Clearing the Path to Market Transformation in the Rapidly Evolving World of Residential Lighting

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ABSTRACT

Several developments are pushing the residential lighting market toward higher efficiency. Federal legislation, particularly the Energy Independence Security Act (EISA), has banned the production and import of traditional incandescent bulbs for common lamp types. Light-emitting diode (LED) technology has gained traction, providing many consumer preferences with efficacy nearly an order of magnitude higher than traditional incandescent lighting. However, other factors are concurrently pushing the residential lighting market toward inefficiency. Halogen sales have exploded and manufacturers are marketing them as “eco-incandescent.” EISA exemptions allow the continued manufacturing of many types of incandescent lamps. LED sales are growing but products remain expensive. Many utilities, including those in California, have dramatically reduced CFL rebates while focusing LED incentives on driving quality instead of pushing high sales volumes.

While many experts predict that LEDs will eventually dominate residential lamp sales, the next few years present uncharted terrain, with both major efficiency gains and backsliding representing distinct possibilities. This paper explores the residential lighting market, including recent purchasing trends, lamp availability in California, and the impact these factors have had on residential lighting electricity usage. We then explore scenarios of how short-term product availability could influence California’s future electricity consumption and its ability to meet statewide residential lighting electricity goals. Finally, we recommend strategies that program administrators and regulators could adopt to guide the lighting market toward continued short term efficiency gains and long term LED market transformation. Results illustrate nationwide opportunities for policies and rebates that push the market towards higher efficiency.

Introduction

Residential lighting today has been largely shaped by the successes and failures of past utility incentive programs and federal legislation. After tepid early adoption of CFLs beginning in the mid-1990s, the market made major efficiency gains. This was at least in part due to several large utility programs, which provided aggressive rebates beginning around 2006. But with only marginal consumer acceptance of CFLs, these efforts resulted in only partial market transformation. As of 2012, nearly half (45%) of residential lamps installed in California continued to be incandescent (based on the California Lighting and Appliance Saturation Survey

- CLASS 2012 [DNV-GL 2014]), and recent trends show an alarming increase in halogen lamps. Because residential lighting continues to comprise a significant fraction[1] of total electricity consumption and peak load, inefficient lighting remains an energy savings opportunity that must be addressed to achieve aggressive targets in energy efficiency and greenhouse gas (GHG) reductions.[2] Yet, as described later, a number of factors have led the California Investor Owned Utilities (IOUs) to reduce residential lighting incentives in the last several years.

The good news is that the long-term value proposition for efficient lighting is stronger than ever. A typical household could cut its lighting electricity use by approximately half with nothing more than a trip to the store and an hour to replace filament-based lamps with LEDs. However, the incremental upfront cost to purchase the LEDs—potentially several hundred dollars when unsubsidized—remains a strong barrier. Despite the fast payback time – both through lower utility bills and fewer replacement lamps – most customers do not conduct a lifecycle cost calculation in the lighting aisle. Consequently, despite the low-hanging fruit of lighting savings, efficacy and price advancements in LEDs, and legislation restricting the manufacture of incandescent bulbs, the availability and sale of high efficacy lamps may have stagnated. In fact, low efficacy lamp availability may actually increase in the short term, and it is unclear if and when LED prices will drop to a point of becoming cost competitive with inefficient options. Strong utility support may be more important now than ever.

Here we investigate past lamp sales and the corresponding effect on residential lighting electricity use, assess the current availability of lamps, and present different lamp purchasing scenarios that could result from varying levels of utility participation (affected by policy directives). We examine progress to-date and the impact of the different purchasing scenarios in the context of California's Lighting Efficiency and Toxics Reduction Act (AB 1109)[3] goal for a 50% reduction in lighting energy use for interior residential lighting from 2007 to 2018.

Background: Past, Current, and Upcoming Code Changes

To understand market trends, it is important to first consider code developments. EISA restricts production of low efficacy lamps by establishing minimum lumen output for a given wattage, effectively phasing out many traditional general service incandescent lamps. As shown later, this has significantly impacted lamp availability and lighting electricity use in California.

While legislators may have envisioned replacement of incandescent lamps with higher efficacy technologies, halogen lamps – which are only incrementally more efficacious – have gained considerable market share. However, a proposed EISA update (phase two) may increase the current 45 lumen per watt threshold backstop that is targeted for 2020 to approximately 70 lumens per watt. Barring development of filament-based lamps that can meet the proposed thresholds, the second phase of EISA should phase out all filament-based lamps (halogen and incandescent) for most general service applications. Even some CFL lamps will struggle to meet

[1]The 2009 Residential Appliance Saturation Study (KEMA 2010) estimated that lighting comprises ~22% of California residential electricity use. Based on our lamp installation model, we estimated it comprised 17% in 2015.
[2] For a copy of the State of California's Energy Efficiency Strategic Plan, go to http://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=5305
[3] http://www.leginfo.ca.gov/pub/07-08/bill/asm/ab_1101-1150/ab_1109_bill_20071012_chaptered.pdf

these proposed performance levels. What remains of the low efficacy products will be relegated to special use categories, as the proposed standards are expected to eliminate many of the common loophole products. In California, the newly adopted Title 20 standard also has higher efficacy requirements that take effect in 2018 and become more stringent in 2019. EISA phase two will preempt the California standard if they are adopted this year. California will then implement those standards on the 2018 timeline, two years ahead of the rest of the U.S.

In short, the proposed EISA phase two standards and the recently adopted Title 20 standards will cause a longer-term shift in the market towards high efficacy lighting. However, in the immediate future, no new standard requirements for existing homes will take effect. Furthermore, with continued consumer skepticism of CFLs and little current understanding of customer satisfaction with LEDs, these proposed standards could be met with high consumer demand for traditional products, which may pressure legislators to relax requirements.

Results

What are consumers purchasing?

Figure 1 shows one indicator of lamp availability for the U.S. (NEMA shipments[4]), one indicator of lamp availability for California (California retail shelf surveys, DNV-GL[5]), and partial[6] California sales data (LightTracker). High efficacy (CFL and LED) lamps are in shades of green, and low efficacy (incandescent and halogen) lamps are shown in shades of red.

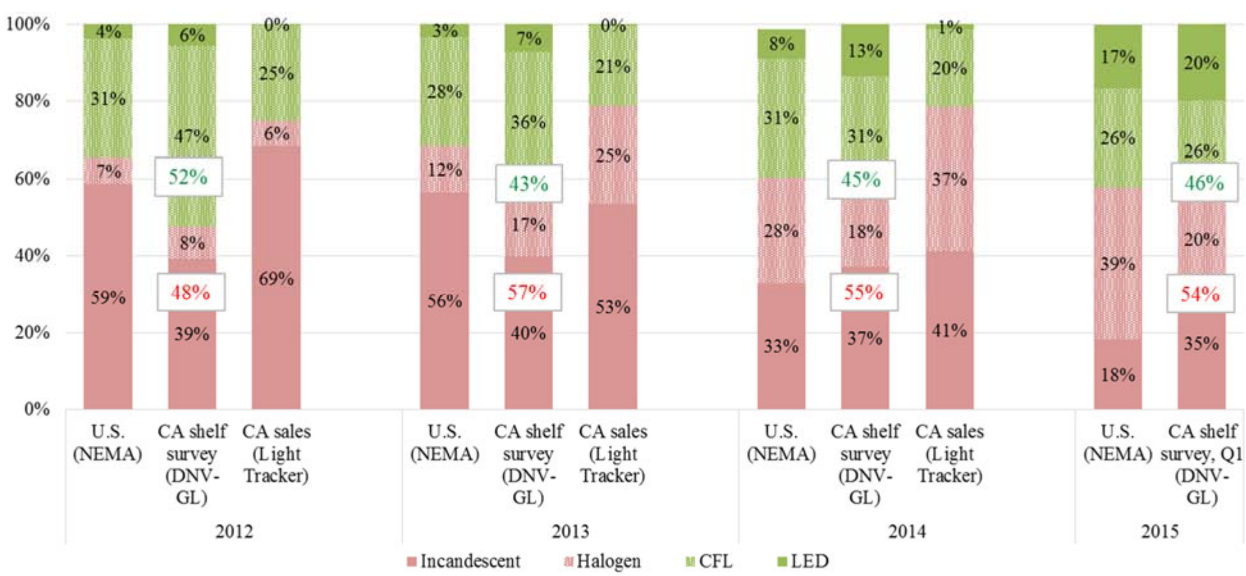


Figure 1. Availability of high efficacy (CFL and LED) and low efficacy (incandescent and halogen) lamps

[4] NEMA lamp indices for A-lamps: http://www.nema.org/Intelligence/Pages/Lamp-Indices.aspx, adjusted to include reflector and globe lamps.
[5] Based on summer 2012, summer 2013, and winter 2014/15 surveys. The 2014 result is an interpolation of summer 2013 and winter 2014/15 data. The 2015 result reflects winter 2014/15 data, so is indicative of Q1 2015.
[6] LightTracker data includes some market channels (e.g., mass merchandise and grocery), but not all (e.g., missing home improvement channel and some membership clubs). It includes approximately 15-30% of lamp sales.

NEMA data indicate that high efficacy lamp share has increased slightly from 2012 to 2015 in the U.S. In contrast, the two California data sources suggest that the share of high efficacy lamps (both stocked and sold) has decreased over the same timeframe. While there may be various factors contributing to the different trends in the U.S. and California, we believe this finding is at least partially attributable to the high levels of CFL rebates provided by California utilities through 2012. From 2006 to 2012, California provided higher numbers of CFL rebates than many other states, which likely increased market availability and sales of CFLs in 2012. California also implemented EISA phase one requirements one year earlier under California AB 1109, with 60W and 45W equivalent lamps phased out in 2013. However, Figure 1 indicates that the AB 1109 regulations, coupled with the decline in the number of CFL rebates beginning in 2013, may have reduced CFL availability and increased halogen availability.

This theory is supported by Figure 2, which presents our estimates of CFL sales in California from 2009 to 2014, alongside the number of CFLs rebated by the California Investor Owned Utilities (IOUs).

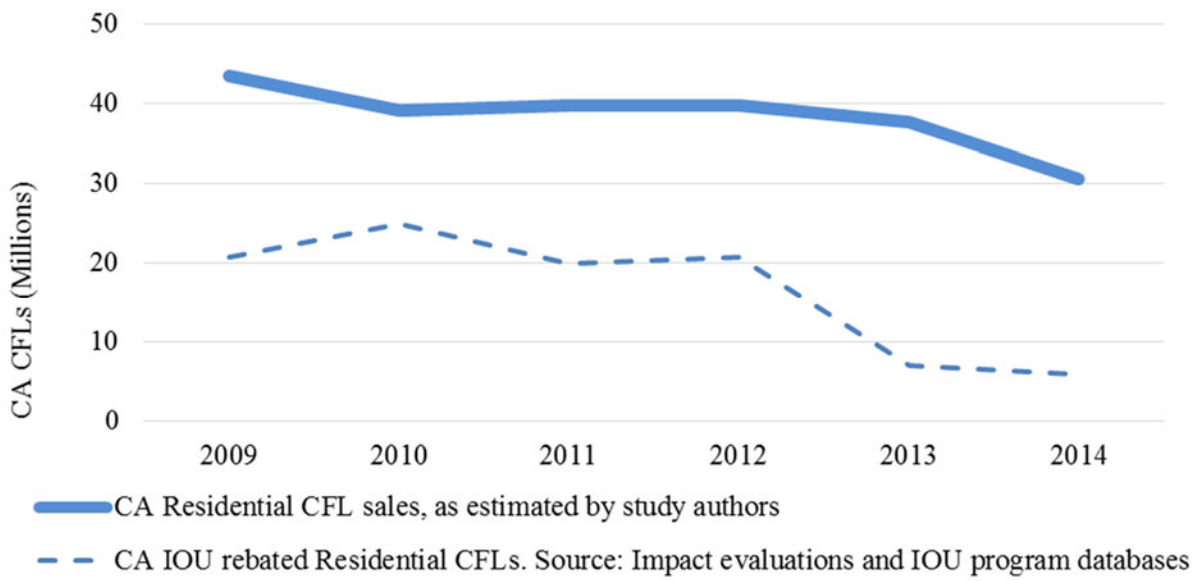


Figure 2. California residential CFL sales estimates compared to rebates

Figure 2 illustrates how the decrease in the fraction of high efficacy products in California from 2012 – 2015 correlates with a dramatic reduction in utility CFL rebates. This figure indicates that residential CFL sales were approximately 40 million lamps per year from 2010 to 2012, when the CA IOUs rebated a high volume of CFLs, but dropped to approximately 30 million lamps by 2014, when the number of CA IOU CFL rebates dropped by a factor of four. The grocery and discount store channels provide further evidence of the importance of rebates on lamp availability. In 2012, these channels received high levels of CFL rebates, and high efficacy lamps comprised over half (58% and 54% for grocery and discount, respectively) of all lamps on shelves in those channels (DNV-GL shelf survey 2012). By 2014, the IOU rebates to those channels had dropped dramatically, and the fraction of high efficacy lamps relative to all lamp types dropped to 16% and 29% (DNV-GL shelf survey winter 2014-15).

Over the same timeframe, halogen availability has increased dramatically. Figure 3 shows partial sales data from LightTracker of halogen sales in California (dotted blue line) and the U.S. (dotted orange line), and halogen lamp shipments for the U.S. from the National Electrical Manufacturers Association (NEMA - dotted red line). All of these data show a steep increase in halogen lamp prevalence, and are a powerful contrast to the CFL decline.

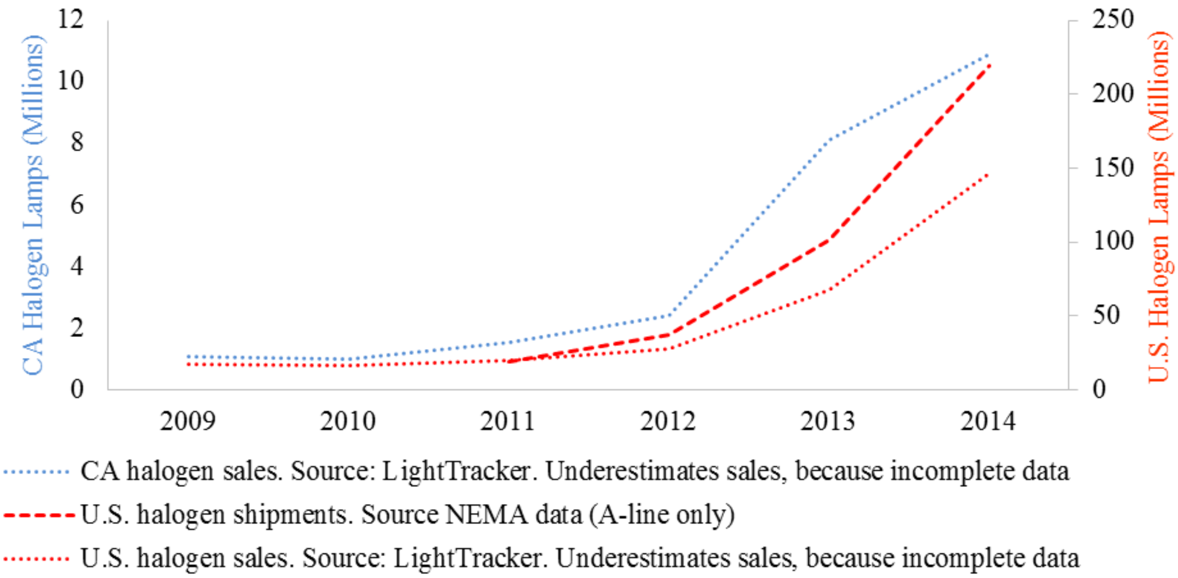


Figure 3. Halogen lamp availability and partial sales data

Overall, Figures 1, 2, and 3 indicate that halogens have largely replaced incandescent lamps, and that the market gains made by LEDs have largely come at the expense of CFLs. In addition, the increase in LEDs (sold and available) has been slower than the rise in halogens.

How have these lamp sales trends impacted residential lighting electricity use?

To understand the impact of recent lamp purchasing trends on residential lighting electricity use, we developed a lamp replacement model for California homes from 2012 to 2015. We started with the inventory of lamps found in the 2012 CLASS (DNV-GL 2014), and projected the inventory forward based on the number of lamps that would have been removed due to burn-out each year and early retirement. For lamp purchases, we assumed that customers installed each lamp type in proportion to its availability in the California retail shelf surveys (DNV-GL)[7] with some adjustments to the incandescent and halogen categories to accommodate

[7] Based on the summer 2013 and winter 2014/15 shelf surveys. This assumes that all lamps in all channels and bulb types have the same sell-through rate. While this is likely an oversimplification, we did not have enough data on sell-through rate trends to correct for this limitation.

the relatively large number of specialty lamps that are stocked but not sold at the same rate as general service equivalent lamps. Overall, we estimated that the average household's lighting electricity has decreased from 2012 to 2015 by approximately 18% over this four-year timeframe. We attribute the decrease to two primary reasons:

- The socket saturation of high efficacy lamps should steadily increase, because they have longer average lifetimes than low efficacy lamps. Incandescent lamps have a short measure life and will burn out more quickly than other technologies, and will often be replaced by other more efficient technologies.
- The efficacy of halogens is slightly higher than incandescent lamps, and the efficacy of LEDs is generally higher than CFLs. Thus, as halogens supplant incandescent lamps and LEDs supplant CFLs, overall lighting energy use will decrease.

Because of the growth in the number of California's households – approximately 1.5% from 2012 to 2015[8]), the household lighting electricity reduction of 18% translates into a statewide reduction in California residential lighting electricity use of 17%.

Progress to Date: Are we on track to meet residential lighting goal?

As described in the Introduction, AB 1109 set a goal of reducing California residential electricity use by 50% from 2007 to 2018. A recent CEC-funded study (CLTC 2014) estimated that residential lighting electricity use declined 7% from 2007 to 2010 (based on 2007 levels). Our results indicate that residential lighting electricity use declined by 17% from 2012 to 2015 (based on 2012 levels). Interpolating between the results of the two studies, residential lighting electricity use declined approximately 8% from 2010 to 2012. As shown in Table 1, this sums to a total decline of 31% from 2007 to 2015.

Table 1. Estimate of California Residential Lighting Electricity Change, 2007-2015

Timeframe[9]	Res. Lighting Electricity Change	Source
2007-2010	-7%	CEC-funded study (CLTC 2014)
2010-2012	-8%	Interpolated between CEC study and authors' estimate
2012-2015	-17%	Authors' estimate from lamp replacement model
2007-2015	**-31%**	**Sum of above** (rounded to nearest whole number)

This is tremendous progress over a short timeframe. Yet an additional 19% must be achieved from 2015 to 2018 to meet the AB 1109 goal, and the recent decline in high efficacy lamps (Figure 1) gives concern that this reduction will occur. In addition, for the California IOUs, the increase in LED rebates has not kept pace with the decrease in CFL rebates, resulting in a sharp decrease in the total number of rebates for energy efficient lamps. (The section Current

[8] CA Department of Finance: http://www.dof.ca.gov/research/demographic/reports/estimates/e-5/2011-20/view.php
[9] Timeframes are presented as follows: 2007-2010 covers a 3-year period: 2007 to 2008, 2008 to 2009, and 2009 to 2010. 2010-2012 covers a 2-year period: from 2010 to 2011 and 2011 to 2012.

Utility Program Challenges provides more detail.) To gauge whether the 2018 goal can be achieved, we first discuss the lamps that are currently available for purchase in California.

What lamp types are currently available to California consumers?

Figure 4 presents the availability of A-lamps on California retailers' shelves by lumen category, based on the California winter 2014/15 shelf survey (DNV-GL). Note that the 750-1049 lumen category includes 60 Watt incandescent lamps and has historically had the highest fraction of lamp sales. Also note that lamps < 310 lumens or > 2600 lumens are not regulated by EISA. We also break out availability of LEDs into three groups:

1. LEDs labeled as meeting the California Quality Standard – commonly known as the CEC-specification ("CEC-spec"): dark green. This standard includes some provisions that set higher requirements than ENERGY STAR, including a color rendering index minimum of 90. Since January 1, 2014, the California IOUs can only provide rebates (for LEDs intended for residential applications) for CEC-Spec LEDs[10]. Approximately half of the CEC-spec A-lamps in the shelf survey were also ENERGY STAR labeled.[11]
2. LEDs labeled as ENERGY STAR, but <u>not</u> CEC-spec: medium green.
3. LEDs not labeled as CEC-spec or ENERGY STAR, referred to here as "Unlabeled": light green.

Thus, ENERGY STAR labeled LEDs are represented by half of the dark green bar, and all of the medium green bar. Compared with CEC-spec and ENERGY STAR lamps, unlabeled LEDs may have lower performance for color rendering index (CRI), measure life, dimmability, and other characteristics, because they do not have performance criteria.

Figure 4 shows that incandescent lamps continue to have a small presence in lamp classes regulated by EISA and AB 1109 (310-2600 lumens)[12], and still account for the majority of lamps in the non-regulated lumen bins. CFLs are prominent in most of the lamp classes regulated by EISA and AB 1109. However, the trends discussed previously (shown in Figures 1, 2, and 3) indicate that CFL penetration is declining (particularly as CFL rebates decline) while halogen and LEDs increase. LEDs have a significant presence, but Figure 4 shows that CEC-spec LEDs are generally unavailable. ENERGY STAR LEDs have a stronger presence than CEC-spec LEDs, but the majority of LEDs available are unlabeled, particularly in the most popular (60W incandescent equivalent) lamp category.

[10] Per CPUC directive: California Public Utilities Commission - Decision 12-11-015.
[11] Because the CEC spec has requirements that are higher than (or at least as high as) ENERGY STAR, we expected that all CEC-spec LED A-lamps would also be ENERGY STAR labeled. It is not clear why this was not the case.
[12] This could be because of slow sell-through, and/or because of EISA (and AB 1109) noncompliance.

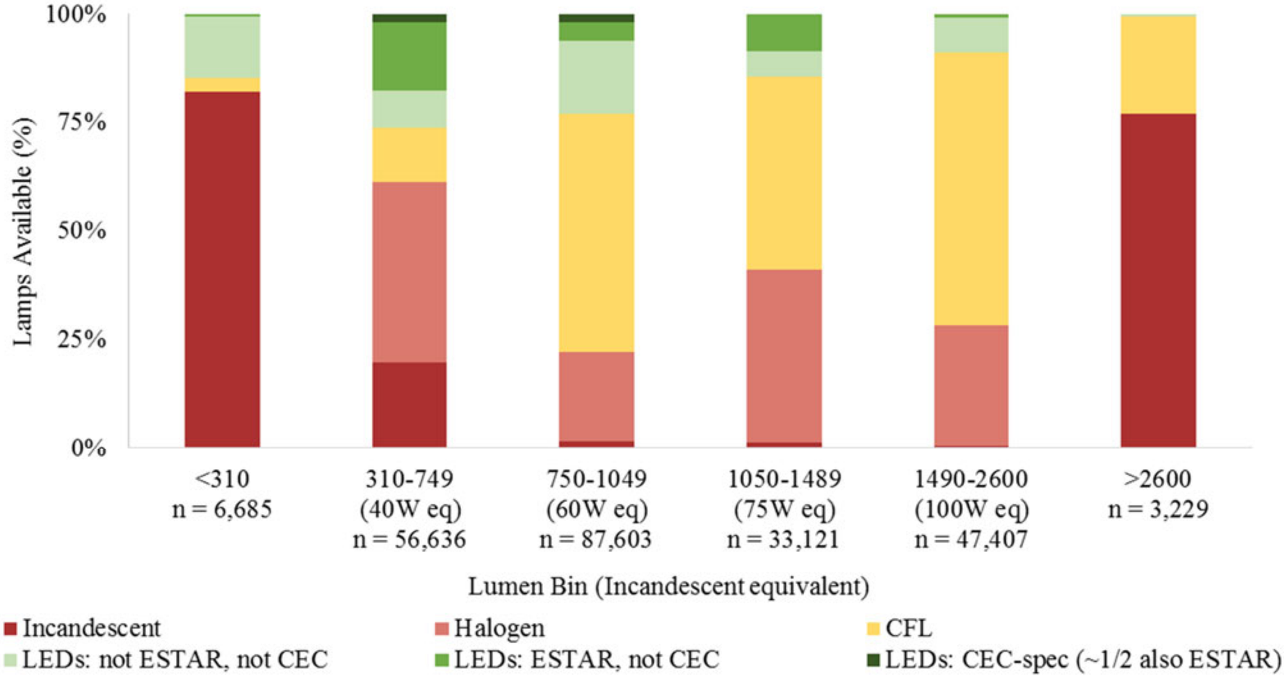


Figure 4. A-lamp Availability by Technology, by Lumen Bin (Data source: DNV-GL 2014/15 shelf survey)

We also investigated availability of reflector lamps (not shown), which have been regulated by a federal standard for Incandescent Reflector Lamps (IRL) since 2012. Aside from availability by lumen bin, we considered availability of reflectors by market channel. Similar to A-lamps, CEC-spec reflector lamps were generally unavailable. There was one exception – membership channels had a high availability of CEC-spec LED reflectors (which were all co-labeled as ENERGY STAR), particularly for 60W and 75W equivalent lamps. Other channels generally had very low availability of CEC-spec LED reflectors – approximately 1% of total reflectors were CEC-spec LEDs (co-labeled as ENERGY STAR) and an additional 5% were ENERGY STAR labeled (but not CEC-spec) LEDs. Excluding the membership channel, just over half of reflectors were low efficacy (36% incandescent, and 18% halogen), while CFLs (13%) and unlabeled LEDs (12%) comprised the remaining available reflector lamps. There were also no CEC-spec LEDs available in any channel for globe lamps, torpedo lamps, and nightlights.

Finally, about half (55%) of all CEC-spec LEDs were rebated in the most recent shelf survey. Over three-quarters (78%) of those rebated LEDs were in the membership club channel, which may explain the much higher availability of CEC-Spec LED reflectors in this channel.

Overall, this analysis illustrates that:

- **EISA has had a major impact on lamp availability**: Incandescent lamps now comprise only a small fraction of lamps in lumen bins regulated by EISA or the IRL, but are the majority of lamps in non-regulated bins. CFLs account for a large fraction of A-lamps available, although halogens are a large fraction of A-lamp and reflector lamps.

- **Very few CEC-spec LEDs are available in the broader market.** CEC-spec LEDs comprised a very small percent of total lamps, except in the Membership Club channel. Since over half of CEC-spec LEDs were rebated, the availability of CEC-spec LEDs would be even lower without the rebates. Availability of ENERGY STAR LEDs is higher, but most LEDs were unlabeled – neither CEC-Spec nor ENERGY STAR.
- **The CFLs and LEDs rebated by the IOUs face competition from both low efficacy lamps (e.g., halogens) and unlabeled LEDs**. The majority of CEC-spec LEDs were rebated. Without rebates, CEC-spec LED availability would likely be lower, and these products would be sold at higher average prices.

How will short term product availability affect future electricity consumption?

To answer the question of whether the residential lighting reduction goals of AB 1109 can be attained (i.e., whether California is projected to meet its goal of 50% lighting electricity reductions from 2007 to 2018), we used our lamp replacement model (described in the section, "How have these lamp sales impacted residential lighting electricity use?") to consider different scenarios for consumer purchasing behavior from 2015 to 2018. Based on the data in Figure 1, particularly the California shelf survey data, we assumed consumers purchased replacement lamps as ½ high efficacy, ½ low efficacy lamps in 2015. We then developed five scenarios for 2016-2018 by varying the penetration of lamp technology availability in the next few years. Scenarios 1 through 4 assumed that most lamps are replaced because of burn out, but included a small rate of early retirement (ER) for incandescent lamps (1%) and CFLs (2%). We also included a fifth scenario that assumed a higher ER rate (10% per year) that could estimate customer behavior under more aggressive incentive or marketing strategies. We define each scenario and describe possible factors that could help contribute to each as follows:

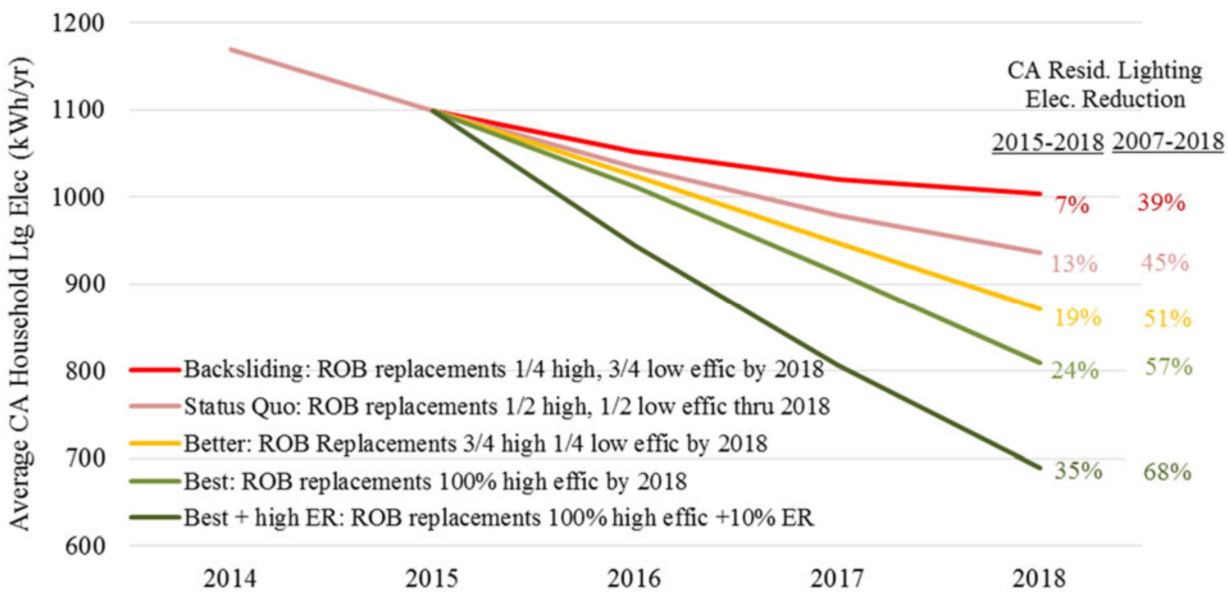
1. **Backsliding:** Replacement lamps shift to ¼ high efficacy and ¾ low efficacy by 2018. This could occur if utilities reduce rebates even further, if low customer satisfaction due to poor quality LEDs emerges, and/or if halogen market share continues to increase.
2. **Status Quo: We consider this to be the most likely scenario, if market conditions and rebate levels continue in California as they have in the past few years.** Replacements continue to be approximately ½ high efficacy and ½ low efficacy lamps. This could occur if utility rebates remain at approximately the same level as in the last few years. This scenario may also represent a bifurcation in the market between customers who are more likely to base decisions on upfront costs or comfort with traditional technologies, and those that prioritize efficient technology and savings.
3. **Better Replacement**: Replacements shift to ¾ high efficacy and ¼ low efficacy by 2018. This could occur if rebates increase and/or LED prices decrease significantly.
4. **Best Replacement**: Replacements shift to 100% high efficacy by 2018. This could occur if utilities dramatically increase rebates and enhance marketing to later adopters, if customer satisfaction with LEDs is high, and/or if LED prices decrease significantly.
5. **Best Replacement + 10% ER**: Replacements shift to 100% high efficacy by 2018 (as in Scenario 4), but 10% of a household's incandescent, halogen, and CFL lamps undergo

ER each year and are replaced with LEDs. This could occur under the Better Replacement conditions, and if consumers purchase high efficacy lamps in "impulse buys". There is evidence of early retirement under certain rebate designs[13].

For Scenarios 1-3, we assumed that low efficacy lamps would become dominated by halogens but that a small fraction of incandescent lamps would remain, based on data showing that incandescent lamps persist in unregulated lamp categories. (For Scenarios 4-5, we assumed that all replacement lamps would be high efficacy by 2018.) We assumed that the high efficacy lamp share would become dominated by LEDs, based on the recent trends showing an increase in LEDs and a decrease in CFLs.[14]

Figure 5

Figure *1*presents results of residential electricity use under each scenario. The values graphed represent the average California household's lighting electricity use. In the embedded table, we present the resulting decline in statewide residential lighting electricity for 2015-2018, which includes an expected 2% increase in the number of California households 2015 to 2018. Finally, by combining the scenario results with findings described in the "Progress to Date" section, we present the resulting estimate for the lighting electricity reduction for 2007 to 2018.



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[13] For example, two members of the Western Regional Utility Network rebated 6-packs of LEDs, and promoted them through emails to customers. In an on-line survey (n>1800) a few weeks after the rebate ended, the majority of participants reported that, in the absence of receiving the email, they would not have purchased any LEDs. But approximately 40% had installed all 6 LEDs, and almost all had installed more than 1 LED. Based on an average of 1 empty socket per home (DNV-GL 2014), participants replaced some rebated LEDs with working lamps.

[14] Other assumptions included: We did not include storage, because of the lack of data regarding how consumers use lamps in storage. We did not include lamps purchased for new construction, because it would have required another set of assumptions, and we estimated these lamps would comprise a small fraction (<5%) of all sales. Finally, we assumed that linear fluorescents would persist at their numbers found in CLASS 2012 – i.e., 5.1 lamps per home.

Figure 1. Scenarios for Future Residential Lighting Electricity, 2015 to 2018

In all scenarios, residential lighting electricity use will decline because incandescent lamps burn out the fastest and are replaced by lamp technologies that are all at least somewhat more efficient. This finding highlights the effect of EISA and AB 1109. However,

Figure *1* indicates the residential lighting electricity goal of AB 1109 would not be met under the Backsliding or Status Quo scenarios. In addition, the Backsliding and Status Quo scenarios show a decreasing rate in lighting electricity savings as the household inventory of incandescent lamps decreases. (For example, the lighting electricity reduction is larger from 2015 to 2016 than from 2017 to 2018.) Furthermore, because halogen lamps have a longer EUL than incandescent lamps, the rate of replacement for halogens – and thus the opportunity for replacement with high efficacy lamps – will be lower in the near future.

Figure *1* also shows that California could exceed its AB 1109 residential lighting electricity goal if all lamps that burn out are replaced by high efficacy lamps by 2018, and that California could significantly exceed its goal if an additional 10% of lamps are replaced by LEDs through early retirement.

Current Utility Program Challenges

The California utilities (both the IOUs and POUs) have rebated millions of high efficacy lamps each year during the past decade. The higher levels of rebated lamps during the 2010-12 program cycle likely contributed to the higher availability of high efficacy lamps and decreasing residential lighting electricity use in 2012. The 2013-14 impact evaluation for the CA IOU residential upstream program found that "Without IOU discounts, incandescent and halogens were the lowest-cost options within each replacement lamp category." (DNV-GL 2016)

But as shown in Figure 2, the IOUs have significantly reduced the number of CFL rebates in the past few years. While this is partially due to a shift in focus to LEDs, the total number of IOU rebates (for CFL and LEDs combined) has declined significantly. The IOUs collectively rebated almost 27 million lamps per year in the 2010-12 program cycle, and less than 10 million lamps per year in the 2013-14 cycle (DNV-GL 2016). While the IOUs have increased the number of LED rebates in recent years, they have not expanded them further due to several reasons. First, in an effort to incentivize high quality LEDs, the CPUC has required the IOUs to only rebate CEC-spec products. Because of the high quality requirements of this standard, the cost of some CEC-spec LEDs is high even with an IOU incentive. Second, California IOU LED work papers do not make a distinction between CEC-spec LEDs and other LEDs. This reduces the incremental measure cost (IMC), effectively capping the rebate the IOUs can provide for CEC-spec products to a value that only makes these lamps cost-competitive with lower quality products. Third, net to gross analysis does not currently differentiate between CEC-spec LEDs and other LEDs. This contributes to the high free ridership estimates for LEDs (40% for ex ante estimates and nearly 70% for ex post), which further reduces cost effectiveness of LED measures. In addition, as supported by the lack of availability of CEC-spec products, some manufacturers have not been enthusiastic about producing high quality LEDs, when they see a larger profit opportunity with standard LEDs. These and other factors have made it challenging for the California IOUs to provide high volumes of LED rebates.

Conclusions and Implications

Overall Findings

Overall, we found that California residential lighting electricity use has decreased by approximately 31% from 2007 to 2015. This is enormous progress in a short timeframe, and it generates immediate energy savings and GHG reductions. Various entities should be credited for this success, including the federal and CA state legislatures for passing EISA and AB 1109; the utilities for delivering lighting programs; the state agencies for their guidance and evaluation of utility programs; and market actors, including manufacturers, retailers, and distributers for serving as program partners.

Our analysis projects that under a status quo scenario, California may fall slightly short of its AB 1109 goal: reducing residential lighting electricity by 45% instead of the targeted 50% from 2007 to 2018. This status quo scenario assumes that half of the lamps purchased by consumers are high efficacy (reflecting recent market availability and partial sales data), and that LEDs continue to take over the high efficacy share. However, the sharp rise in halogen market share, and the faster rise in halogen lamps compared to LEDs in recent years, is of immediate concern. In the absence of IOU CFL rebates, customers making purchase decisions based on up-front cost are likely to choose halogens. Further, while the focus on CEC-spec LEDs is well-intentioned, cost effectiveness challenges have kept total IOU rebates low, which has contributed to CEC-spec products remaining a niche market. Without a strong utility presence, the LED market is at risk of stagnated market transformation, while halogen market share continues to increase. Recent CPUC analysis suggests that 40% of current installed CFLs would revert to an incandescent in the absence of utility rebated CFLs (DNV-GL 2016). Providing these customers continued support for energy efficient purchases would establish an important backstop to halt the backsliding scenario until high quality LED prices decline.

On a positive note, California could exceed AB 1109, if high efficacy lamps comprise over 50% of available lamps, and/or if consumers remove more of their existing lamp stock through early retirement and replacement with LEDs. However, these scenarios are likely to occur only if the California utilities significantly increase the number of rebates, and/or if LED prices steeply decline in the short term (under three years).

A Path Forward

Given the instability in the lighting market for the next few years, with forces pushing towards both rapid efficiency gains and the continuation – and possibly expansion – of low efficacy technologies (primarily halogens), strong market interventions and supporting policy are essential to achieving efficiency and GHG reduction goals. Policies that promote high quality LED products are important for ensuring customer satisfaction, but must be balanced with program cost effectiveness and the willingness of the market to produce and stock qualifying products. We recommend the following strategies, both for California and for other states:

- Adjust policies and rebate strategies that strike a balance between quality and price, so that high efficacy lamps can better compete against halogens and unlabeled (possibly lower quality) LEDs.
    - Rebate ENERGY STAR LEDs, at least temporarily in California, particularly for lamp types where there are no CEC-spec products available, and where the cost of CEC-spec products are high enough that even their rebated price may exceed the price of low efficacy lamps.
    - Temporarily continue CFL rebates, particularly in market channels where customers are likely to be driven primarily by first costs (e.g., discount stores, small groceries).
- Research consumer preferences to guide quality requirements. The CEC-spec for LEDs was inspired by lessons learned from early CFL rebates, when product quality was not prioritized. However, California may be overcorrecting by putting too much emphasis on quality over price. More research is needed on what level of performance (e.g., for CRI and dimmability) consumers consider preferable and their willingness to pay for this performance, to inform requirements for rebates and code. The California IOUs are partially addressing this, by planning for a Lighting Customer Decision Study.
- Ensure evaluation methodologies account for product quality and regulatory requirements. For example, evaluators could develop a free ridership assessment that credits a high quality program LED purchase over a low-quality LED. This would align with market transformation goals by promoting a positive initial LED experience.
- Design programs that encourage early retirement of lamps, including trade-in programs for incandescent and halogen bulbs, and account for early retirement in evaluations.

These strategies will be important for enabling California and other states to continue reducing lighting electricity use, particularly in the short-term before the next phase of EISA takes effect.

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