program models so that they have the following features:

- Directions to retailers and manufacturers to create conditions in which efficient lamps and only efficient lamps are the default for impulse and, if possible, planned purchase."
- "Feedback to retailers on their performance relative to the incentive
- Flexibility on pricing for retailers and manufacturers so they can maximize top line sales revenue and profit.
- Options that enable and encourage the participation of most stores in frequently visited retail channels and/or those stores responsible for the majority of lamps sales, as well as the manufacturers who supply them."

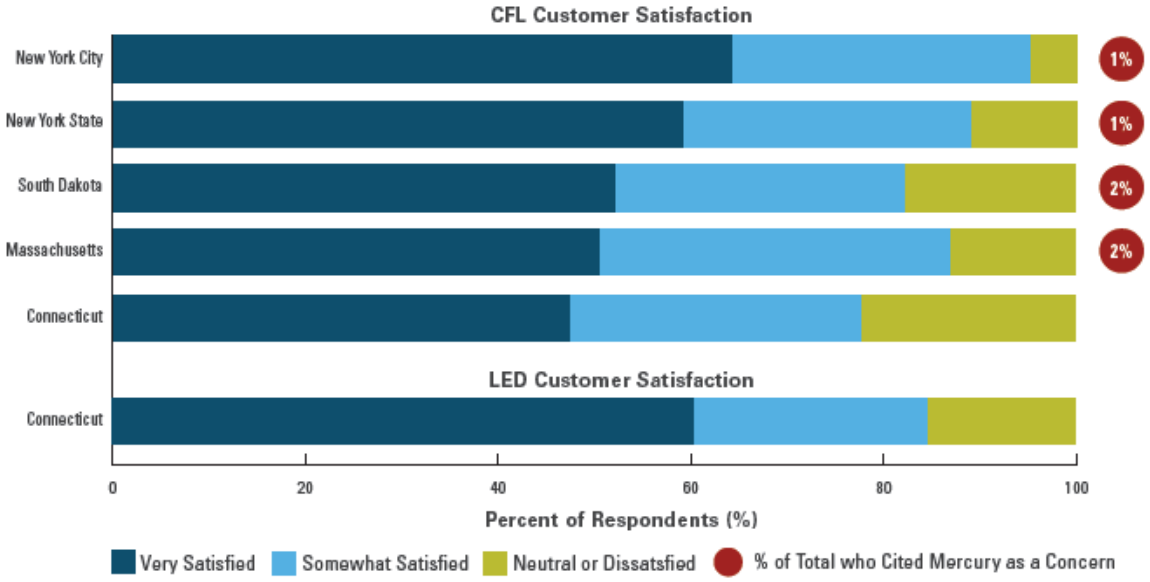
Customer Satisfaction

"Consumers are generally satisfied with CFLs. In surveys conducted in four states between 2009 and 2012, 78% or more of respondents reported that they were somewhat or very satisfied with CFLs. Satisfaction is similarly high across regions. (While self-reported data cannot be relied upon in most cases, they are indispensable for assessing attitudes such as level of satisfaction with a product.) On-site audits support this finding. CFLs are found in rooms throughout the home, which suggests that, at the population level, consumers like CFLs enough to purchase and install them wherever a light bulb is needed." [TRC notes that this finding should be balanced with the finding above, that seven out of 8 bulbs purchased is incandescent.]

"Because so few customers have experience with LED lamps, there is a lack of data on consumer satisfaction with LEDs. However, the LED satisfaction study available, a survey conducted in 2012 in Connecticut, indicates that 83% of 76 customers were satisfied with LEDs, a greater percentage than those satisfied with CFLs (77%). Also, 59% of survey respondents indicated that there was nothing they did not like about LEDs, compared to 39% who had the same response for CFLs.

Mercury has often been cited as a serious drawback of CFLs, in both mass media and discussions within the lighting industry. However, surveys of CFL users indicate that no more than 2% cited mercury or disposal among their concerns.
[TRC notes that this is different from the findings of Optimal Strategix Group, 2011.]

Figure 25. Consumer Satisfaction with CFLs and LEDs and Concern with Mercury



Notes: Customer satisfaction values are from 2010 Multi-State Study, except for that of Connecticut which is from 2012. Only respondents who reported being neutral or dissatisfied with CFLs were asked what concerns they had with CFLs.

25 — NMR Group, Inc. "Connecticut EISA Lighting Exploration: Stage 2 Results." May 21, 2012. Draft..

Figure 14 – Consumer Satisfaction with CFL and LEDs, Concerns with Mercury (D&R, 2012b)

Primary Focus on Price

"Efficient lighting program incentives, be they coupon, instant rebate, or buy-down, assume that price is the primary driver of sales. However actual lighting sales data provided to the D&R show tremendous variation in sales lift from incentives among retailers—between sales channels and even within a single channel. Figure 34 shows the sales lift associated with incentives in five national retail chains in 2010-2012. Note the tremendous difference in sales lift among "Do it Yourself" (DIY) retailers. One achieved only a 20% increase in sales of incentivized vs. non-incentivized CFLs, while another achieved 200%! The dramatic sales increase is thus not solely a reflection of the price discount. Those retailers with much higher sales with incentives must be engaged in other activities that either deliver the substantially higher sales or tremendously enhance the impact of the price discount. Walmart's 137 million CFLs sold in 2007 illustrate this concept, as it sold these lamps for $2.52 per lamp—a much higher price than many spiral CFLs today. By focusing on other in-store factors, such as targeted messaging and optimal in-store placement, Walmart was able to overcome the price differential of CFLs and boost demand."

Figure 15 – Percent Increase in CFL Sales with Incentives for Different Retailers (D&R, 2012b)

Mismatch with Retailer Business Metrics

"Current buy-down and coupon incentive program models have negative impacts on primary retailer business metrics, reducing their value to retailers, lighting buyers, and merchants."

How do people make choices?

Several situational factors have been shown to very strongly influence decision making. These factors are listed roughly in order of their importance and strength. The more factors present, the stronger the effect. Text in parentheses represents the corresponding scientific terminology for these effects.

1. The default condition (status quo bias)
2. What we see other people doing (social norms/social proof)
3. Urgency, often due to limited supply or limited time (scarcity effect)
4. Whatever is readily at hand (status quo bias)
5. Reminders, prompts, and other attention-getters (prompts)
6. Relative cost/comparative value (contrast effect/anchoring and adjustment)
7. The number of things to choose among (choice overload/option paralysis)
8. Recommendations from similar people (homophilicity)
9. Familiarity, confidence, and emotional associations (availability heuristic)

Figure 16 – Primary Reasons (in order of importance) for Decision Making (D&R, 2012b)

"The Power of Suggestion. One study conducted by Brian Wansink, published in the Journal of Marketing Research, indicates that a simple suggestion may be enough to influence how much shoppers buy. Sales almost doubled simply by suggesting that shoppers buy more—without any discount at all!" [Note that this recommendation is for marketing in general, not based on a lighting example.]

Figure 37. The Power of Suggestion over Quantity Purchased

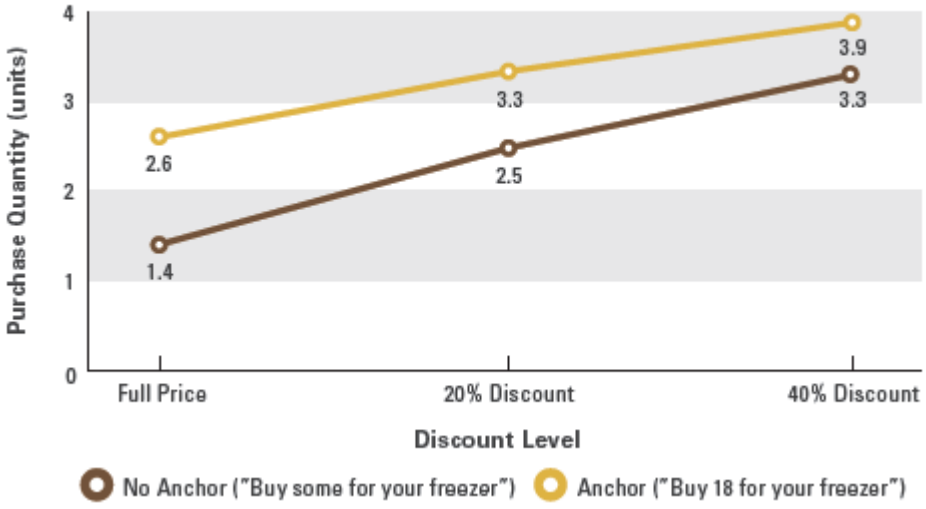


Figure 17 – The Power of Suggestion and Impact on Quantity Purchased (D&R, 2012b)

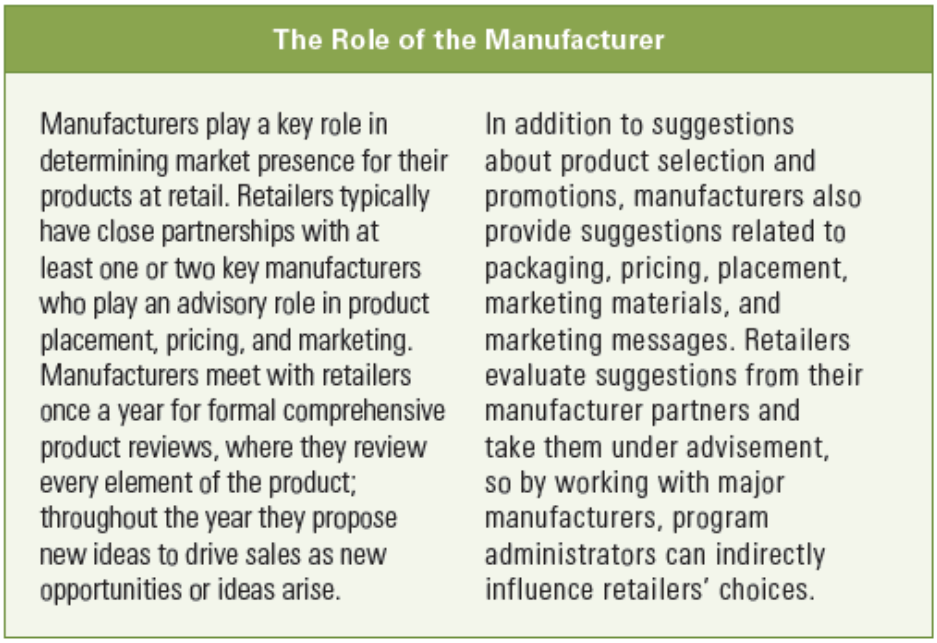
Choice Architecture in the Store: "The in-store choice architecture can be designed to increase sales without a huge increase in spending. Anchoring signs, greater visibility, and an emphasis on dollar savings can all have a big impact on sales." […] "A field study D&R conducted for the U.S. DOE in 2006 found that well-designed signage in the lighting aisle was sufficient to lift CFL sales 10%-15%. In-aisle product stack-outs and end caps should be even more effective because they make the efficient lamp the default for impulse purchasers. Data D&R gathered as part of the 2006 study showed that the presence of an in-aisle product stack-out for 99-cent bare spiral CFLs was associated with 300%-700% increase in sales at participating stores!"

"The key components of Walmart's 18Seconds campaign were the following:

Improved packaging and package messaging	Had GE redesign packaging to be visually cleaner and simpler
	Rebranded the lamps as "Energy smart"
	Made "Saves $38 in energy" the primary message
Installed an in-shelf display in the lighting aisle	Showed 10 types of CFL and incandescent lamps side by side
	Incorporated messaging comparing lifetime costs and highlighting savings
Lowered the actual and percieved product price and promoted purchase of multipacks	Dropped the price of a 3-pack from $9.58 to $7.58, which decreased the per-bulb price from $3.19 to $2.52
	"Saves $38 in energy" made $7.58 seem even smaller in contrast
Placed CFLs in more prominent locations	Increased CFL shelf space by 40%
	Replaced a portion of incandescent product shelf space with CFLs
	Demoted incandescent lamps to lower shelves and placed CFLs at eye level and within easy reach
	Retained section of lighting set previously devoted to CFLs
	Placed stack-outs in the grocery section of the store and periodically featured the product on the "Catch the Season" wall at the front of the store
Increased advertising and PR	Advertised CFLs in weekly circulars
	GE ran a complementary print advertising campaign
	Campaign was covered in national newspaper and magazine stories

Figure 18 – Key Components of Walmart's 18 Seconds Campaign for CFLs (D&R, 2012b)

"The retailer is the gate keeper for the in-store choice architecture. What the retailer allows to be actively promoted will have a strong impact on market share. For both large and small retailers, the manufacturer also plays a very important role, and as Efficiency Vermont and others have shown, there is often a need for program implementers to provide direct support and monitoring to make sure promotions are executed as agreed, even more important when the goals are to ensure stores maintain a particular choice architecture."



The Role of the Manufacturer

Manufacturers play a key role in determining market presence for their products at retail. Retailers typically have close partnerships with at least one or two key manufacturers who play an advisory role in product placement, pricing, and marketing. Manufacturers meet with retailers once a year for formal comprehensive product reviews, where they review every element of the product; throughout the year they propose new ideas to drive sales as new opportunities or ideas arise.

In addition to suggestions about product selection and promotions, manufacturers also provide suggestions related to packaging, pricing, placement, marketing materials, and marketing messages. Retailers evaluate suggestions from their manufacturer partners and take them under advisement, so by working with major manufacturers, program administrators can indirectly influence retailers' choices.

Figure 19 – The Manufacturer Role in Retailer Decisions (D&R, 2012b)

KEMA 2013a: 2012-2013 Northwest Residential Lighting Market Tracking Study

Primary Author: DNV KEMA Energy & Sustainability

Client: Northwest Energy Efficiency Alliance

Publication Date and Report Type: July 8, 2013, Final Report

Link: http://neea.org/docs/default-source/reports/2012-2013-northwest-residential-lighting-market-tracking-study.pdf?sfvrsn=10

The study investigated Northwest consumer awareness of CFLs, motivations for CFL purchases, and consumer familiarity with emerging lighting technologies. The study used market actor interviews, phone surveys with customers, shelf surveys, and a regional CFL sales assessment.

Excerpts and Relevant Findings:

Residential

- **"Purchase Motivations.** CFL purchasers cite energy savings and length of life as the best features of CFLs. The 2013 surveys gauged whether current CFL users are likely to purchase CFLs within the next year; among those who are unlikely to purchase CFLs, the survey asked why. Nearly a third reported that they didn't need more CFLs, and nearly one in five reported that it was because they were storing CFLs or because CFLs are not bright enough. Satisfaction with CFLs also declined between 2011 and 2012; the survey asked respondents to rate their satisfaction with CFLs on a scale of 1 to 10 where 1 means, "not at all satisfied" and 10 means, "very satisfied" and the percentage of respondents who were "very satisfied" (ratings of 9 or 10) declined by a statistically significant margin (from 37 to 32%) while the percentage who were only "somewhat satisfied" (ratings of 3 to 5) increased by a statistically significant margin (from 16 to 24%).
- **Familiarity with emerging lighting technologies.** Consumer survey results suggest that 85% of Northwest consumers were aware of LED lamps as of early 2013 and that 56% were aware of energy-efficient (EISA-qualifying) incandescent lamps. Only 30% of the Northwest population had purchased LED lamps by that time, and only 21% had purchased energy-efficient incandescent lamps. Across all Northwest consumers, LED lamps represented 14% of the lamps purchased in 2012 and energy-efficient incandescent lamps represented 6% of all lamps purchased."

The study found the following lighting marketing materials in Northwest retail stores:

- **"Messaging.** The most common messages in 2012 replacement lamp promotional activities related to energy or money savings; materials with these messages were present in 16% of Northwest retail stores during the shelf survey visits. Utility representatives also mentioned energy or money savings as a key theme in their messaging (mentioned by 12 of 14 utility representatives who had promotional activities in 2012), and two-thirds of suppliers also reportedly mentioned savings in their messaging as well (6 of 9 respondents). More suppliers mentioned promotional materials with messaging regarding length of lamp life in 2012 (8 of 9).

  A handful of utility program managers mentioned some gaps in messaging regarding energy-efficient lamps in the Northwest market, including messages to help consumers understand lumens or color rendering (each mentioned by 3 utility representatives), light quality (2 mentions), and general information about LEDs (2 mentions). Half of the utility program managers whose organizations used promotional materials in 2012 suggested that a possible role for NEEA might be to help provide consistent providing marketing and outreach materials for energy-efficient lighting throughout the region (7 of 14 utility representatives)."

Drivers of customer decision-making regarding lamp purchases and influences on those decisions:

- "[T]he research and data collection activities included in this study did not support a thorough exploration of this objective. However, the consumer telephone survey explored consumer opinions regarding seven CFL qualities and attributes in particular, and these results provide some indications regarding possible misunderstandings of CFL technology that, if addressed, may motivate consumers to purchase CFLs. The survey asked respondents to agree or disagree with seven statements regarding CFLs. The level of agreement was strongest with the statement "CFLs are not suitable for use in all of the rooms in my home," with 55% of CFL purchasers agreeing with this statement. These results may suggest a lack of understanding regarding the range of CFL styles and color rendering capabilities available to consumers. Nearly half of CFL purchasers agreed that "CFLs take too long to light up," echoing the sentiment expressed by more than a third of CFL purchasers in response to a survey question regarding the worst features of CFLs. However, "instant-on" CFL technologies exist, and this capability could be promoted as a feature of other energy-efficient lamp technologies (such as LED lamps)—indeed, one utility program representative mentioned using a promotional message for LED lamps in 2012 mentioning this feature."

"Consumers may be shifting some of their focus away from CFLs and toward other energy-efficient lamp technologies:

- Survey results suggest a small but noteworthy drop in consumer awareness of CFLs between the 2012 and 2013 surveys. But it is more likely that consumers have shifted some of their focus away from CFLs and toward other energy-efficient lighting technologies given the high level of awareness of LED lamps and moderate awareness of energy-efficient incandescent lamps.
- Declining satisfaction with CFLs may also reflect increasing consumer familiarity with other energy-efficient lamp technologies; as consumers are increasingly exposed to these other technologies, their expectations regarding CFLs (and thus satisfaction with CFLs) may be changing."

"Promotional messaging for replacement lamps in Northwest retail stores largely focuses on energy savings, money savings, and long lamp life—messages with which Northwest customers already seem familiar (at least for CFLs).

- Interviews with residential lighting program managers at the region's utilities and shelf survey results suggest that saving energy or money is the most common message highlighted in promotional materials for residential replacement lamps. Nearly all suppliers mentioned that a lengthy lamp life was their most common message, but two-thirds also mentioned energy and/or money savings as a key message.
- In consumer surveys through 2012, consumers consistently mentioned length of CFL life as their best feature. In the 2013 survey, more consumers mentioned the energy saving features of CFLs than any other feature—but lamp life was close behind. These results suggest that consumers may already be familiar with these features of CFLs."

Recommendations:

- **"Consistent regional messaging regarding energy-efficient lamps.** NEEA should consider working with the region's utilities (and other energy-efficiency program sponsors) as well as lamp manufacturers and retailers to develop consistent, region-wide messaging to support energy-efficient replacement lamp sales. Half of the region's stores are already displaying some sort of promotional materials—and the concepts of energy or money savings and long lamp life dominate these messages. Since consumers already appear to be aware about these positive benefits among CFLs, there may be an opportunity to include other messages that will further drive consumers toward purchasing energy-efficient replacement lamps, such as raising consumer awareness and understanding of lumens, color temperature, and color rendering.
- **Consumer knowledge, preferences, and purchasing motivations.** Related to the above recommendation, consider conducting further and more extensive research to understand consumer knowledge, preferences, and purchasing motivations for replacement lamps. This will enable the region's energy-efficiency program sponsors to develop more effective marketing messages to support energy-efficient lamp sales."
- **"Expanded market tracking efforts.** Given the uncertain future of CFL sales (including a possible leveling off or decline), the increasing impacts of EISA over time, and increasing market presence of LED lamps, expanding sales tracking efforts beyond CFLs would provide NEEA with a more complete picture of the Northwest market for energy-efficient lamps. Tracking sales of incandescent lamps (in addition to CFLs and LED lamps) would also enable NEEA to estimate the share of the Northwest lighting market comprised by energy-efficient alternatives and gain a better understanding of the overall lighting market."
- **"Educational efforts in rural areas**. Rural consumers in the Northwest typically have few (if any) big box stores in which they can shop for energy-efficient lamps, and are therefore less likely to be exposed to promotional materials regarding these products. (Recall that nearly two-thirds of urban stores visited during the late 2012/early 2013 shelf survey visits displayed promotional materials for replacement lamps

compared to less than 10% of rural stores). These efforts may be particularly important going forward as the retail presence of LED lamps (and possibly energy-efficient incandescent lamps) increases, which in turn will present consumers with more energy-efficient lamp choices (and potentially more confusion regarding those choices)."

NMR 2012a: Massachusetts Consumer Survey Results 2012

Primary Author: NMR Group

Client: Cape Light Compact, National Grid, NSTAR, Unitil, Western Massachusetts Electric Energy Efficiency Advisory Council

Publication Date and Report Type: October 23, 2012, Final Report

Link: http://www.ma-eeac.org/Docs/8.1_EMV%20Page/2012/2012%20Residential%20Studies/FINAL%20Massachusetts%20Consumer%20Survey%20Results%20Wave%202%20102312.pdf

Excerpts and Relevant Findings:

Residential

"The research presented here compares the results of a telephone survey (here after the 2012 survey), performed between June 18, 2012 and August 2, 2012, with the results of a similar survey (here after the 2011 survey) performed between December 8, 2011 and January 19, 2012. The 2011 survey sought to establish a baseline at the onset of the changes in lighting standards resulting from the Energy Independence and Security Act of 2007 (EISA) while the 2012 survey searched for possible changes in the lighting market since the initial implementation of EISA….In total, we surveyed 604 households [in 2012], with three respondents answering the Spanish version of the survey. [582 households were surveyed in 2011]. We weighted the data by education and home ownership status so that the results are representative of all households in Massachusetts."

Results from the executive summary reiterate what is shown in the following charts.

Figure ES-1: CFL Awareness and Familiarity, 2009 to 2012

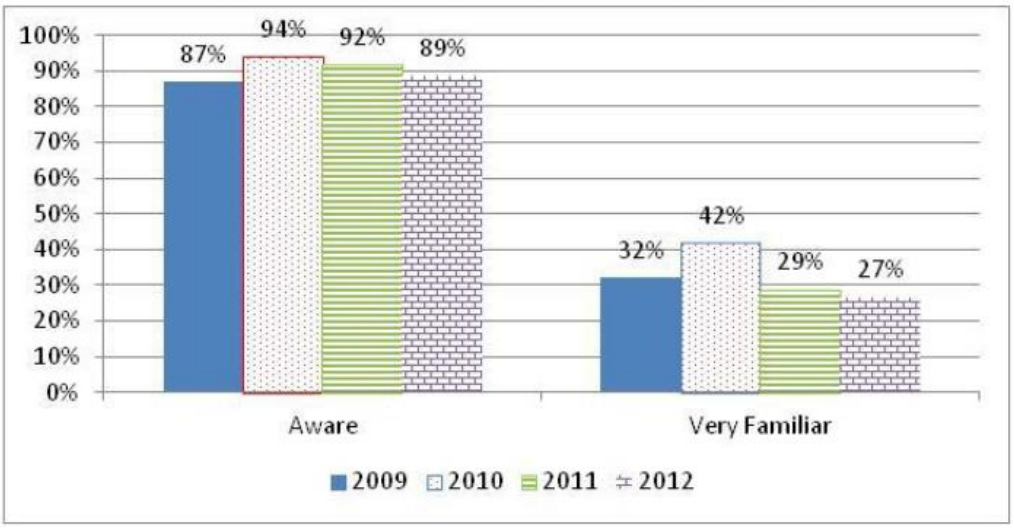


Figure 20 – Awareness and Familiarity with CFLs in Massachusetts Households (NMR, 2012)

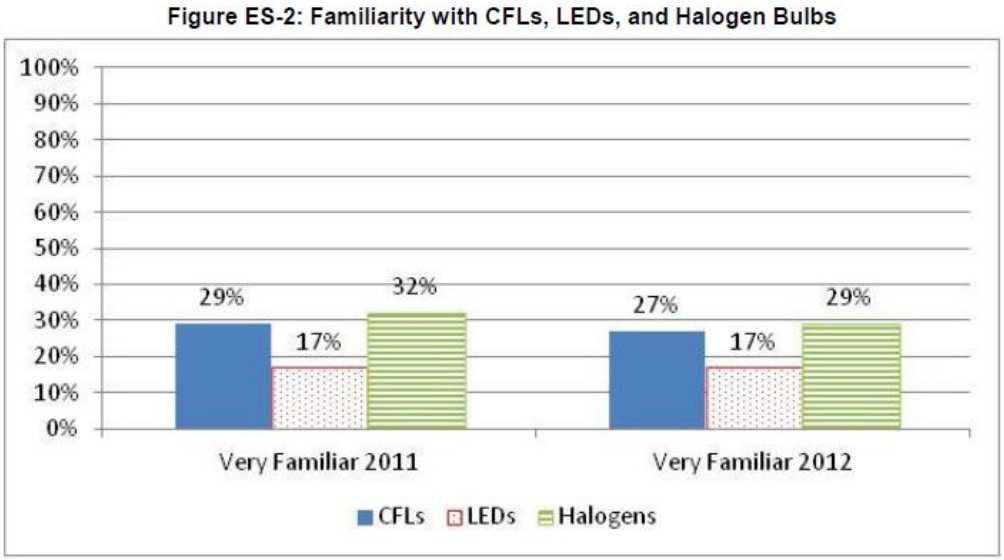


Figure 21 –Massachusetts Households Reporting to be "Very Familiar" with CFLs, LEDs, and Halogens (NMR, 2012)

"When asked what types of information they look for on bulb packing, 96% of respondents report that they consider wattage, 92% consider price, and 70% consider wattage equivalency. These percentages are statistically similar to those reported in the 2011 survey. Other characteristics considered by more than one-half of the respondents include bulb life, color appearance, the ENERGY STAR label, and bulb shape.

Given that lumens and color appearance will become increasingly important aspects of choosing a light bulb after the phase-out of incandescent bulbs, the Team asked respondents if they had heard of these terms, and, if so, what the terms meant. Most consumers had heard of lumens (55%) and the terms warm white and cool white (67%), which were similar but slightly higher percentages to those we observed in 2011. Of those who had heard these terms, 74% (or 45% of all 604 respondents) correctly understood that lumens referred to light output or brightness, the same percentage as in 2011. Of those who had heard the terms warm white and cool white, 83% (or 60% of all 604 respondents) correctly identified them as referring to the color appearance of the bulb. This percentage is statistically lower than the 92% from 2011. In 2012, more respondents (7%) seemed to confuse color rendition and color appearance."

"When asked to explain their bulb choices, those who said they would buy CFLs or LEDs most often mentioned the energy savings associated with these bulbs, while those that chose the other bulb types cited preference for the light color or brightness. The possibility that consumers will buy many incandescent bulbs and save them for use after the incandescent phase-out has been the subject of much discussion in the energy-efficiency community and in the media discussions of EISA. Our research concludes that about one-fourth (24%) of all respondents are likely to engage in this stockpiling or hoarding behavior; however, 30% of respondents who were aware of EISA prior to the survey reported being likely to stockpile incandescent bulbs."

"The percentage of respondents that were very satisfied with CFLs increased significantly from 2011 to 2012, but remained statistically lower than satisfaction in 2009 and statistically similar to satisfaction in 2010 (Figure ES-4).

Due to the concerns raised in response to the decreased levels of satisfaction found in the 2011 survey, the Team added a question in 2012 to determine if respondents' satisfaction with CFLs had changed over time, and, if so, why their opinions had changed. More than three out of four CFL users (76%) said their satisfaction with CFLs had stayed the same, and 18% said their satisfaction had increased. Only 5% replied that they were less satisfied with CFLs now than a year ago."

Figure ES-4: CFL Satisfaction, 2009 to 2012

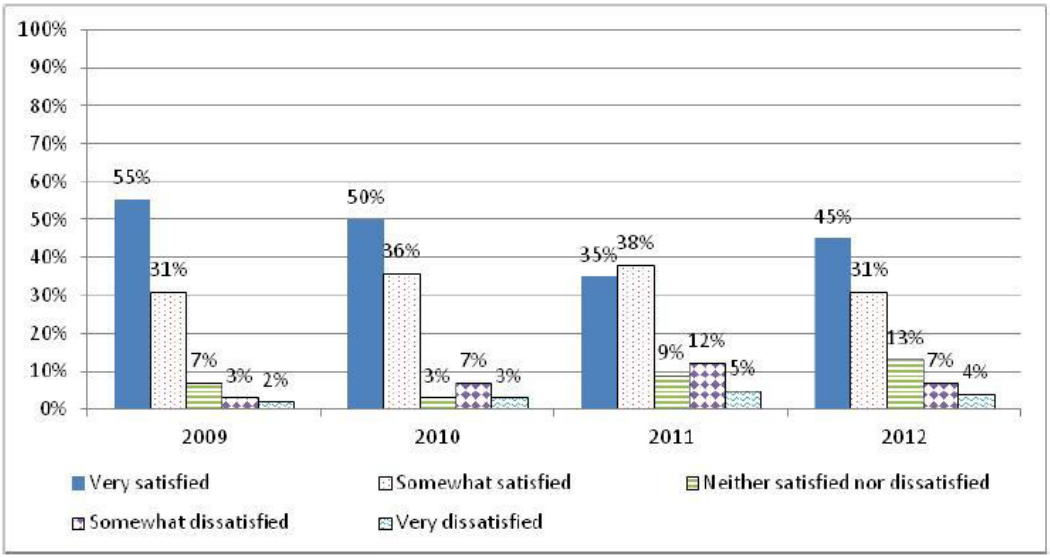


Figure 22 – Satisfaction with CFLs in Massachusetts Households (NMR, 2012)

"Out of the 31 respondents who indicated their satisfaction with CFLs increased over the past year and who had been exposed to media stories about lighting, 67% said that news stories contributed to their increased satisfaction. Alternatively, of the 13 respondents whose satisfaction with CFLs decreased and who had been exposed to lighting news stories, 59% indicated that news stories were responsible for the decrease. These findings indicate that media attention toward lighting has the capability to sway opinions toward the bulbs in either direction, depending on the content of the story, but, on the whole, the influence appears to have been more positive than negative in the past year.

When asked what they did like about CFLs, respondents—both those who are and are not satisfied with them—most often cited that they save energy, have a long bulb life, and save money on bills. In contrast, respondents are less happy with how slow CFLs are to brighten, mercury and disposal issues, and poor light color. For dimmable CFLs, respondents focused on the fact that these bulbs are also slow to turn on/brighten, and do not dim as much as other bulb types."

Recommendations

"Bulb Dimmability: In the 2011 survey results, NMR noted that users of dimmable CFLs generally tended to like them, but the most persistent complaint about them is that they do not dim consistently or as much as other types of light bulbs. At that time, we recommended that the PAs consider removing dimmable CFLs in favor of promoting LEDs for dimmable applications. However, since making the recommendation, the Team has learned from various sources that LEDs may have dimmability concerns as well. Therefore, we withdraw the recommendation and refrain from making new recommendations about dimmable bulbs specifically. However, the previous recommendation

about continuing to promote only the highest quality energy-efficiency bulbs certainly applies to dimmable energy-efficient bulbs."

"Stockpiling of Incandescent Bulbs: The results presented for both the 2011 and 2012 surveys as well as the onsite saturation effort suggested that about one-fourth of respondents will consider stockpiling incandescent bulbs, and that some respondents have already started to do so. Therefore, NMR continues to recommend that the PAs may want to consider placing a consumer education campaign that helps consumers make more informed bulb choices, rather than simply defaulting to the incandescent bulb with which they are most familiar. Moreover, as explained in the onsite study, the PAs may also want to consider asking partner retailers not to repeat "get them while you can" incandescent bulb campaigns in late 2012 and 2013, as they did in late 2011 before the 100 Watt phase-out started.

Consumer Understanding of Key Lighting Concepts: While consumers are becoming more familiar with the term "lumens" and understand that it means light output or brightness, they still buy bulbs based on wattage or wattage equivalence. Therefore, we believe that the suggestion that the PAs continue their efforts at helping consumers make the transition from thinking about Watts to thinking about lumens remains relevant."

NMR 2012b: Massachusetts Consumer Survey Results Winter 2012

Primary Author: NMR Group

Client: Cape Light Compact, National Grid, NSTAR, Unitil, Western Massachusetts Electric Energy Efficiency Advisory Council

Publication Date and Report Type: October 23, 2012, Final Report

Link: http://www.ma-eeac.org/Docs/8.1_EMV%20Page/2013/Residential%20Program%20Studies/Winter%202012%20Consumer%20Survey%20Results%20Final%20Report%205-30-13.pdf

This "Winter 2012" study was a follow-up to the "2012" study (see above). Much of the results in the Winter 2012 report were the same as in the 2012 report, so TRC did not excerpt these findings. We provide unique findings below.

Excerpts and Relevant Findings:

Residential

"Conclusion 3: A subset of Winter 2012 survey respondents explained in open-ended responses to certain questions that they wanted to move to LEDs as their preferred lighting source, but were hesitant to spend $20 for a light bulb. As LED technology continues to improve and the market matures, it is likely that the lumens achieved per watt will increase, the price of the bulb will come down, and consumers will become convinced of the bulb's long life. At that point, more of them may be willing to pay the higher price for LEDs over halogens or CFLs. They also address some of the respondents' issues with CFLs, most notably, mercury content and slowness to brighten, although conflicting reports still exist on dimmability.

- Consideration 3a: In trying to increase adoption of LEDs, the PAs may want to consider educational materials that highlight the advantages of LEDs, but in a manner that does not denigrate CFLs. Further, the PAs should likely continue their efforts to keep the upfront cost of LEDs down while still maintaining program cost effectiveness.

- Consideration 3b: The PAs could explore the optimal price point for LEDs in future evaluations and market assessments."

HMG 2013: Comprehensive Commercial Lighting Initiative Pilot Evaluation Report

Primary Author: Heschong Mahone Group (HMG)

Client: Northwest Energy Efficiency Alliance

Publication Date and Report Type: April 12, 2013, Final Report

Link: http://neea.org/docs/default-source/reports/comprehensive-commercial-lighting-initiative-pilot-evaluation-report.pdf?sfvrsn=8

HMG conducted an assessment of a comprehensive commercial lighting initiative (CCLI) pilot for NEEA in territories of Idaho Power, Idaho Falls Power, NorthWestern Energy, and Energy Trust of Oregon.

NEEA and utility stakeholders developed the CCLI pilot to move away from focusing on individual measures to an integrated, design-based approach that makes much greater use of lighting controls. In addition, the utilities offered tiered incentives on overall kWh reductions to encourage deeper energy savings instead of incentives per piece of equipment. To support this pilot, the CCLI provided in-depth training for participating trade allies, as well as one-on-one design support for individual projects conducted as part of the pilot programs. This report discusses findings from the evaluation of the CCLI pilot conducted by HMG, including an assessment of the initial effectiveness of the pilot projects, and recommendations for future lighting program initiatives.

Excerpts and Relevant Findings:

Nonresidential

"Overall, the process analysis portion of the evaluation found that program implementers and program participants were generally satisfied with the outcomes of the pilot program. Building owners reported satisfaction with the improved light quality delivered by the comprehensive retrofit projects. Program implementers and utility program managers stated that the training and education provided by the CCLI increased the skill level of the participating trade allies. However, they also felt that trade allies need even more education and training to effectively implement comprehensive retrofit approaches and new lighting technologies.

In addition, program implementers, utility program managers, and participating trade allies all reported that added administrative burdens, such as additional reporting and paperwork required for comprehensive projects, and longer wait times to receive incentive payments, were barriers to participation in the CCLI pilot. The relatively short time period for the pilot program (less than a year) also limited participation, as trade allies need a longer time to develop and complete business. Many utility program managers reported challenges developing an appropriate incentive structure for comprehensive lighting retrofits that was distinct enough from traditional incentive offerings and balanced with the added effort required by trade allies, while still maintaining program cost-effectiveness."

"There was little consistency in the responses relating to motivations and barriers for the participating trade allies. However, when asked about what barriers customers face, a majority (five of eight) cited the higher cost of comprehensive projects." The main motivation for program participation was the number of projects they could sell. Trade allies tended to cite the higher incentives as their main motivation for participating. Building owners/facility managers were most motivated to conduct comprehensive retrofits by increased energy savings and improved lighting quality.

ERS 2013: Emerging Technologies Research Report for the Regional Evaluation, Measurement, and Verification Forum

Primary Author: Energy & Resource Solutions

Client: Northeast Energy Efficiency Partnerships

Publication Date and Report Type: February 13, 2013 Final Report

Link: https://www.neep.org/Assets/uploads/files/emv/emv-products/NEEP_EMV_EmergingTechResearch_Report_Final.pdf

The study team investigated LED lighting to establish savings values that could be utilized by Regional EM&V forum facilitated by the Northeast Energy Efficiency Partnership.

Excerpts and Relevant Findings:

General

"Lighting systems based on LED technology offer the prospect of transforming the commercial and residential electric lighting market in a way unprecedented since the introduction of the ballasted fluorescent lamp in 1938. While most other types of lamps are approaching their maximum theoretical efficacy, the best performing white-light LED products are only half way to their theoretical potential. At the same time, production costs and market pricing for LED lighting systems are dropping and are expected to continue to decrease in both cost per lumen and cost per lamp."

Nonresidential

"In large part, lighting efficiency programs have focused on the adoption of advancing technologies as replacements for existing equipment or as substitutes for baseline, standard-practice equipment at time of replacement or for new construction and major renovations." […] "In contrast, ASHRAE Standard 90.1-based energy codes approach lighting energy savings on connected lighting load metrics, expressed as lighting power allowance (LPA), which is the maximum lighting power density (LPD; in watts/ft2) allowed for each space or building area. Several of the Forum member organizations have implemented LPD-based lighting design programs that serve as models for a regional procedure that could be fully shared. This program model is commonly termed "performance lighting" in the Northeast and promotes lower LPDs and automated control of the subsequent lighting load. Additionally the program model promotes advanced technologies such as LEDs, low-power ballasts, high-efficiency fixtures, and high-efficacy lamps and ballasts as a means to obtaining lower LPDs, and bi-level switching, daylight dimming, vacancy/occupancy sensing to further reduce consumption."

"For commercial applications, LEDs are currently replacing exterior incandescent and high-intensity discharge (HID) lighting as well as special display lighting and incandescent and halogen lighting for retail applications. Flat panel LED lighting is showing promise as general space lighting."

Residential

"In the residential sector, advancing federal lighting standards defined in Energy Independence and Security Act (EISA) legislation call for the phasing out of standard incandescent lamps beginning with 100-watt bulbs in 2012, with other incandescent phase-outs planned for the following years. Although halogen and compact fluorescent lamps will be market options, LEDs promise to grab a large share of the household lamp market."

NMR 2012c: Results of the Massachusetts Onsite Compact Fluorescent Lamp Surveys

Primary Author: NMR Group

Client: Cape Light Compact, NSTAR, National Grid, Unitil, Western Massachusetts Electric, Energy Efficiency Advisory Council

Publication Date and Report Type: October 23, 2012 Final Report

Link: http://www.ma-eeac.org/Docs/8.1_EMV%20Page/2012/2012%20Residential%20Studies/Lighting%20Onsite%20Report%2010.23.12%20Final.pdf

"This report presents the findings of research conducted to understand use, saturation, and purchases of lighting products in Massachusetts households in support of the Massachusetts ENERGY STAR® Lighting Program (the Program). The study also sought to understand baseline conditions early in the implementation of the Energy Independence and Security Act (EISA) of 2007 and search for possible impacts on lighting use and purchase behavior that may be the result of the new lighting standards."

Excerpts and Relevant Findings:

Residential

"To conduct this research, the team performed 150 onsite lighting inventories in Massachusetts households between January and April 2012. The onsite respondents were recruited through a prior telephone survey among 582 households in Massachusetts in 2011."

"Only 7% of onsite households used LEDs at the time of the onsite, and they collectively used 92 LEDs. Most of these LEDs did not have the A-shaped profile and were instead used as track or under cabinet lighting. One household accounted for 29 of the LEDs, and the mean number of LEDs was 0.6 for all households. Only two LEDs were found in storage."

"The 2011 telephone survey results demonstrated a persistent decrease in satisfaction with CFLs between 2009 and 2011; 55% of respondents were very satisfied with standard CFLs in 2009 compared to 50% in 2010 and 34% in 2011. This trend raised the concern that lower satisfaction could translate into lower CFL use. In order to determine if satisfaction had an effect on verified CFL use, saturation, and purchases, the team compared these indicators between respondents who said they were "somewhat satisfied" or "very satisfied" with CFLs to those who were less satisfied or did not know their level of satisfaction. As expected, the results suggest that households that are satisfied with CFLs buy more CFLs and have them installed in more sockets. This confirms the concern that decreased satisfaction may eventually lead to lower rates of CFL use, and this will be particularly important if consumers turn to halogens instead of LEDs or CFLs to replace incandescent bulbs in the post-EISA lighting market. Yet, it is also the case that households reporting greater levels of satisfaction with CFLs also have fewer sockets, suggesting that the homes are smaller. It may be that households living in bigger homes have more specialty applications and are dissatisfied with the performance of CFLs in those sockets."

Recommendations

"Consider revisions to program design to reinvigorate adoption of standard and specialty CFLs. These revisions should include updated marketing strategies to boost use of energy-efficient bulbs in standard and specialty applications. Bulb buyback programs – Either buying working incandescents back at slightly below their retail value, or offering to replace incandescents with CFLs. This could be accomplished at store kiosks or other central locations. Ending "get them while you can" incandescent promotions at program retailer stores last September (prior to the

100-Watt phase-out), a team member noted that some program retailers had displays of incandescents in or near lighting aisles and even at the check-out lanes with signs urging consumers to "get them while you can." To the extent that this is still occurring or may occur again prior to the phase-out of 40-Watt to 75-Watt incandescents, the PAs may want to exert pressure to stop the practice, perhaps by negotiating a "cease fire" among some of the major retail partners to stop promoting incandescents at the very least, and preferably to phase them out early."

"Continue working with the residential retail products and other residential evaluation teams as well as program implementers to understand the dynamics of consumer satisfaction with CFLs and LEDs more fully. The telephone survey demonstrated that respondents who say they are satisfied with CFLs often have similar concerns about the technology as those who are dissatisfied with CFLs. The onsite analysis suggested that dissatisfied households used and purchased fewer CFLs, on average, than did those who were satisfied with CFLs. Yet, despite these findings, we still do not have a clear understanding of what makes one person decide not to use CFLs; for example, one person may decline to use them because he or she takes a while to warm up and another person may shrug this concern off as unimportant when compared to the things he or she likes about CFLs. The Wave 2 consumer survey will explore reasons for satisfaction and dissatisfaction with CFLs—including the role of media attention—in more depth. However, additional strategies, such as more in-depth questioning during onsite inventories or focus groups, may be needed to understand these dynamics more fully and could also reveal steps the PAs could take to increase satisfaction among consumers."

"Continue efforts to educate consumers about their bulb choices post-EISA, helping them to make the most efficient choices possible for their lighting needs. This recommendation echoes those made in the consumer survey report, but its importance is highlighted by the fact that consumers currently have little awareness of A-shaped halogens but are fairly aware of CFLs. The opportunity now exists to help them understand the benefits of using CFLs and LEDs over halogens in most applications in the home. A-shaped CFLs offer a unique opportunity, as they resemble incandescents and can be used with clip-on lampshades, unlike standard CFLs. Related to this recommendation is the suggestion to consider the cessation of promotions of CFLs and LEDs that do not perform at levels consumers desire; dimmable, three-way, and candelabra CFLs and LEDs are among the products the PAs should consider not supporting until the technology improves to standards desired by consumers. The PAs should review performance data for all types of specialty CFLs and LEDs to determine which ones have the quality to justify promotion."

NBI 2013: Enlighted Technical Proof of Concept Study

Primary Author: New Buildings Institute (NBI)

Client: Northwest Energy Efficiency Alliance

Publication Date and Report Type: July 9, 2013, Final Report

Link: http://newbuildings.org/sites/default/files/NEEA_Enlighted_Report.pdf

The "Enlighted" system describes an emerging technology for nonresidential lighting applications. Its features include sensors and controls at the luminaire level. The Northwest Energy Efficiency Alliance (NEEA) is particularly interested in this system, and plans to launch an initiative to incentivize this type of advanced lighting controls system.

The study below describes technology and results from its installation in 4 pilot sites.

Excerpts and Relevant Findings:

Nonresidential

"The First Generation Enlighted system is comprised of five main components: Enlighted Sensor, Enlighted Control Unit, off-the-shelf dimmable ballast, Enlighted Gateway and Enlighted Energy Manager. The sensor bundle collects data on occupancy, light levels and temperature. The control unit collects energy consumption information and passes this information from the sensor unit to the dimmable ballast. The sensor unit stores the control profile/program and wirelessly communicates with the Enlighted gateway. One Enlighted gateway can cover 50-150 fixtures, depending on the floor plan. The gateway relays information via Ethernet to a dedicated server called the Enlighted Green Energy Manager. Out of the box, the Enlighted system controls each luminaire independently, but operators can also program the system from a central location in order to maximize user satisfaction and energy savings."

"After installation of the Enlighted controls, occupants generally experienced increased comfort and satisfaction with the light levels and with their ability to control those levels. In general, most thought the new system improved the brightness levels of fixtures originally deemed too bright; decreased the gloominess; increased the pleasantness of the surface brightness; and decreased glare and burning eyes and headaches (except for one site, where headaches increased). Task lighting elicited a diversity of opinions. Most thought the system was an improvement, but that it was too dim to complete high-light tasks, such as reading or filing. A few found the new controls distracting when the lights turned off while they occupied the space. Feedback on daylighting varied depending on the type of office space. Open office occupants typically felt they have insufficient daylight, while occupants in private offices along the window wall considered their levels of daylight sufficient."

Philips Research 2013: Advanced Lighting Controls for Reducing Energy Use and Cost in DoD Installations

Primary Author: Philips Research, Lawrence Berkeley National Laboratory

Client: Environmental Security Technology and ESTCP/SERDP

Publication Date and Report Type: March 2013, Final Report

Link: http://www.serdp.org/Program-Areas/Energy-and-Water/Energy/Conservation-and-Efficiency/EW-201012

"The [Department of Defense's] Environmental Security Technology Certification Program (ESTCP) commissioned a team consisting of Philips and LBNL to study the performance of advanced lighting control systems in DoD buildings. Philips developed and deployed the lighting control systems and LBNL carried out the evaluation of energy savings and occupant surveys by collecting pre and post retrofit data and performing all the data analysis. In this report we present the cost and performance analysis of three lighting control systems deployed in three buildings in Ft. Irwin, CA. The advanced lighting control systems deployed are: Hybrid ILDC (Integrated Lighting and Daylight Control), OccuSwitch Wireless and Dynalite."

Excerpts and Relevant Findings:

Nonresidential

"Ten out of 24 occupants responded to the pre-retrofit survey, and 13 out of 20 responded to the post-retrofit survey. This gave this building the most extensive survey results out of 3 buildings surveys. Key findings are:

- None of the pre-retrofit occupants were satisfied with their ability to control their lighting, while 4 of 13 post-retrofit occupants were satisfied. This suggests that while the retrofit improved occupants' lighting controls experience somewhat, it still left plenty of room for improvement.
- Several post-retrofit free response comments from open office occupants expressed frustration with the open office lights being too bright, lack of ability to dim the lights, and inconsistent system operation. However, the survey took place during a period of time when the system was malfunctioning and there was no dimming control in the open office. This makes it difficult to separate out the effect of the malfunction with occupants' overall perceptions.
- In both pre- and post-retrofit surveys, the most common desired improvements listed were:
  - Fixtures that emit less light
  - To change the color appearance of the lighting fixtures
  - To have the ability to control the light output of the overhead light fixtures
  - Better access to windows and daylight"

"In general, occupants in this building seem to prefer very low workspace light levels. Since the retrofit increased open office light levels somewhat in accordance with DPW's preferences, this may have caused some dissatisfaction. Feedback suggesting that occupants would prefer lower light levels is a strong argument in favor of lighting controls that make it easy for occupants to control light levels, since these will potentially improve occupant satisfaction while reducing energy use.

Finally, in the OccuSwitch system [a room-based lighting control system which reaps energy savings through occupancy sensing, dimming and daylight integration] demonstrated in building 602, the user selected dimming levels reset to default levels each time the space becomes unoccupied. Based on the feedback from occupants, Philips developed a software upgrade that stores the user preferred dimming level as the new defaults, thereby setting the lights to the most recent selected level the next time a space is occupied. This updated firmware was installed on July 26, 2012. This is expected to improve occupant satisfaction considerably by giving occupants lasting control over workspace light levels."

KEMA 2013b: Process Evaluation of the 2012 Bright Opportunities Program

Primary Author: DNV KEMA

Client: National Grid

Publication Date and Report Type: June 14, 2013, Final Report

Link: http://www.ma-eeac.org/Docs/8.1_EMV%20Page/2013/Commercial%20&%20Industrial%20Program%20Studies/13%20-Large%20C&I%20Yr.%202012%20Bright%20Opportunities%20Program%20Process%20Evaluation%20Final%20Report%206-14-13%20.pdf

Excerpts and Relevant Findings:

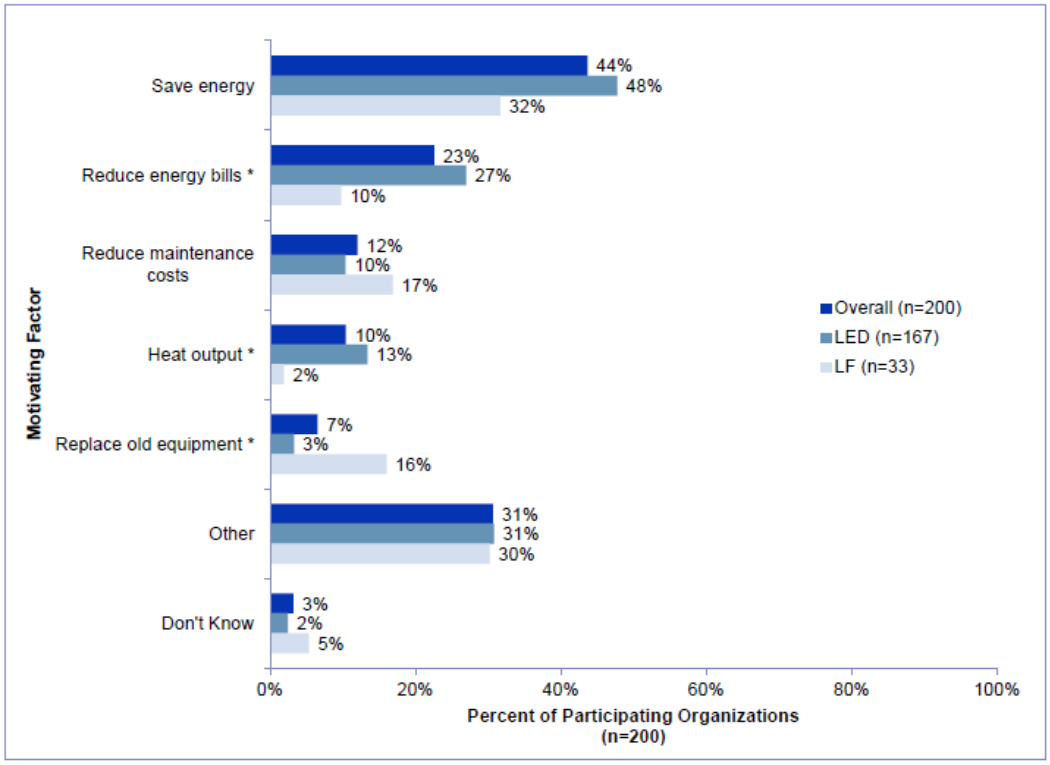
Nonresidential

Bright Opportunities is a relatively new program from the Massachusetts Program Administrators that provides incentives directly to distributors of specific lighting technologies (LED bulbs and linear fluorescent tubes). While

these "upstream" incentives go directly to the distributors, the program design assumes that the discounts will be passed down the supply chain so that lighting contractors and end users will be able to purchase the participating technologies at a substantially discounted price. The study conducted surveys with 200 end users, interviews with 33 participating and nonparticipating distributors, interviews with 25 participating contractors, and interviews with program staff.

"Motivation to Participation: The most common reasons that participants provided for participating in the Bright Opportunities were to save energy [(44% of respondents)] and to reduce their utility bills [(23%)]. A hypothesis proposed by the evaluation team was that LED end users were more likely to have energy efficient practices and policies than linear fluorescent end users. The survey results produced mixed evidence for this hypothesis. On one hand, LED and linear fluorescent end users had similar frequencies of having energy-using equipment purchase guidelines and energy managers on staff. On the other hand, LED end users were more likely than linear fluorescent end users to say that they made the purchase to reduce their energy bills."

Figure 4-10: Motivations to Participate



* Difference between LED and linear fluorescent is statistically significant at 90% confidence level.
Note: Totals exceed 100% because multiple answers were accepted.
Other included the following, each mentioned by less than 5% of the respondents: get incentives, pro-environmental corporate policies, longevity, old equipment failed, quality of light, installer/contractor recommendation, old equipment working poorly, distributor/salesperson recommendation, recommendation of pa staff, the technical assistance offered through the program, recommendation of internal staff, past experience with program, and unspecified other reasons.

Figure 23 – Massachusetts Nonresidential Customers' Motivation to Participate in a Program by Lamp Type (LED v. Linear Fluorescent) (KEMA 2013b)

Program Delivery: "Figure 1-1 shows that over 90% of both the LED participants and the linear fluorescent participants were satisfied (4 or 5 on a 5-point satisfaction scale) with the program-discounted bulbs/lamps and with the contractors or suppliers who sold them. The 90% figure is for all bulbs, including those in dimmer switches. However, as discussed in the main body of the report, the participating end users were less satisfied (72% of respondents) with the performance of the bulbs/lamps in dimmer switches."

Figure 1-1: Participating End User Satisfaction

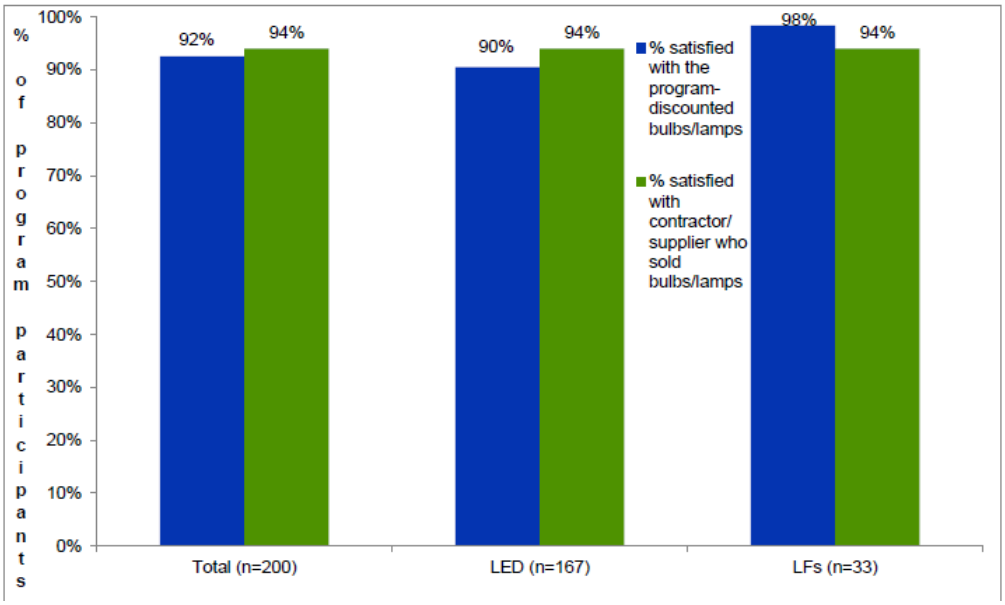


Figure 24 – Nonresidential Customers' Satisfaction with Lamp Performance (LED v. Linear Fluorescent)

"We also asked the participating distributors and contractors about their level of satisfaction with various aspects of the program:

- **Distributor/contractor satisfaction with the program-discounted bulbs/lamps**: We asked the participating lighting distributors and contractors whether they had received any customer complaints about the LED bulbs that the program discounted. Nearly half (46%) of the distributors and nearly two-thirds (64%) of the contractors said that they had received no complaints. Of those distributors/contractors reporting customer complaints, the most frequently-cited complaint concerned the performance of the LED bulbs controlled by dimmer switches. However, the distributors/contractors reporting these customer complaints also commented that they were relatively infrequent."
  - **"Recommendation**: Do more consumer education about the use of LED bulbs in dimmer switches. We recommend that the program provide more education/resources on the performance of LEDs on dimmer switches and encourage distributors/manufacturers/contractors to do the same. Such information might include recommended dimmer lists and general information on the technical challenges of LEDs on dimmers, including minimum load ratings. We make this recommendation based on the following evidence:
    - While overall 90% of the participants who used LED bulbs through the program were satisfied with the performance of these bulbs, only 72% of participants who had used LED bulbs in dimmer switches were satisfied with their performance."

- Of the few end users (about 16%) who reported any barriers to using the LED bulbs, nearly half (46%) of those reporting problems said they had trouble operating the bulbs with dimmer switches.
- Of those distributors/contractors reporting customer complaints, the most frequently-cited complaint concerned the performance of the LED bulbs controlled by dimmer switches.

- **"Distributor/contractor satisfaction with the incentives, marketing and the program as a whole:** Satisfaction levels for the incentive payment process and the program as a whole were very high. However, only a small majority of the participating distributors and contractors were satisfied with the program's marketing efforts. The most common reasons for dissatisfaction were unawareness of any marketing efforts and low customer awareness of the program."
  - **"Recommendation:** Do more marketing of the program, especially to end users. As shown above, only a small majority of the participating distributors and contractors were satisfied with the program's marketing efforts. As discussed in the body of this report, participating distributors who were less-than-satisfied cited a lack of marketing support, saying that while distributors are receiving information and marketing, it is not reaching end users who ultimately drive sales."

Figure 1-2: Participating Trade Ally Satisfaction w/ Incentive Payment Process, Marketing, and Program as a Whole

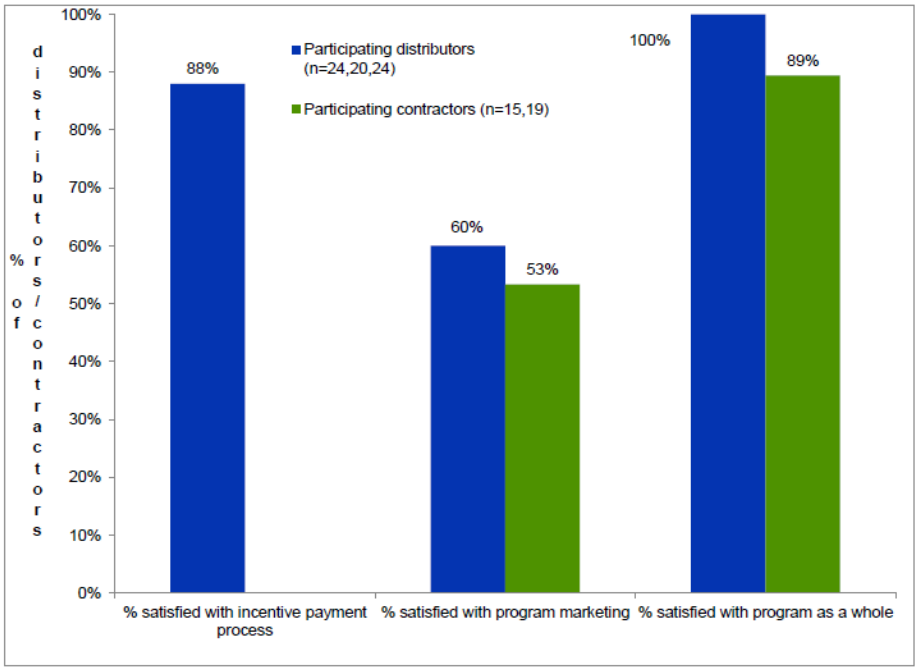


Figure 25 – Massachusetts Trade Ally Satisfaction with Nonresidential Upstream Program (KEMA 2013b)

"We asked participating lighting distributors if participation in the program had any impacts on the mix of lighting products that they sold. 73% of respondents stated that they had changed what they carry, 27% said that it had not. Those who responded 'Yes' cited stocking more LEDs. We also asked the participating lighting distributors if they could characterize or make generalizations about the types of customers they were selling to. A majority of distributors refused to identify specific customers or customer categories, making comparison to customer profiles largely meaningless. Of those that did respond, responses included retail; institutional (hospitals, colleges, property management companies); hotels/hospitality; school districts; and commercial."

"There were several additional interesting differences within LED end users:

- LED end users who owned all of their space were more likely than those who leased some space to say that their guidelines involved energy savings (67% who owned; 8% who leased). Owners typically have more incentive and ability to make energy-saving improvements to their space than lessees.
- LED end users in the retail or office sectors were more likely than those in any other sectors to say their guidelines involved the quality of the light. Light quality may be more directly relevant to theses economic activities, and thus be more important to these organizations.
- Neither of these findings applied to linear fluorescent end users, in part because the small sample sizes limited the power of statistical tests.

We asked the lighting contractors how they decided what products to purchase from distributors. Nearly half (46%) of the contractors cited price as a factor in deciding what products to buy. A number of contractors elaborated on this, stating that they would specifically look for rebates in order to get a better price. Other considerations they cited less frequently included bulb brand, their perceptions of the quality or reliability of the bulbs, choosing from whatever the distributor sells, and availability of stock and quantity. Figure 4-4 shows the frequency with which they cited these various factors."

Of course, in many situations, the lighting contractors are not asked to purchase the lighting, only to install it. One respondent responded that price would make a difference in their bidding but "people don't want us to get involved with buying lights because they know they can get them cheaper themselves.""

Figure 4-4: Decision factors of contractor purchases

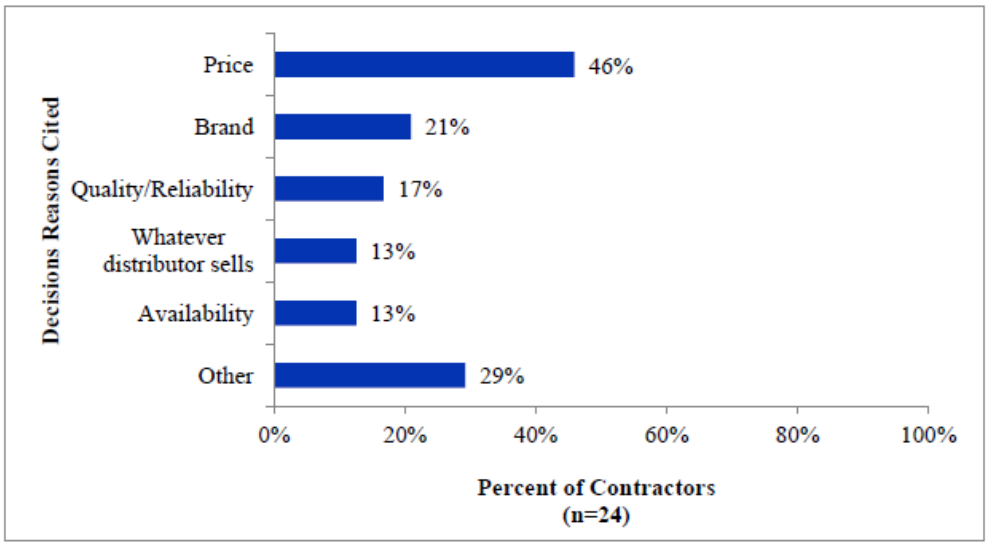


Figure 26 – Massachusetts Nonresidential Contractors' Lighting Purchase Decision Factors (KEMA 2013b)

"Participating Distributors/Contractors: We also asked the participating lighting distributors why they decided to participate in the Bright Opportunities Program. They provided a variety of reasons, with some citing multiple reasons. The most common reasons were to increase or make sales (45%) or due to the incentive levels (35%).Other responses, as shown in Figure 4-12, include a belief in quality or efficient products, customer awareness of the program, already being involved with similar programs and competitors being involved."

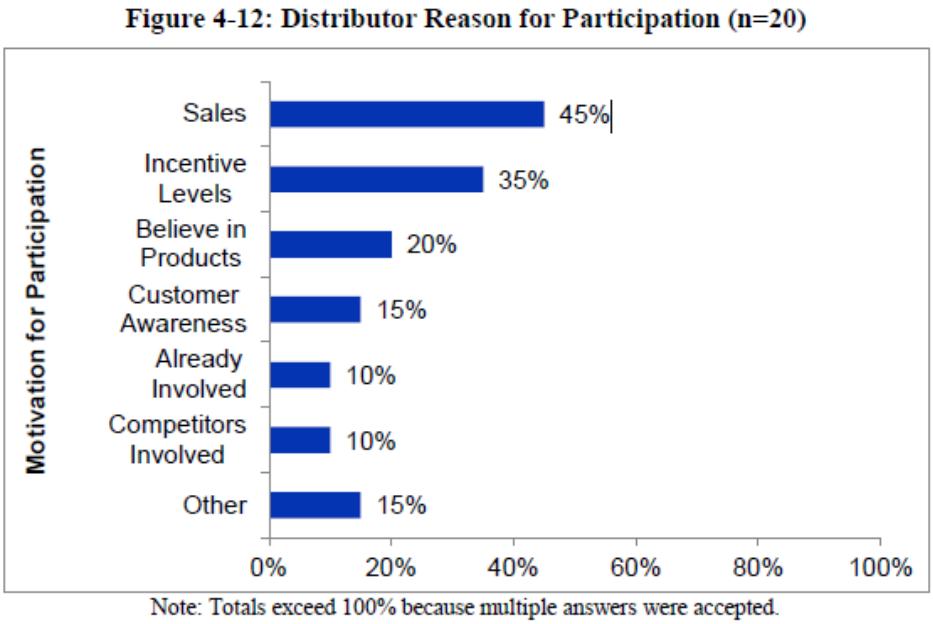


Figure 27 - Massachusetts Nonresidential Distributors' Reasons for Participating in Upstream Program (KEMA 2013b)

Barriers to Participation: "We asked these LED participants who said they had encountered barriers/challenges what challenges they faced. Most of what they reported were performance or lighting quality issues with the LED bulbs. Nearly half (46%) of those reporting problems said they had trouble operating the bulbs with dimmer switches and one third (33%) said that they had difficulty fitting the bulbs in fixtures."

"Twenty-one of the respondents were less than satisfied (satisfaction ratings of 3 or lower) with the performance of their bulbs/lamps in the dimmer switches. When asked to explain why they were less-than-satisfied, the most common reasons included the bulbs/lamps not working properly (39% of the respondents) and the bulbs flickering (36%)."

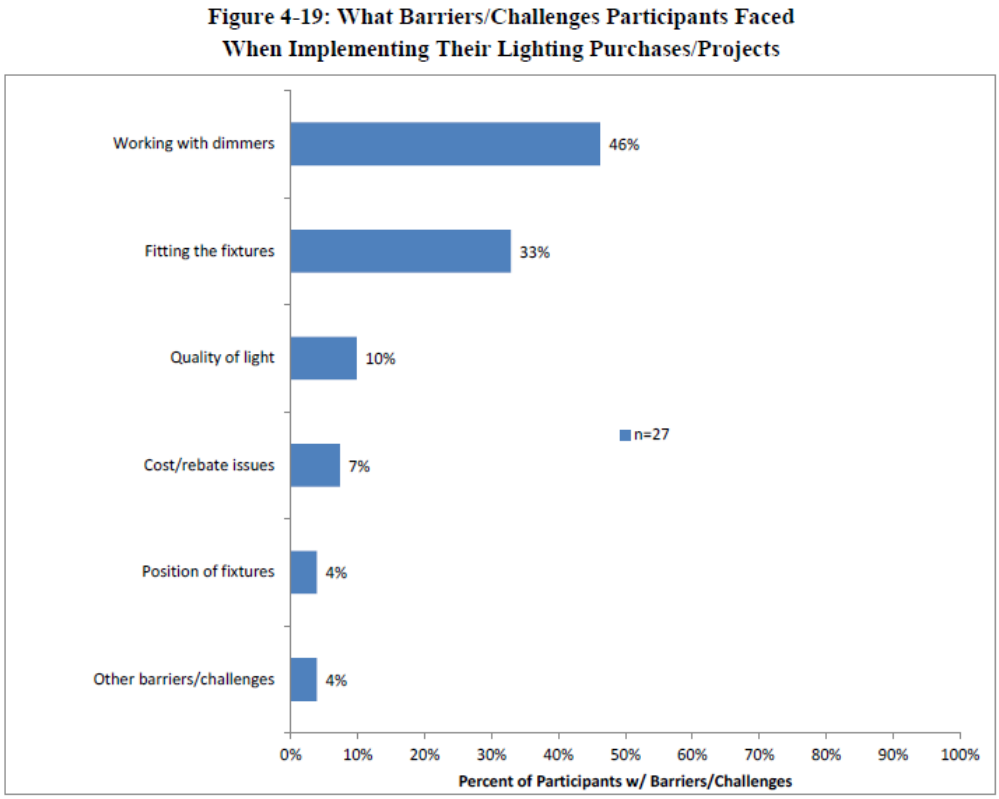


Figure 28 –Nonresidential Upstream Program Participant Challenges with LED Bulbs (KEMA 2013b)

"Certain types of companies or organizations were also more likely to report certain problems with the LED bulbs than others. For example, the non-profit organizations were more likely to report problems with dimmer switches, the non-food retailers were more likely to report problems with fixture fit, and the industrial/warehouse participants were more likely to report issues with light quality. These differences were all statistically significant at the 90% confidence level."

Satisfaction: "Participant satisfaction with the LED bulbs and linear fluorescent lamps was very high with participant satisfaction (4 or 5 satisfaction ratings) above 90% for both lighting types. The average satisfaction rating was 4.7. LED participants were more likely to be very satisfied with the bulbs/lamps than the linear fluorescent participants, but they were also more likely to be less than satisfied with the bulbs. We asked the 15 LED participants and one linear fluorescent participant who were less than satisfied with their bulbs/lamps why they said that. Their most-cited reason was dissatisfaction with the quality of the light (cited by 54% of the less-than-satisfied participants) followed by dissatisfaction with the length of the life of the bulb/lamp (26%)."

"We asked the participating lighting distributors and contractors if they had experienced any complaints from customers or had other problems with the performance of LED bulbs sold through Bright Opportunities Program. Almost half (46%) of the participating distributors and almost two-thirds (64%) of the participating contractors did not report any problems. A quarter of the distributors and 14% of the contractors reported dimming problems with the LED bulbs, but a number of them described these problems as infrequent. One distributor reported that restaurants will sometimes complain because they are used to having the color of the light change when they dim the lights, but this does not happen with LED bulbs."

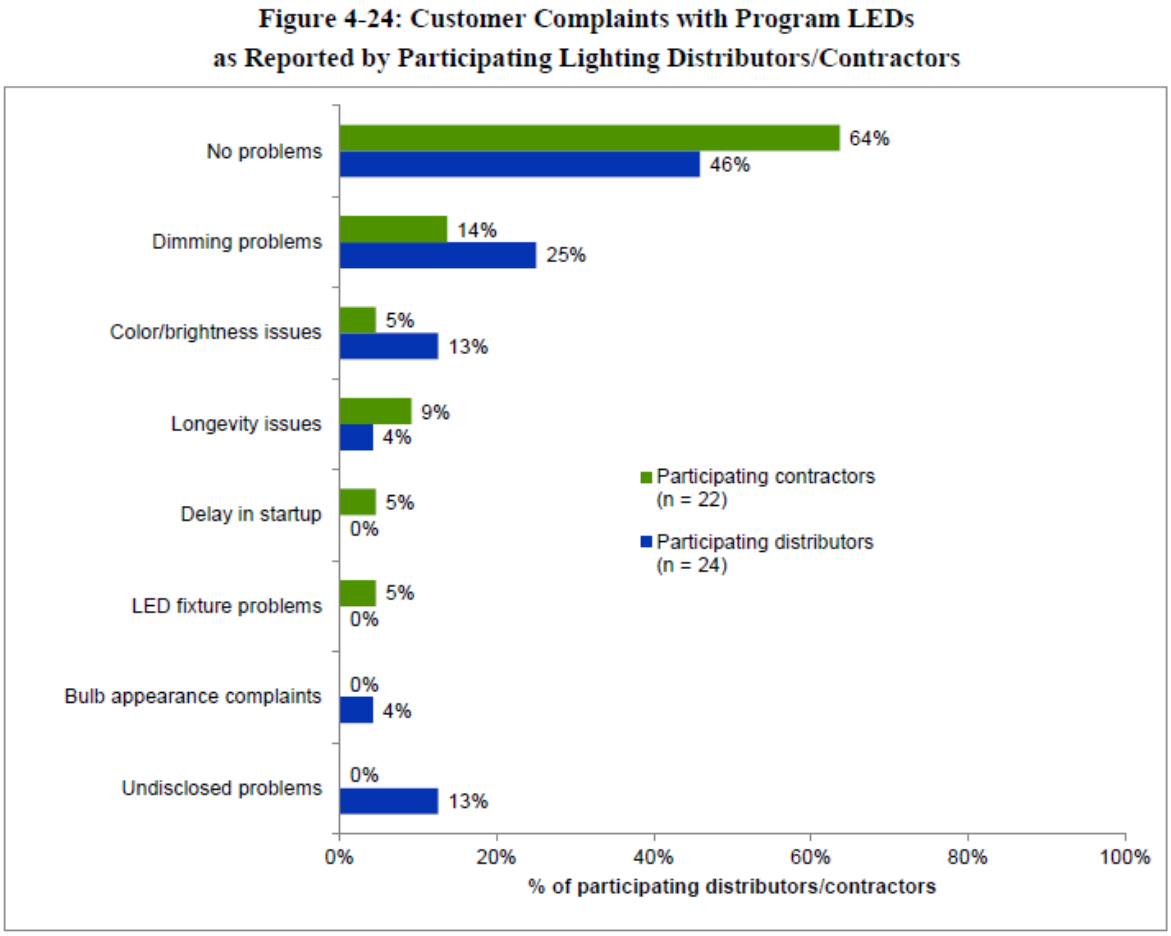


Figure 29 – Nonresidential Upstream Program Participant Complaints Regarding LED Bulbs (KEMA 2013b)

NMR 2013: Lighting Retailer, Supplier Perspectives on the Massachusetts Energy Star® Lighting Program

Primary Author: NMR Group, DNV KEMA

Client: Massachusetts Electric Energy Efficiency Advisory Council

Publication Date and Report Type: June 2013, Final Report

Link: http://www.ma-eeac.org/Docs/8.1_EMV%20Page/2013/Residential%20Program%20Studies/Residential%20Lighting%20Retailer%20Supplier%20Perspectives%20Final%20Report%20June%202013.pdf

This report presents the findings from retailer and supplier interviews conducted in support of the evaluation of the 2011-2012 Massachusetts ENERGY STAR® Lighting Program. The study team also surveyed 240 store managers who participated in the Massachusetts ENERGY STAR® lighting program in between December 2012 and January 2013.

Excerpts and Relevant Findings:

Residential

Impacts of the EISA

"Lighting manufacturers and retail buyers pointed to factors that both increased and limited the sales of the CFLs during the early stages of the EISA phase-out.

- Factors increasing the sales of the CFLs included:
  - The willingness of the Massachusetts program to continue to offer buy-down discounts on the higher-wattage CFLs, thus keeping them cost competitive with the EISA-compliant halogens.
  - The fact that there was not a higher-wattage LED bulb that was an affordable alternative.
- Factors limiting the sales of the CFLs included:
  - Four of the ten manufacturers we interviewed mentioned a spike in the price of phosphorous from China in 2011, which caused CFL prices to surge before eventually coming down again.
  - Six of the ten manufacturers mentioned that consumer discontent with some performance aspects of the CFLs (e.g., problems with dimmability and slow start-up times) were limiting consumer demand for CFLs to a certain degree.
  - As indicated previously, some market actors cited some evidence of hoarding of incandescent bulbs."

"Lighting manufacturers and retail buyers reported that emerging LED technologies are more likely to take market share away from specialty CFLs than from standard spiral CFLs. Some lighting manufacturers speculated that the specialty CFLs that will face the biggest competition from the LED bulbs will be A-line CFLs and reflector CFL bulbs such as the R-30s. They said that this was due to the superior performance of the new LED bulbs in terms of start-up times and dimming capability. They also observed that the price difference between LED bulbs and specialty CFLs was smaller than it was between LED bulbs and standard spiral CFLs."

The Market for LED Bulbs

"There were many reasons why store managers were not selling LEDs, the most cited reason being that the bulbs are too expensive. To better understand the barriers to selling more LED bulbs in the Massachusetts market, we asked the retailers in our sample who were not selling LED bulbs why they were not offering these products. Our survey revealed that, rather than there being a few major barriers, there were many smaller ones. The most frequent responses included the bulbs being too expensive for their customers (19%), their corporate offices making the purchasing decisions (16%), their lack of an LED bulb supplier (14%), and the LED bulbs not fitting in well with the rest of their product line (14%). However, there were many other barriers cited."

"Effects on product promotions: About one-third (31%) of the store managers who were selling LED bulbs said that the program had had some effect on how they promoted the LED products they sell. Most of the store managers who said that the program had affected their promotional practices explained that they were doing more promotion of these LED bulbs than they had done before, including more signage and giving the bulbs more prominent placement in their stores. A number of the store managers also said that, while they had sold the LED bulbs before becoming involved with the program, they had not really promoted them, mostly because of the high price points.

Retailer suggestions for increasing program LED sales: We sought the suggestions of all the store managers, whether they were currently selling LED bulbs or not, on how the Massachusetts Program Administrators could increase sales of LED bulbs over the next few years. The three most common suggestions were to bring down the

price/offer additional discounts (37% of respondents), provide more customer education about LED bulbs (22%), and to do more/better advertising of the program and the products it rebates (14%)."

Program Activity in the Hard-to-Reach Lighting Markets

"The large majority of store managers agreed with the program's definition of hard-to-reach lighting markets. We told the 2012 participating store managers that the program was currently defining "hard-to-reach" (HTR) markets for energy-efficient lighting as those that serve low-income, ethnic, non-English-speaking, and less educated customers. We then asked them if they agreed with this definition of HTR markets. Seventy-eight% of the store managers agreed.

Whether the program's HTR strategy was focusing on the right retailers: The large majority (84%) of store managers thought that discount stores and small grocery stores were the right kinds of retailers for the program to work with to make CFLs more accessible to HTR customers."

Conclusions

"The PAs should consider doing more marketing of the program in general and the LED rebates in particular, including through both more point-of-purchase signage and more mass advertising. Evidence to support this consideration includes:

- We sought suggestions from all the store managers, whether they were currently selling LED bulbs or not, on how the Massachusetts Program Administrators could increase sales of LED bulbs over the next few years. The three most common suggestions were to bring down the price/offer additional discounts (37% of respondents), to provide more customer education about LED bulbs (22%), and to do more/better advertising of the program and the products it rebates (14%).
- When we asked store managers for their ideas about ways to get lighting retailers more involved in marketing of the program, the three most common suggestions were to provide more/better signage (17% of respondents), to do more advertising (unspecified methods - 15% of respondents), and to do television ads (9%)."

"The program could improve its outreach efforts to participating store managers. Outreach would involve more visits and face-to-face time with participating store managers to make sure they understand how the program works and to collect feedback on the program. Since many participating retailers are already offering LED products outside the program, this face-to-face time might also be a good opportunity for program staff to try to bring these LED products into the program. Evidence to support this consideration includes:

- As noted, we asked all the store managers whether they had any additional suggestions for program improvements besides the marketing suggestions listed above. The two most common suggestions were more customer education (17% of store managers with additional suggestions) and better program communications with retailers (13%).
- As noted, the need for more or better point-of-purchase signage or displays was a frequent participant suggestion for program improvements. A more frequent in-person presence in the participating stores by program staff or contractors would help the program better identify these needs."

Navigant 2013: Adoption of Light-Emitting Diodes in Common Lighting Applications

Author: Navigant

Client: U.S. Department of Energy

Publication Date and Type: May 2013

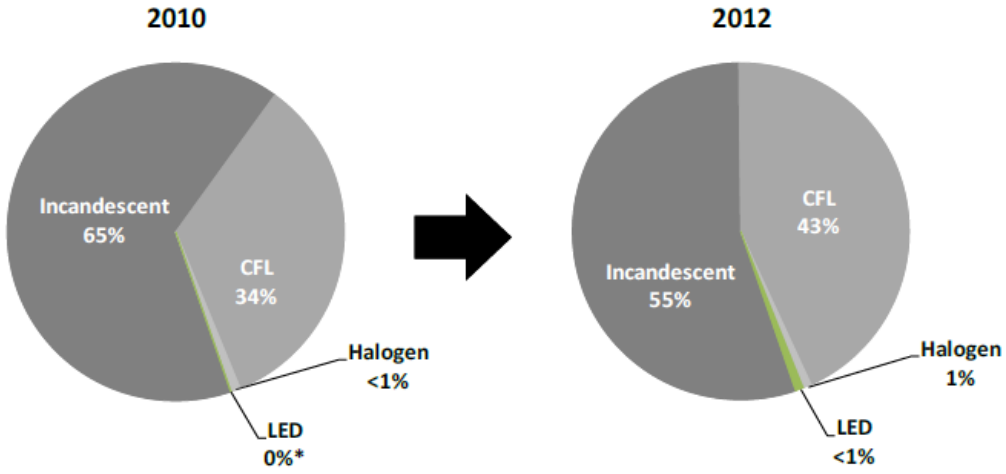
Link: http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/led-adoption-report_2013.pdf

Excerpts and Relevant Findings:

"The 2012 inventory calculation begins with installed stock figures from the 2010 U.S. Lighting Market Characterization (LMC). These figures are projected to 2012 using the DOE's forecast model, which utilizes assumptions of projected efficacy, retail price, and operating life. The 2012 projection estimates the installed base of LED lighting as well as conventional lighting technologies, such as incandescent, fluorescent, and high intensity discharge (HID). However, the LED projections are not utilized in this report. Instead the 2012 adoption of LED lighting in the selected nine applications is calculated using LED sales and financial reports provided by manufacturers, retailers, industry experts, as well as the shipment data from National Electrical Manufacturers Association (NEMA) and ENERGY STAR."

"In 2012, about 49 million LED lamps and luminaires were installed in the nine applications. LED A-type lamps are about 41 percent of these installations, but currently only have a penetration rate in this application of less than one percent. LED MR16 lamps have the highest penetration rate at about 10 percent of all MR16 lamps."

"Based on the projected LMC data, in 2012 there were 3.3 billion A-type lamps installed within the U.S., of which about 97 percent are in residences. The A-type lamp market is experiencing a transition away from traditional incandescent lamps towards higher efficiency halogen lamps, CFLs, and LED lamps. As seen in Figure 2.2, from 2010 to 2012 the installed base of incandescent A-type lamps decreased from 65 percent to 55 percent, while CFLs increased from 34 percent in 2010 to 43 percent in 2012. While nearly 20 million LED A-type lamps are installed in the U.S. this is less than one percent of the total A-type lamp installed base."



*Values less than 0.1% are considered negligible

Figure 2.2 – A-Type Lamp Installed Base

"In 2012 LEDs have reached an installed base of 11.4 million lamps, or about 4.6 percent of the total directional lamp sockets. This penetration rate is one of the highest for any of the applications analyzed in this report, and has increased dramatically from 2010 which had an LED installed base of less than one percent."

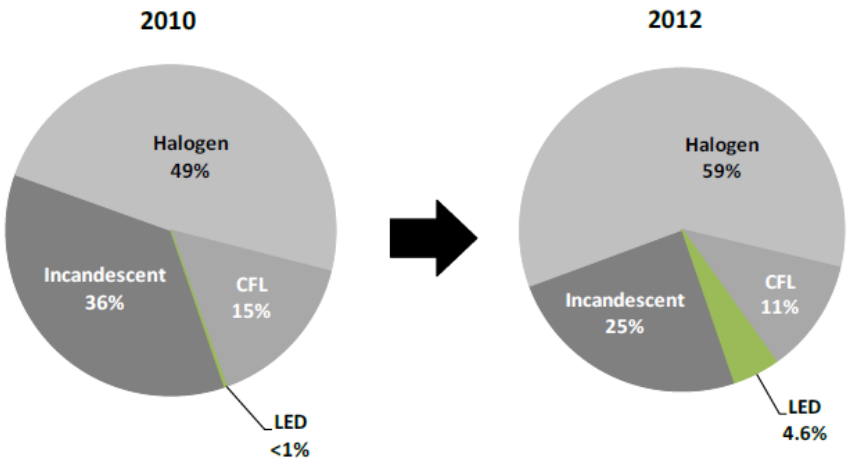


Figure 2.4 – Directional Lamp Installed Base

"In 2012, the national inventory of decorative lamps was approximately 1.2 billion. Similar to the A-type market nearly all of these installations are in residential residences and about 90 percent are incandescent bulbs. However, the decorative lamp market has been much slower to adopt more efficient lighting technologies with only about 10 percent representing CFL installations. As seen in Figure 2.8, from 2010 to 2012 the installed base of incandescent decorative lamps decreased marginally from 93 percent to 90 percent, while CFLs increased from 7 percent in 2010 to 10 percent in 2012. Figure 2.8 below indicates that the installed base of LED decorative lamps is less than one percent of the total U.S. decorative lamp installed base."

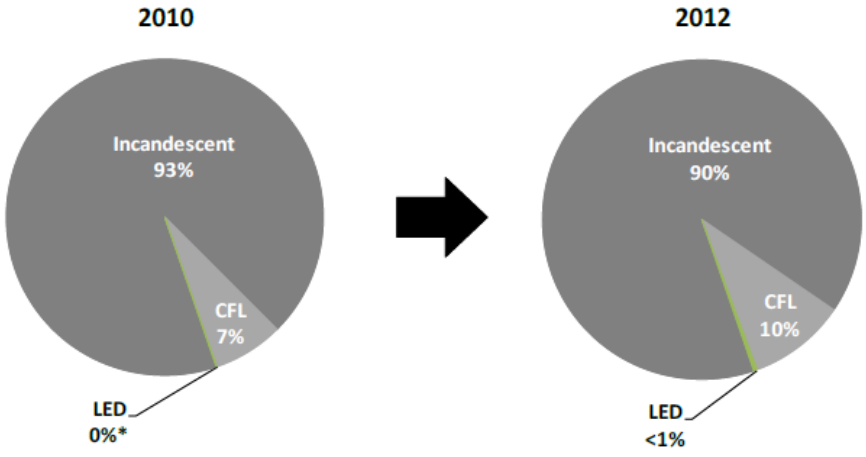


Figure 2.8 – Decorative Lamp Installed Base

Navigant 2010: Energy Savings Potential of Solid-State Lighting in General Illumination Applications, 2010 to 2030

Primary Author: Navigant Consulting

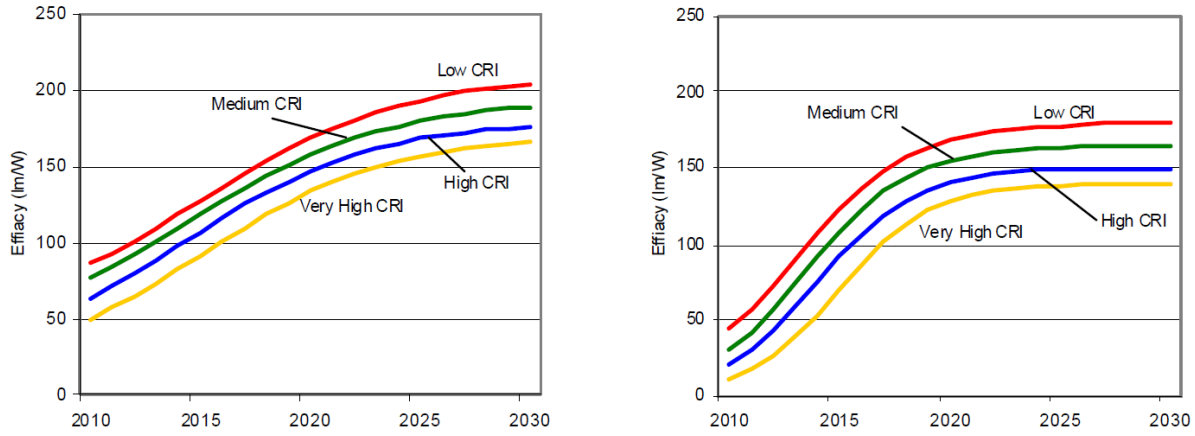
Client: U.S. Department of Energy, Lighting Research and Development

Publication Date and Report Type: February 2010, Final Report

Link: http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/ssl_energy-savings-report_10-30.pdf

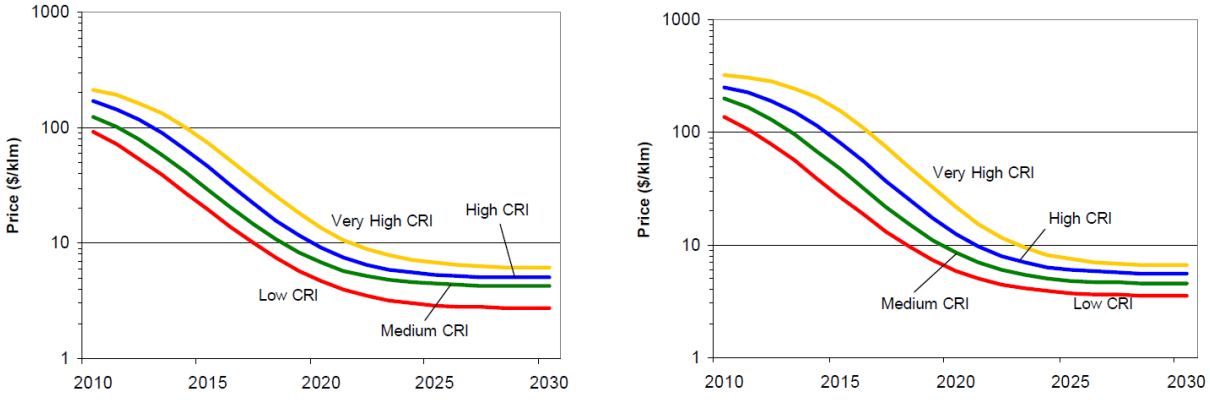
This study focused primarily on estimating potential national energy savings if energy –efficient SSL by modeling the lighting market and various technologies, so TRC did not summarize the findings here (as this was beyond the scope of this memo). However, TRC excerpted the following figures, which project LED (and organic LED – OLED) efficacy improvements and costs. The four scenarios represent different color referencing index (CRI) bins, which are meant to associate similar lighting services. Typical 'low CRI' LED lamps would be comparable to mercury vapor and high pressure sodium lamps, while 'very high' CRI LED lamps would be comparable to incandescent and halogen lamps.

Excerpts and Relevant Findings:



LED Efficacy Projection *OLED Efficacy Projection*

Figure 5-1. Commercialized SSL Efficacy Improvements for the SSL Scenarios



LED Price Projection *OLED Price Projection*

Figure 5-2. Commercialized SSL Price Improvements for the SSL Scenarios

Figure 30 – Projected Efficacy Improvements and Price Changes for LEDs and OLEDs (Navigant 2010)

D&R 2010: ENERGY STAR CFL Market Profile

Primary Author: D&R International

Client: U.S. Department of Energy

Publication Date and Type: 2010, Final Report

Link: http://www.energystar.gov/ia/products/downloads/CFL_Market_Profile_2010.pdf

Excerpts and Relevant Findings:

"CFLs still have the potential to deliver considerable residential lighting energy savings. As most light sockets in America still hold incandescent lamps, more than two-thirds of the CFL savings potential remains unrealized."

"The market for CFLs has declined by more than 30 percent following a peak of shipments in 2007. While shipments of CFLs remain much higher than those in 2000, more than five of every six general service lamps shipped is still an incandescent. If CFL market share remains at current levels, unit sales will decline and future growth in socket saturation will slow further."

"More than 85 percent of consumers report that they are satisfied with the performance of CFLs. The reasons for the decline in shipments are many, including reduced promotion by retailers and the recession, but consumer dissatisfaction is not a major contributor."

"The standards set by the Energy Independence and Security Act of 2007 may have less effect on the lighting market than program sponsors and regulators expect. Many specialty lighting products are exempt from the new standards, and compliant incandescent lamps, which offer minimal energy savings over non-compliant lamps, are already available to consumers."

EPA 2011: Next Generation Lighting Programs: Opportunities to Advance Efficient Lighting for a Cleaner Environment

Author: US Environmental Protection Agency

Client: None

Publication Date and Type: October 2011

Link:
http://www.energystar.gov/ia/partners/manuf_res/downloads/lighting/EPA_Report_on_NGL_Programs_for_508.pdf

Excerpts and Relevant Findings:

This report was a compilation of findings from other reports, data from public databases, and discussions and reviews with efficiency program managers and other experts.

"A number of factors may explain why CFL sales are not increasing dramatically to fill those sockets:

- Most consumers prefer incandescent bulbs in dimmable sockets because many CFLs do not dim at all and "dimmable" CFLs are larger, more expensive, and do not always dim in a way that is pleasing to consumers.
- Some consumers dislike the small amount of mercury in the bulbs because they are worried about in-home breakage, landfill impacts, or the effort associated with recycling.
- CFLs have a slow warm-up time compared to incandescent bulbs.
- Some CFLs have a different color appearance than incandescent bulbs.
- Some higher wattage CFLs are too large to fit in fixtures, and the "pig tail" appearance is not attractive in fixtures with exposed bulbs.
- Incandescent bulbs are cheaper to buy than CFLs, even though CFLs save money over the life of the product due to energy savings and additional incandescent bulb replacement costs."

KRC 2013: OSRAM SYLVANIA Socket Survey 6.0 2013 Research Results

Author: KRC Research

Client: OSRAM Sylvania

Publication Date and Type: December 2013

Link: http://assets.sylvania.com/assets/Documents/Socket Survey 6 0 2013 web.ace8e42b-1aa1-4d10-897c-78e40ff72ccb.pdf

Excerpts and Relevant Findings:

"The Socket Survey 6.0 is OSRAM SYLVANIA's tracking survey of consumer attitudes and behaviors around lighting options, conducted annually since 2008. [Since 2008, the survey has been conducted for approximately 300 American adults on landline and cell phones.]

"Bulb Purchasing

- Almost all consumers are involved in light bulb purchase decision making in their households, and are most likely to get information about bulbs from in store displays or employees.

Bulb Factors

- Since the first Socket Survey in 2008, Americans are increasingly citing getting more or less light and better light quality as reasons to switch bulbs.
- Brightness and longevity remain the most important factors when consumers are evaluating light bulb options.

Bulb Usage

- Americans are most familiar with halogens as an alternative to incandescent bulbs, and a majority are also aware of LEDs and CFLs.
- Consumers say they're using various types of light bulbs at relatively consistent levels in their home despite the ongoing phase out.

LED Bulbs

- While usage of LEDs remains low, consumers are interested in many of the potential benefits of LEDs.
- Longevity, amount of light and price are the most important factors to consumers when considering buying LED bulbs.

Phase Out

- When aided, most consumers are aware of the 2007 phase out of traditional incandescent bulbs, though only 4 in 10 are aware of the continued phase out taking effect in January 2014.
- A majority of consumers say they're excited for the phase out because more Americans will be using newer technology bulbs.

Consumer Adoption

- As a result of the legislation, most say they'll switch to newer technology bulbs: Half (46%) will switch to CFLs, a quarter (24%) to LEDs, 13% to halogens, and 16% are not sure.
- However, 3 in 10 consumers say they plan to stock up on incandescent bulbs while they're still available.

Smart Lighting

- Half of consumers are aware of smart lighting options, but only 1 in 10 consumers are interested in purchasing a smart lighting system to control home lighting remotely."

PlaNYC 2011: Energy-Aligned Lease Language: Solving the Split Incentive Problem

Author: New York City

Client: None

Publication Date and Type: December 13, 2011, Presentation

Link: http://www.nyc.gov/html/planyc2030/downloads/pdf/111213_eal_presentation.pdf

Excerpts and Relevant Findings:

New York City developed energy-aligned lease language that would base owners' cost recovery on predicted savings, but limit owners' capital expense pass-through to 80% of these predicted savings; the additional 20% "performance buffer" was designed to protect tenants from underperformance of the system. The lease language was developed by a working group that included owners, tenants, management companies, and engineers. The project also developed a financial model to demonstrate how the lease language impacts finances. The lease language has been used in at least two large office spaces.

RPI 2009: A System for Communicating Color: What Do Consumers Think?

Author: R.P. Leslie et al.

Organization: Lighting Research Center, Rensselaer Polytechnic Institute

Publication Date and Type: 2009, Final Report

Link:
http://www.lrc.rpi.edu/programs/lightingTransformation/colorCommunication/pdf/whatDoConsumersThink.pdf

Excerpts and Relevant Findings:

"Light source color is poorly understood by consumers. Is it because color has not been adequately promoted as a feature of light sources?" Six focus groups were held and consumer attitudes and awareness about color were documented and analyzed. "Variations of a color communication system were presented and assessed for consumer interest, comprehension, and suggested modes of educating consumers. Results indicated that color is not a primary driver in current purchasing behavior, but that it could be….Once actual color differences among light sources were seen by the focus groups, there was consensus that a color communications system would be desirable and probably yield better opportunities for improved home lighting. Incorporating the results of the focus group with the foundations for color science, a revised color communication system is proposed."

UMCH 2012: Applicability and Efficacy of Variable Light in Schools

Author: Claus Barkmann et al.

Organization: University Medical Center (UMC) Hamburg-Eppendorf, Germany

Publication Date and Type: February 2012, journal article

Link: http://www.sciencedirect.com/science/article/pii/S0031938411004690

Excerpts and Relevant Findings:

"There is a range of reliable, empirical data on the effects of special lighting techniques on the performance of adults in the work environment in the literature. However, these studies have not adequately addressed the effects of lighting on school children in the classroom environment. In [this] study, the effect of variable lighting (VL) i.e., lighting that is variable in illuminance and color temperature, was studied in the classroom using a variety of student performance and attitude measures….The results showed that the students made fewer errors, particularly fewer errors of omission, on a standardized test of attention under the VL "Concentrate" program. Reading speed, as measured using standardized reading tests, rose significantly. Reading comprehension also improved, but this improvement was not statistically significant. In contrast, the achievement motivation of the students and the classroom atmosphere did not change over the nine-month period. Overall, the students and teachers rated VL positively and found it useful during lessons. These results are in line with previous research findings."

NRC 2010: Lighting and Office Renovation Effects on Employee and Organizational Well-Being

Author: Jennifer Veitch et al.

Organization: National Research Council (NRC)

Publication Date and Type: September 2010

Link: http://www.lumenergi.com/sites/default/files/downloads/rr306-Lighting-and-Office-Renovation-Effects-on-Employee-and-Organizational-Well-Being.pdf

Excerpts and Relevant Findings:

"**Workstation-specific lighting with individual control is the higher-quality lighting solution.**

Workstation-specific lighting with individual (personal) control was preferred over parabolic-louvered luminaires regardless of the surface reflectances of the furnishings. The workstation specific luminaires with individual control were rated as providing lighting that was better than in other similar workplaces; the parabolic-louvered luminaires were seen as being the same as in other similar workplaces. In the most sensitive statistical tests, small effects were found for several outcomes. Pleasure, room attractiveness and illumination, lighting satisfaction, overall environmental satisfaction, job satisfaction and organizational commitment were all higher for the people in offices with workstation-specific luminaires. The frequency and intensity of physical symptoms and the intent to turnover were all lower for the people in offices with workstation-specific luminaires.

Several previous laboratory and field investigations have found that people prefer to control the local lighting in the workstation, and this investigation found no effects that were contrary to the expected direction.

Luminous conditions matter to organizational productivity.

We tested the overall linked mechanisms map using structural equation modelling. The best-fitting model was based on the Albany experiments' linked mechanisms map. Luminous conditions (rated on a scale from parabolic/low reflectance to workstation-specific-control/low reflectance to workstation-specific-control/high reflectance) predicted lighting appraisals, and these in turn indirectly related to reduced health problems and to reduced intent to turnover."

NRC 2001: Psychological processes influencing lighting quality

Author: Jennifer Veitch et al.

Organization: National Research Council (NRC)

Publication Date and Type: 2001

Link: http://archive.nrc-cnrc.gc.ca/obj/irc/doc/pubs/nrcc42469/nrcc42469.pdf

Excerpts and Relevant Findings:

"This review paper summarizes the state of knowledge concerning mediating psychological processes: perceived control, attention, environmental appraisal, and affect. These processes were selected because of their relevance to the explanations often given for lighting design choices. More explicit use of theoretically-driven predictions to guide lighting research would result in greater precision in our comprehension of lighting-behavior relationships to form the foundation of empirically-based lighting recommended practice."

LBNL 2004: A Comparison of Traditional and High Colour Temperature Lighting on the Near Acuity of Elementary School Children

Author: S.M. Berman et al.

Client: None

Publication Date and Type: November 2004

Link: http://humancentriclighting.com/wp-content/uploads/2013/11/Berman-school-study.pdf

Excerpts and Relevant Findings:

"The near visual acuity (400 mm distance) of 27 children aged 10 /11 years old was measured by a licensed optometrist under two common fluorescent lamps of CCT 3600 K and 5500 K. Acuities were measured for three lighting conditions, either both lamps providing equal task luminance or a condition where the task and room luminance from the 5500 K lamps was set 50% lower. For the equal luminance condition, the results showed visual acuity was significantly better (PB/0.001) under the higher CCT lamp with 24 of 27 children having better acuity. Paired t-tests comparing the lower luminance condition showed significantly less acuity for the 5500 K lamps at the lower luminance, but no significant difference between the 3600 K lamps at the higher luminance compared with the 5500 K lamps at the lower luminance."

UTUM 2012: Illuminating the Effects of Dynamic Lighting on Student Learning

Author: Michael S. Mott et al.

Client: None

Publication Date and Type: May 2012

Link: http://sgo.sagepub.com/content/early/2012/05/03/2158244012445585.full-text.pdf+html

Excerpts and Relevant Findings:

"A total of 84 third graders were exposed to either focus (6000K-100fc average maintained) or normal lighting. Focus lighting led to a higher percentage increase in oral reading fluency performance (36%) than did control lighting (17%)."

APPENDIX B: LIST OF STUDIES EXCLUDED FROM REVIEW

Below are studies that were considered for this literature review, but were not included. Many studies included valuable information, but were outside the scope of this project (i.e., "irrelevant"). Other studies were included in previous literature reviews that we reviewed, so it was not necessary to review the original source.

Client / Funding Source	Contractor	Study Title	Publication or Estimated Completion Date	Review?
CPUC	DNV KEMA	Final Evaluation Report: Upstream Lighting Program	Feb 2010	No - in D&R study
CPUC	DNV KEMA and Itron	High Bay Lighting Market Effects Study	Jun 2010	No - in D&R study and Evergreen study
CPUC	DNV KEMA	I Know What You Lit Last Summer: Results from California's Residential Lighting Metering Study	2010	No - irrelevant
CPUC	DNV KEMA	Fall 2011 California Lighting Retail Store Shelf Survey Report	May 2012	No - irrelevant
CPUC	James Hirsch Assoc.	CFL Lab Testing Report	May 2012 (draft)	No - irrelevant
DOE	Navigant	2010 U.S. Lighting Market Characterization	Jan 2012	No - in D&R study
DOE	D&R International	Product Snapshot: LED Replacement Lamps	May 2011	No - in D&R study
DOE	DNV KEMA, Left Fork Engineering, Apex Analytics, others	DOE and PNNL, Uniform Methods Project	Late 2012	No - irrelevant
DOE	PNNL	CALiPER - Application Summary Report 20: LED PAR38 Lamps.	Nov 2012	No - irrelevant
DOE	PNNL	CALiPER - Report 20.1: Subjective Evaluation of Beam Quality, Shadow Quality, and Color Quality for LED PAR38 Lamps	Oct 2013	No - irrelevant
DOE		Next Generation Luminaires - Competition for almost market-ready lighting technologies, for indoor commercial/industrial applications.	Feb 2013	No - irrelevant
DOE		Life Cycle Analysis of LED Lighting, Part 3 (Pts 1 and 2 completed in 2012)	2013	No - irrelevant
DOE	DNV KEMA, PNNL	Residential Lighting End-Use Consumption Study: Estimation Framework and Initial Estimates	February 2013	No - irrelevant
DOE, LBNL	Verified Energy	Harmonization of Zigbee, BACNET, and DALI in Wireless Dimming Lighting Control		No - irrelevant
EPA	Cornell University	Hybrid Fiber Optic LED Lighting	Aug 2013	No - irrelevant

Client / Funding Source	Contractor	Study Title	Publication or Estimated Completion Date	Review?
National Grid	Cadmus Group	Billing analysis for small business	Spring 2013	No - irrelevant
National Grid	Cadmus Group	Multi-season lighting logger study of non-controlled lighting fixtures in small business	Spring 2012	No - irrelevant
National Grid	Cadmus Group	Pre/post evaluation of occupancy sensors in small business	Estimated for Fall 2012 (not released yet)	No - irrelevant
National Grid	DNV KEMA	12 month logging study of prescriptive lighting in large commercial and industrial	Spring 2013	No - irrelevant
National Grid	NMR Group	Massachusetts ENERGY STAR Lighting Program: 2010 Annual Report	Spring 2011	No - irrelevant
NEEA	Xenergy	Commercial and Industrial Lighting Study, Volume 1	Dec 2000	No - in D&R study and Evergreen study
NEEP	Energy Futures Group, Optimal Energy	Northeast Residential Lighting Strategy: 2013-2014 Update	Oct 2013	No - irrelevant
NYSERDA		PON 2606 - Advanced Buildings Program		No - irrelevant
PG&E	Mary Matteson Bryan	Advanced Lighting Control System EM&V Guidelines	2013	No - irrelevant
PG&E	HMG	LED high bay lighting and controls	Mid-2013	No - irrelevant
PG&E	HMG	Light emitting plasma (LEP) technologies	Mid-2013	No - irrelevant
PG&E	PG&E and other utilities	Western Regional Utility Network On-line Rebate Program Guidance Document		No - irrelevant
PG&E	DNV KEMA	Advanced Lighting Baseline Study	Aug 2011	No - in D&R study and Evergreen study
SCE	Cambridge Systematics	Customer Decision Study: Analysis of Nonresidential New Construction Equipment Purchases	Dec 1994	No - irrelevant
SCE	Lockheed Martin Aspen	SPP Program Final Report: Additional Control Technologies (ACT) for Small/Medium Commercial Customers	Apr 2006	No - irrelevant
Terrapin	n/a	The Economics of Biophilia	2012	No - irrelevant
ZVEI	LightingEurope	Human Centric Lighting: Going Beyond Energy Efficiency	July 2013	No - irrelevant