Some Light Reading: Understanding Trends Residential CFL and LED Adoption

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ABSTRACT

The introduction of Compact Fluorescent Lamps (CFLs) as part of utility incentive programs in the late 1980's offered significant opportunities for homeowners to reduce consumption and for program administrators to generate substantial program savings. Yet, despite these potential benefits, CFLs have only been installed in roughly 30-40% of residential sockets across the country. The remaining unconverted sockets provide ample opportunity for Light Emitting Diode (LED) lamps, which offer even higher savings potential and versatility. At the early stages of market and technology development, many lighting industry stakeholders focused on ensuring LEDs entered the market in a position to overcome many of the quality and environmental issues CFLs faced. The record shows that, in comparison to CFLs, LED lighting products gained customer acceptance and vendor support quickly, even in geographic areas not served by public benefit programs.

This paper summarizes a large volume of recently completed primary research, developed over time for states with high program support for residential lighting and those typically characterized as non-program areas, to document trends in residential customer acceptance (adoption and saturation) of LEDs and in retailer pricing. We compare this information to the corresponding historic record of CFLs and also investigate manufacturer motivations to understand how these products fit into their strategic plans and the effect that had on the development of each market.

Introduction

Residential lighting has long been a core component of many program administrators' program plans and energy savings goals and achievements. Energy efficiency programs began in the late 1980's and early 1990's in early adopter areas like Massachusetts, California, and the Northwest and continued developing across the country throughout the turn of the century. The majority of the initial energy savings generated from these programs can be attributed to residential lighting improvements. However, the technology that is often synonymous with energy efficiency, the CFL lamp, was met with hesitation from consumers and took many years to reach noticeable levels of saturation in American households despite the energy and bill savings potential. On the other hand, as we discuss later in this paper, after the technology developed into lamps that could be used in residential applications, LEDs penetrated the market with much more success and speed than CFLs.

To better understand the evolution of the CFL and LED markets, this paper summarizes a large volume of publically available data developed over the past two and half decades to discern trends in the following market indicators for CFLs and LEDs:

- Installation Rates as a measure of adoption

- Socket Saturation
- Retail pricing
- Manufacturer opinions on how CFLs and LEDs fit into their business plans

Residential Lighting Market Background

In 1997 residential lighting was estimated to account for 8% of total electricity use in California (PNNL 2006). Despite the increase in home sizes and number of sockets per home observed across the country since 1997, overall energy consumption from lighting has decreased; EIA data shows that lighting was only 5% of total electricity usage in the United States in 2013. (EIA 2015). Program administrators, retailers, manufacturers, government agencies, and other energy efficiency groups quickly recognized the savings potential of efficient lighting products and have provided various types of support to the industry and consumers in order to support market growth for many years.

CFLs have been commercially available for residential applications since the 1970s and began appearing in utility programs in the late 1980's. However, despite program administrator and retailer 's early efforts to promote CFLs through these programs, consumers remained mostly unknowledgeable about CFLs or deterred by their numerous issues including the size and shape of the lamp compared to the known technology- incandescents, poor light quality and other performance issues, and environmental concerns. Adding to these consumer barriers, manufacturers initially gave their CFL products different names such as "CFBs", "triple tubes" and "biax bulbs" to prevent consumers from associating CFLs with "cold and sterile" fluorescent tube lighting; however, this lack of a consistent naming convention only confused and deterred consumers further. Similarly, consumers treated lighting as a commodity and often purchased replacement lamps at grocery stores as opposed to big box stores like Wal-Mart and Home Depot. The grocery retail channel was not known for stocking CFLs and this lack of availability became another barrier to early adoption (PNNL 2006).

To overcome these barriers, regional groups such as the Northwest Energy Efficiency Alliance (NEEA)) and Northeast Energy Efficiency Partnership (NEEP) began working with manufacturers and program administrators to adjust program requirements and provided training and marketing resources at the retail level. In 1999 the first ENERGY STAR specification for CFLs was introduced by the U.S. Department of Energy (DOE) to provide manufacturers with national specification standards which would afford consumers with a way to distinguish quality products.

A turning point in CFL adoption trends came in 2001. The U.S. Environmental Protection Agency (EPA) launched the "Change a Light, Change the World" Campaign which provided additional marketing to consumers and influenced more manufacturers to participate in the ENERGY STAR program. The 2001 California Energy Crisis, rising energy prices, and decreasing CFL prices also had a large impact on the shift in consumer attitudes towards trying CFLs for the first time or purchasing more for their homes. Adoption of CFLs continued to grow after 2001 and they still comprise a large part of many efficiency programs today.

Compared to CFLs, LEDs offer a significantly longer useful life, more versatility, and better performance and quality, yet initial reports of consumer awareness and attitudes towards LEDs showed the main barriers were price and quality, as many consumers were skeptical of overstated claims after their CFL experiences. LEDs first entered the market in the 1970's as indicator lights in electronic devices, but the technology was very expensive and produced only low levels of light within a limited color spectrum, and early interior and exterior LED lighting

applications were not available until the early 2000s (DNV GL, 2015). The Energy Policy Act of 2005 directed the DOE to provide research and development support for solid state lighting technologies; this extensive support, provided through the Solid State Lighting (SSL) initiative, quickly spurred further advances in LED technologies and increased the availability of LEDS for interior lighting applications. Manufacturers largely cooperated with government agencies and utility-sponsored efforts to establish performance criteria and testing regimes for LED products to support reducing quality concerns and DOE also manages the CALiPer program which test LED products and report on the tested performance. DOE also set initial price per lumen goals as part of the SSL program, but these goals have required numerous revisions because the market has advanced more rapidly than expected. As of 2014, DOE's goal "is to achieve a 266 lumen/watt efficacy at $0.50 per thousand lumens by 2030" (PNNL 2014).

Manufacturers also mounted robust marketing and education campaigns to support sales of their new LED products. Other market actors, such as retailers and program administrators are also vigorously promoting the technology and the EPA added an ENERGY STAR specification for LEDs which began in 2010. To date, program administrators in 48 states have programs which support LED screw-based lamps (Navigant 2015).

Trends in Residential Adoption

This section explores how the residential market responded to CFLs and LEDs by reviewing the rate of adoption and socket saturation of standard screw-based lamps over time and across the US. We compiled data from various publically available market characterization studies and evaluations conducted since 1994 to show trends in the aforementioned market indicators.

Rate of Adoption

Figure 1 and Figure 2 present the rate of residential CFL and LED adoption observed between 1994 and 2015. These data represent the percentage of customers that have at least one CFL or LED installed in their home during the study period. While these data are sourced from a variety of evaluation and market characterization reports, they were each derived from on-site visits and customer phone surveys in the study area of interest. To the extent possible, if the reported data are only based on purchase rates, we used the observed installation rate to determine the rate of adoption.

The CFL adoption time series in Figure 1 shows the slow market growth observed during the early stages of program and technology development as well as the rapid growth that began after the inauguration of the ENERGY STAR program in 1999 and the California energy crisis and the Change a Light Change the World campaign in 2001. Although the high cost of CFLs unquestionably influenced consumers' decision to not initially purchase these lamps, rebate programs that tried to address this barrier actually led to market confusion and arguably kept adoption low. Early programs often offered inferior low-cost, products to customers to keep their program costs low and often either gave away CFLs for free or offered them at a much lower cost than what could be found at stores, leading to sticker shock for returning adopters (PNNL 2006).

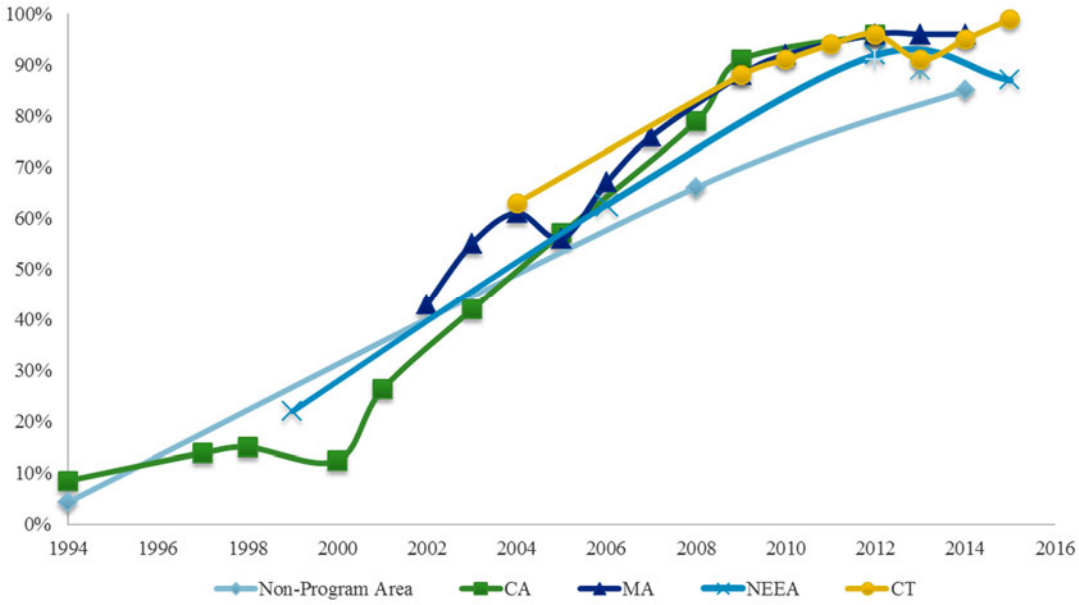

Figure 1: Trends in Residential CFL Purchase Rates 1994-2015. Various Sources.

Interestingly, the data shown in Figure 1 suggest that growth in CFL adoption began to stagnate around 2008 and adoption began to decrease slightly starting in 2012. LED adoption (Figure 2), on the other hand, grew quickly once LEDs for common residential applications were commercially available towards the end of the previous decade. Unlike CFLs which experienced slow growth in adoption despite being available in the market for many years, LED lamps quickly made their way into homes across the country once they were commercially available. By 2014, 20-40% of customers, depending on the region, had at least one LED installed in their home.

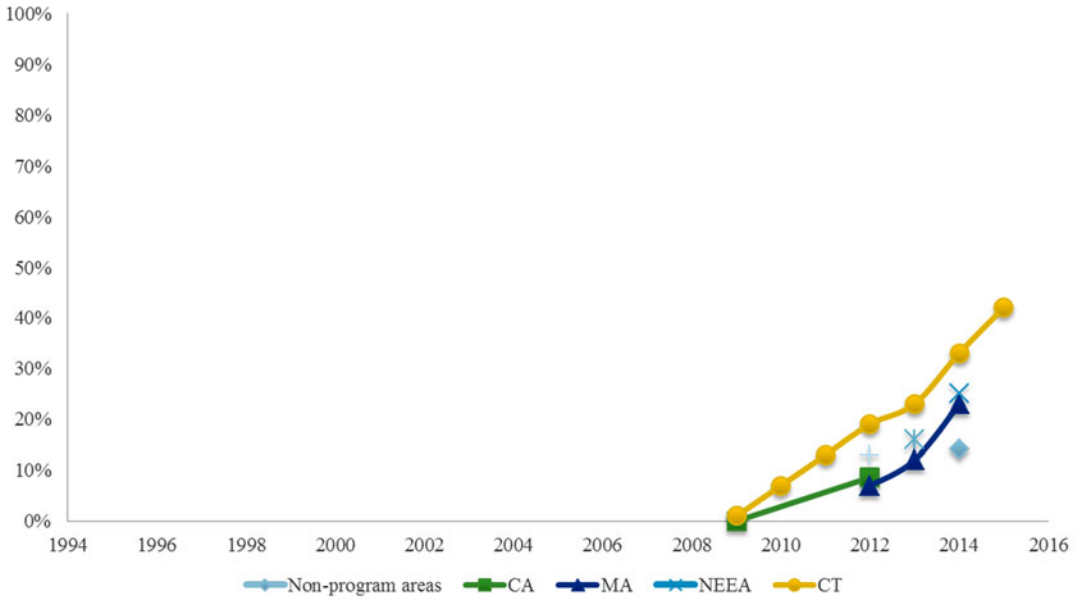

Figure 2. Trends in Residential LED Penetration 2009-2015 *Sources:* Various Sources

Socket Saturation

Trends in CFL and LED socket saturation, shown as the average number of CFLs or LEDs installed within a home, are shown in Figure 3and Figure 4. Similar to the rate of adoption, the average number of installed CFLs remained low, at less than one lamp per home, prior to 2001. Although the rate of adoption began to increase in 2001, growth in the number of CFLs per home lagged this milestone by a few years as new adopters tested the product and manufacturers started producing more products at cheaper costs due to increased competition and economies of scale which ultimately led to lower costs to the consumer. By 2012, homes across America had approximately 10-15 CFLs installed in their interior sockets. Saturation has continued to grow in New England since 2012 despite possible stagnation on the west coast.

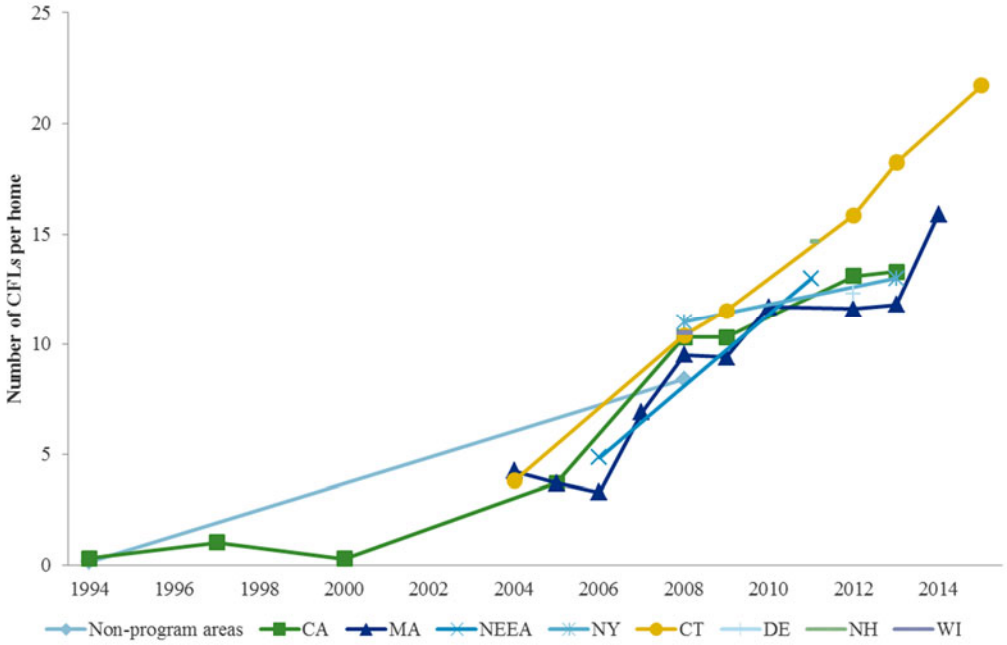

Figure 3. Trends in Residential CFL Saturation 1994-2015. *Source:* Various Sources

Despite an increase in the number of homes with at least one LED, socket saturation between 2008 and 2013 did not increase much and was estimated at less than one LED per home. High initial costs and consumer hesitation about quality and performance likely deterred customers from installing multiple LEDs until they felt comfortable with the products' energy savings and performance. LED users are largely satisfied with their purchases and aware of the benefits of LEDs, thus as currently installed halogens and incandescent lamps, and the previously installed CFLs, are due for replacement, it would not be surprising to see LED socket saturation to increase, particularly as the cost per lamp continues to decline (DNV GL 2015).

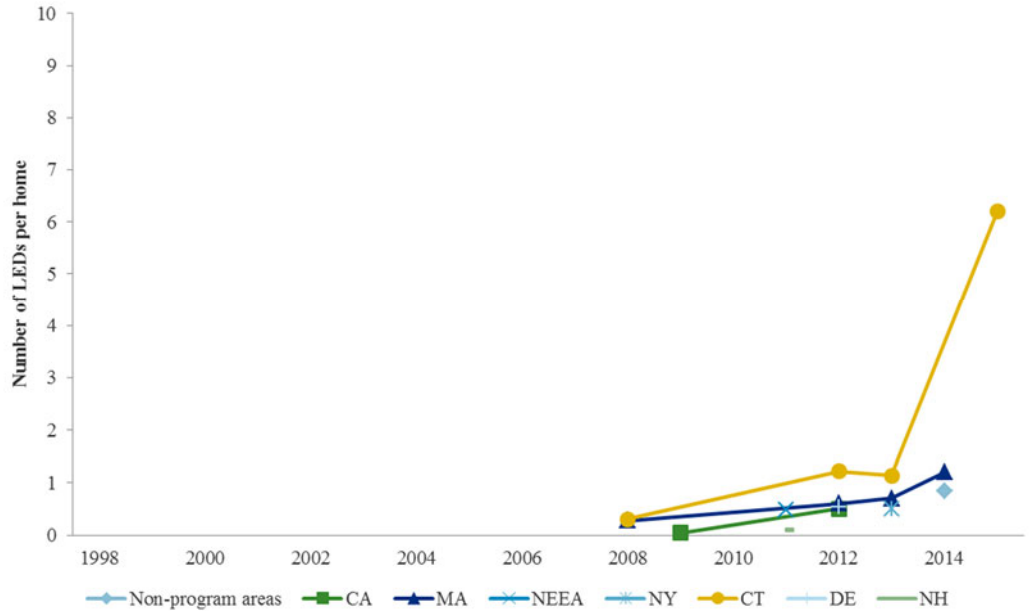

Figure 4. Trends in Residential LED Saturation 2008-2015. *Source:* Various Sources.

Pricing Trends

Figure 5 and Figure 6 present the average retail price per CFL and LED, respectively. The cost per lamp shown in these figures represents the pricing consumers experienced at retail locations in each state or region and do include the effect of rebates, if applicable. Similar to the adoption trends seen above where CFL adoption did not increase until 2001, the observed retail prices of CFLs did not become decrease to cost-competitive levels until this time period as well.

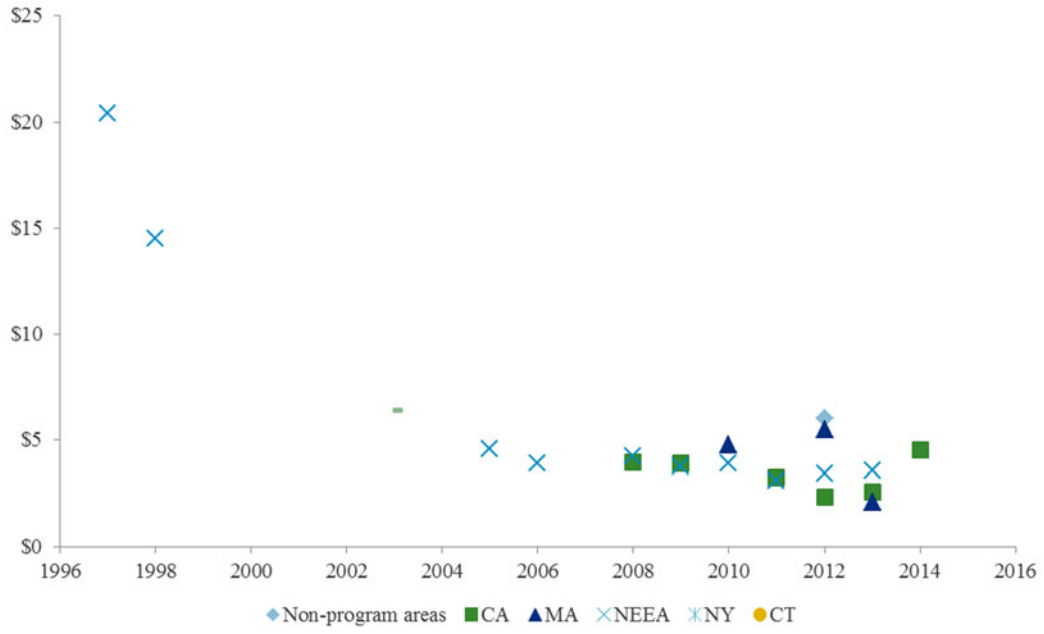

Figure 5. Average Retail Price per CFL Lamp 1997-2014. *Source:* Various Sources.

Prices for LEDs, on the other hand, started to decline shortly after they entered the residential lighting market. While the most recent price observations shown in Figure 5 and Figure 6 imply ENERGY STAR certified LEDs are still not cost-competitive with CFLs and halogens, it is expected that costs will continue to decline in response to market interest and the high levels of manufacturer competition and program support. McKinsey (2012) anticipated the prices of LEDs would become cost-competitive with CFLs in 2015. Similarly, a manufacturer interviewed in 2013 noted that they haven't seen a decrease in CFL sales "but I'm sure once the price point of LEDs comes down and you're able to buy an LED for under $5, I think that will change… and I think that will happen in 2014" (DNV GL 2014b). While it is not clear from the currently available data whether prices reached this level in 2014 or 2015, a review of current prices on Home Depot's website suggests they are converging and a number of A-lamp models are now available for less than five dollars per lamp.

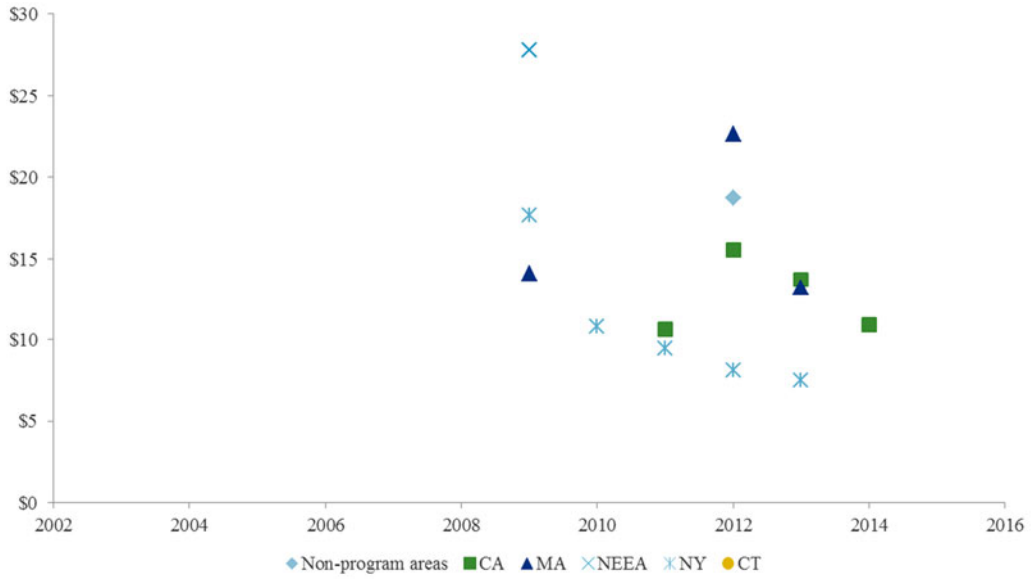

Figure 6. Average Retail Price per LED lamp 2009-2014. Various Sources.

Manufacturer Attitudes towards Residential Lighting

The saturation trends presented above confirmed our hypothesis that CFLs took much longer to penetrate the residential lighting market than LEDs for the same applications. To further understand why the market did not address consumer concerns with CFLs as quickly as they did with LEDs, we investigated how manufacturers reacted to each technology. While we know that consumers were unhappy with the performance of early CFLs and had concerns regarding the environmental and safety aspect of the lamps (Cadmus 2010), manufacturers were slow to adjust their production lines to address these barriers to increased adoption. On the other hand, LEDs entered the market quickly despite initial hesitation from consumers.

Manufacturers significantly impact what is available in the market through their responsiveness to programs, research and development efforts, and ability to produce products at a price consumers are willing to pay. Retailers also provide market feedback to manufacturers based on reorders and consumer requests for product features. The green lines in Figure 7 show the flow of influence within the market. With regards to manufacturers, the EPA's ENERGY

STAR program influences the performance of products they produce and energy efficiency programs determines the measures eligible for program rebates.[1] The blue arrows indicate the direction of sales; manufacturers often sell residential lamps to retailers or distributors who then market and sell the products to consumers.

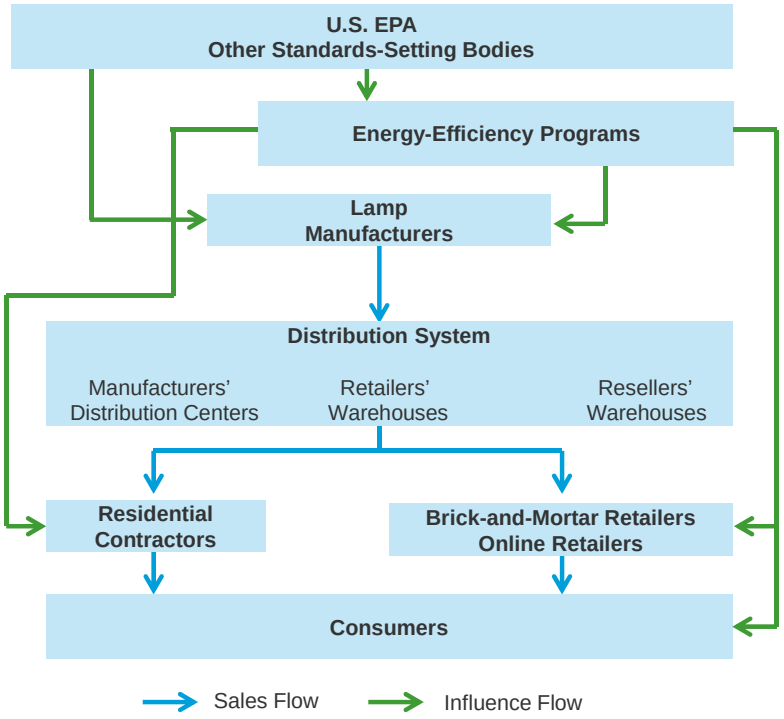

Figure 7. Typical Residential Lighting Market Structure. *Source*: DNV GL, 2015

The EPA maintains a list of the ENERGY STAR qualified lamps which can be used as an indicator of lamp manufacturing organizations interest in producing lamps that meet certain quality standards by analyzing the number of ENERGY STAR partners with qualifying lamps over time.[2], [3] Many manufacturers design their products to meet the ENERGY STAR specifications because consumers are familiar with this label and many utility-sponsored programs refer to the qualified products list when designing programs.

Based on the qualifying product lists for the CFL and LED Version 4.3 and Lamp Version 1.0 specifications, only two CFL manufacturers qualified for the ENERGY STAR label during its first full year in effect (2000), and an average of 12 additional manufacturers qualified annually under Version 4.3. On the other hand, 24 LED manufacturers qualified for the ENERGY STAR label during its first full year (2011) and an average of 55 partners were added each year.[4] By 2013, the final full year of the separate LED and CFL specifications, the number of qualified LED manufacturers outnumbered CFL manufacturers for the first time. When

[1] The EPA began managing the ENERGY STAR CFL program in 2010
[2] An ENERGY STAR partner is defined by the EPA as "an organization that signed a Partnership Agreement with EPA to manufacture or private label ENERGY STAR qualified products."
[3] It is worth noting that these counts may over-represent the total number of LED lamp manufacturers, since some manufacturers may produce lamps under more than one brand name.
[4] The first LED specification, version 1.0, went into effect on August 31, 2010

ENERGY STAR partners could begin qualifying for the Version 1.0 specification in 2014, LED partners continued to outnumber CFL partners and have continued to do so throughout the duration of the specification.[5] The growth in the number of LED partners suggests it is a market no longer dominated by the major lighting manufacturers and interest in producing CFLs is on a decline. An observed decrease of CFLs shipments and increase in LED shipments in 2014 further supports this idea; manufacturers appear to be focusing on LED production and less on CFL manufacturing at this time (Navigant 2015).

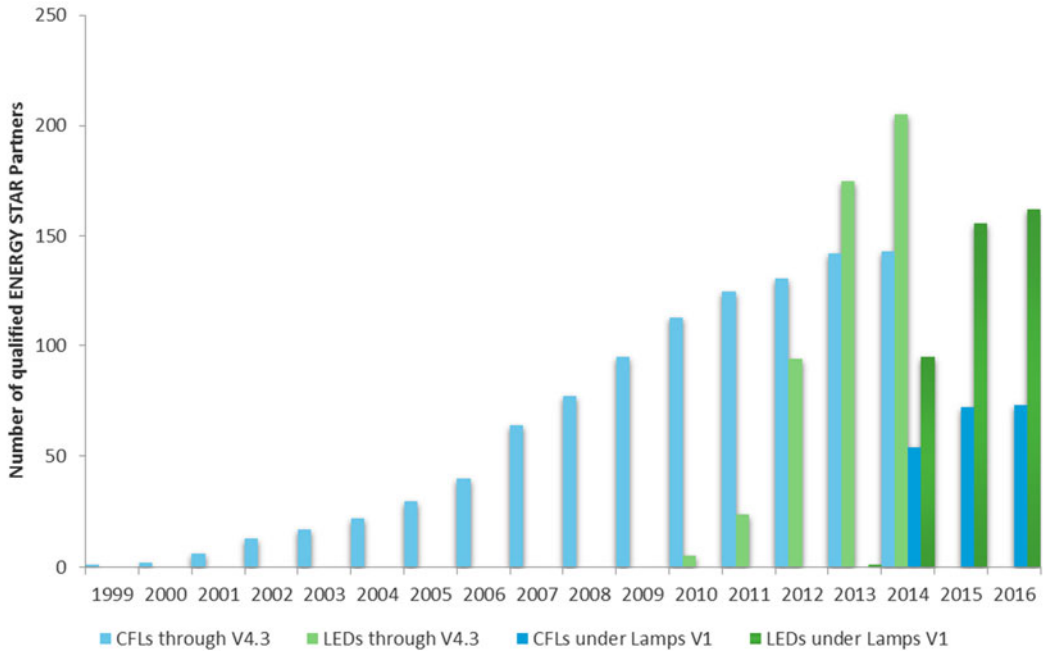

Figure 8. Number of ENERGY STAR Partners with qualifying lighting products, by year and lamp technology. *Source*: US EPA 2014a, 2014b, 2016.

CFLs

Initially manufacturers did not view residential CFLs as a product with high profit potential, and without national marketing campaigns and regional efforts to promote energy efficiency manufacturers remained focused on traditional lighting products such as incandescent lamps (PNNL 2006). A survey of CFL manufacturers interviewed in 1999 observed that large manufacturers believed incandescent lamps would continue to dominate the market (Dethman 1999). In another manufacturer survey, one noted that "the Big Three bulb producers could dominate the CFL market if they chose to, but they have been happy with their dominance in the incandescent market" (KEMA-XENERGY and Quantum Consulting 2003), suggesting that CFLs were not considered a major part of manufacturers' business strategies at this time.

Similarly, prior to the EPA's "Change a Light, Change the World" campaign which provided national marketing for residential CFLs, manufacturers were not focusing their marketing efforts on residential CFLs as they instead marketed to commercial customers and

[5] Version 2.0 has been announced and ENERGY STAR partners are able to apply for early certification at this time. This specification will be effective on January 2, 2017.

retailers who determined what was stocked on shelves (PNNL 2006). As such, residential consumers were not exposed to consistent messaging regarding CFLs and the associated benefits.

Increased consumer awareness and interest in CFLs as a result of national and regional campaigns at the turn of the century and advances in efficiency program design motivated manufacturers to place more focus on their CFL product lines to capture this market. As many programs stipulated that CFLs must have the ENERGY STAR label as an eligibility requirement, manufacturers began innovating in order to qualify for the label and stay competitive. As one manufacturer noted in 2005, "there's probably virtually no business outside of the incentive areas. To me, ENERGY STAR is almost synonymous with utility rebates" (Kates and Bonanno 2005). At the same time, increased consumer awareness and program support also influenced new manufacturers to enter the market and participate in the ENERGY STAR program, thus increasing competition and ultimately lowering prices. After this point, manufacturers continued innovating and improving their CFL products in order to take advantage of various program rebates and consumer requests for additional functionality and features.

LEDs

As LEDs were on the verge of entering the market, manufacturers were asked to discuss lessons learned from their experience with CFLs. Many felt that consumers were not well educated on the benefits of CFLs, but they were not afforded large marketing budgets for consumer outreach to reduce this barrier. Moving forward they felt they should focus their marketing efforts on advertising product benefits and retailer education, particular at large national chains that have a lot of influence on the lighting market (PNNL 2006). After imprudently producing low quality CFLs that spurred consumer dissatisfaction and created negative perceptions, the large lighting manufacturers determined that they would not promote LED products until they were truly ready, despite the desire to be first to market (PNNL 2006).

In contrast to early CFL manufacturers who did not focus on CFL R&D or marketing, LED manufacturers interviewed in 2013 reported that their companies spent the majority, if not all of their R&D and marketing funds to support LED products (DNV GL and TRC Solutions 2014). The presence of various manufacturing partnerships such as the Next Generation Lighting Industry Alliance (NGLIA) and other stakeholder groups and networks such as the DOE's Technical Information Network for Solid-State Lighting (TINSSL), the Illuminating Engineering Society (IES) and International Alliance of Lighting Designers (IALD) pushed the envelope on LED development by bringing stakeholders together, supporting product design competitions, and developing product standards and testing procedures that continue to ensure a certain level of product quality (PNNL 2014).

The LED industry has also brought new manufacturing players to the market including start-up businesses and traditional electronics and semiconductor manufacturers. Manufacturers from the LED backlighting industry also started shifting production to general LED lighting as the backlighting market became saturated (McKinsey 2012). This influx of new manufacturers has also forced traditional lighting companies to invest in R&D for innovation and to meet quality and performance standards to remain competitive. This competition amongst manufacturers also induced better product quality and availability and a rapid decrease in prices.

Conclusions

Trends in adoption and saturation observed across the country suggest that LEDs gained market acceptance much quicker than CFLs and the market appears to be shifting towards LEDs as a significant portion of consumers are adopting these lamps and a larger share of manufacturers are focusing their efforts on LED technologies. Manufacturers and other industry stakeholders, such as ENERGY STAR and DOE, considered lessons learned from CFLs to properly prime the market for LED products rather than treat them as a niche product with low profit margins and high consumer costs (PNNL 2014). However, though the road to market for CFLs was bumpy, the industry learned to focus on product quality and marketing from this experience that has arguably contributed to the current success of the LED lamp market.

Despite advances in LED lighting product quality and a decrease in prices, programs must stay play a large role in supporting this market, particularly as LEDs are not yet cost-competitive with halogens. Although industry stakeholders in the LED market have addressed many of the issues CFLs faced, continued support from programs and manufacturers is critical. Consumers are largely aware and satisfied with the quality and performance benefits of LEDs program (DNV GL 2015), but ensuring the high-quality and tested products get into homes is necessary to avoid future consumer dissatisfaction and advance market adoption. Efficiency programs should continue to provide financial support to market actors and consumers through rebates and assist in marketing and consumer education efforts to ensure quality LEDs continue to penetrate the market while programs like ENERGY STAR and CALiPer should continue product testing to ensure a product's quality claims are accurate before they reach consumers.

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