Designing and Evaluating Residential Lighting Programs in a Rapidly Changing Market

Jeff Erickson, Navigant Consulting, Verona, WI

ABSTRACT

Residential lighting programs have accounted for a significant fraction of total energy efficiency portfolio savings for several utilities in the recent past. Most of those savings have come from compact fluorescent lamps (CFLs). The federal Energy Independence and Security Act (EISA) of 2007 mandates that general service lamps have to meet minimum efficiency standards. The first standard came into effect at the beginning of 2012 and affected 100 Watt incandescents. One year later 75 Watt incandescents were affected. Manufacturers responded by producing halogen bulbs that meet the requirements. They are also hard at work reducing the cost and improving the performance of LEDs.

In light of these market dynamics, residential lighting program managers must adjust their program designs to help move the market toward more efficient bulbs while at the same time avoid claiming savings that would have happened anyway. This task is now much more difficult than it was a few years ago. Which bulbs should they incent? How much can they pay to help the LED market develop and still run a cost-effective program? How do they choose bulb types and efficiency levels to balance evaluation risk with savings and cost-effectiveness goals?

Residential lighting program evaluators also face a more difficult task than a few years ago when they are charged with measuring net impacts as they must divine the counterfactual in a complex, fast moving market. This paper will provide the background and context on these issues and make recommendations to program designers and evaluators.

Introduction

Residential lighting programs often account for a significant fraction of a utility's energy efficiency portfolio savings (D&R International 2010). With the Energy Independence and Security Act of 2007 (EISA) standards, matured CFL technology, and LEDs coming on fast, the market for residential lighting is rapidly changing. This presents both a challenge and risk to the reliability of savings from utility programs and a significant challenge to evaluations charged with estimating net savings from these programs. This paper will describe the key issues for programs and evaluations and discuss how the issue is being handled in several different states.

Context

Electricity consumption for lighting is one of the single biggest end uses in the United States, accounting for 21 percent of electricity consumption (DOE Buildings Energy Databook, 2011) and adding to 700 TWh in 2010 (Navigant 2012b). Global lighting sales have reached $100 billion per year (Barringer 2013). Those sales are spread across a wide range of products and sectors (see Figure 1) (Navigant 2012b). Residential bulbs account for about 25 percent of the U.S. annual lighting consumption. Of those, incandescent bulbs represent the largest fraction by a significant margin.

Residential lighting energy efficiency programs have accounted for a significant fraction of total energy efficiency portfolio savings for several utilities in the recent past. A 2009 study found residential CFL lighting savings from various jurisdictions varying from 25 to 50 percent of portfolio savings (D&R International). For example, Commonwealth Edison Company (ComEd) runs an upstream buy-down residential lighting program in Illinois. That one program accounted for 43 percent of its ex ante projected savings in the program year ending in 2012 and 37 percent in 2013. Most of those savings were from CFLs with relatively few LEDs.

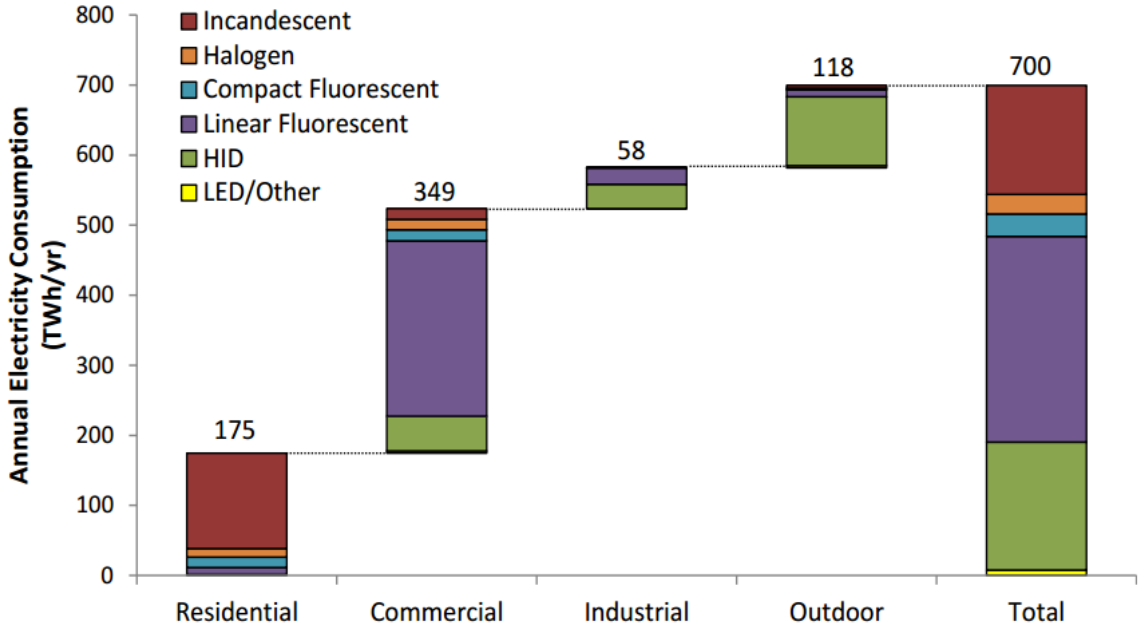


Figure 1. U.S. Lighting Electricity Consumption by Sector and Lamp Type in 2010

EISA mandated that general service lamps equivalent to 100 Watt incandescent bulbs had to meet minimum efficiency standards starting in January 2012. In January 2013 the rule expanded to cover 75 Watt incandescents and in 2014 it will expand to 60 Watt and 40 Watt bulbs. Manufacturers are responding to those mandates in a variety of ways, the most obvious is by producing halogen bulbs (sometimes referred to as "high efficiency incandescents") that meet the requirements. Manufacturers are also hard at work trying to reduce the cost and improve the performance of LEDs for standard consumer applications.

Table 1. EISA Standard

Incandescent	Under EISA	Effective Date
100 Watt	<= 72 Watts	January 1, 2012
75 Watt	<= 53 Watts	January 1, 2013
60 Watt	<= 43 Watts	January 1, 2014
40 Watt	<= 29 Watts	January 1, 2014

Source: EPA 2011

Prior to EISA taking effect, most residential customers were unaware of the coming changes. By mid-2012, though, awareness was higher. In ComEd's territory, 53 percent of respondents to an in-store intercept survey said they were aware of EISA[1] and 77 percent of those were 'somewhat or very familiar' with the law (Navigant 2013).

[1] Survey respondents were first provided with a brief description of EISA and were asked whether or not they had heard of the new standards.

In contrast to some expectations, residential customers did not appear to stock up on incandescents in response to the coming changes. In a survey for ComEd in April and May 2012, 91 percent stated that they had not stocked up on 100 Watt incandescents in anticipation of the law (Navigant 2013). However, the shelf survey done at the same time found that there were still 100 Watt incandescents retail shelves four to five months after the law went into effect. A shelf survey in Ohio done in November and December found few 100 Watt incandescents on the shelves with only 15.9 percent of the stores examined having one or more brands of 100-Watt incandescents (Navigant 2013b).

Along with regulatory changes have come other market changes. Prices for CFLs have been steadily dropping for years and are projected to continue dropping. In Illinois in 2012, the average price of an incandescent bulb was $0.77, the average halogen cost $2.48, and the average CFL twister cost $2.01 if it was part of a utility rebate program and $3.27 if it was a non-program twister (Navigant 2013). In Ohio in 2012 a 100W incandescent cost $1.04 and a halogen $2.46 (Navigant 2013b). The Natural Resources Defense Council (NRDC) in January 2013 pegged the price of a 100 Watt incandescent at 50 cents, a 72 Watt Halogen at $1.50, and a 23 Watt CFL at $3 (NRDC 2013). Prices for LEDs have also been dropping and are projected to continue to decline significantly in the coming years (see Figure 2) (Navigant 2012a).

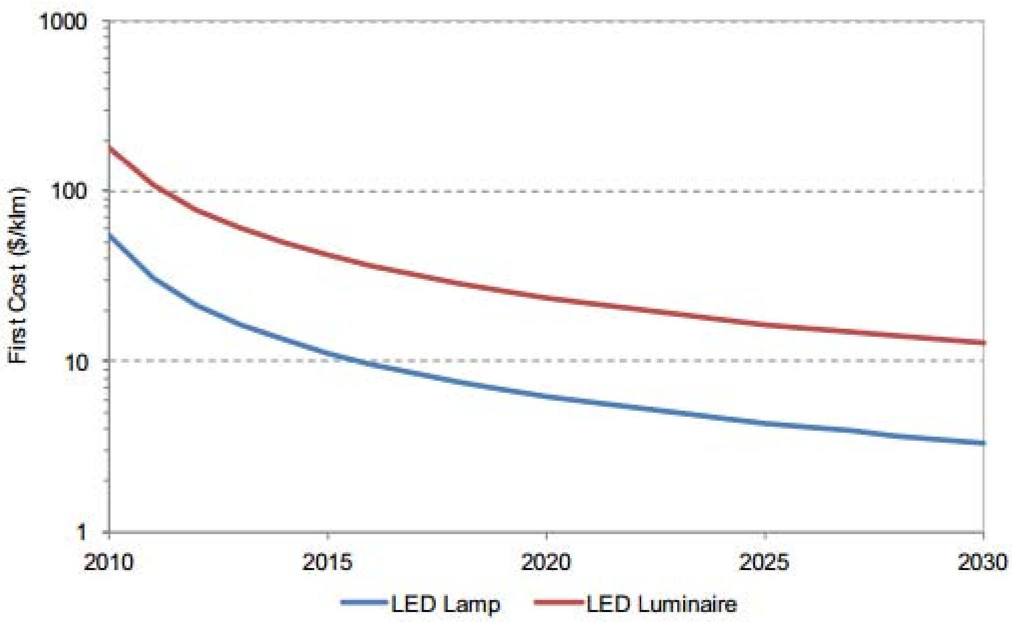


Figure 2. LED Price ($/klm) Improvement

Change in the Market

Two market changes are particularly important for residential lighting energy efficiency programs – the growth in halogens that meet the EISA standards and the arrival of LEDs at prices that are attracting more attention.

Halogen. Manufacturers reacted to the EISA standards by producing halogen bulbs that meet the new standards and look quite similar to the profile of the familiar incandescent bulb. Their prices are higher than standard incandescents, but probably not so high that many customers will balk. In Illinois in 2012, the average price of an incandescent bulb was $0.77 and the average halogen cost $2.48 (Navigant 2013). In Ohio later in 2012, the average halogen cost $2.46 and the average 100W incandescent cost $1.04 (Navigant 2013b).

LEDs have been on the market for some time but only in recent years have they started appearing in a form and at a price that customers other than early adopters might consider buying.

Manufacturers have been driving down the price and increasing the longevity and efficiency of LEDs. They are racing to get a piece of what McKinsey believes will be an $84 billion market by 2020 up from $12.5 billion today (Barringer 2013). Retailers have been demanding LEDs at lower price points and manufacturers have been responding, but there is some concern that the price pressure is leading some manufacturers to produce lower quality products that may not live up to customers' expectations (Forrester 2013).

Efficacy. When LEDs first started appearing in the market, their efficacy[2] was not substantially better than CFLs. LED manufacturers have been working hard to improve that situation. LED lamps are expected to reach 100 lumens/Watt in 2015 and almost 200 lumens per Watt in 2020 (see Figure 3) (Navigant 2012a). In comparison, incandescents produce about 13 lumens/Watt and CFLs between 55 and 70 lumens/Watt (EPA 2011) and are projected to improve their efficiency by only 10 percent by 2030 (Navigant 2012a).

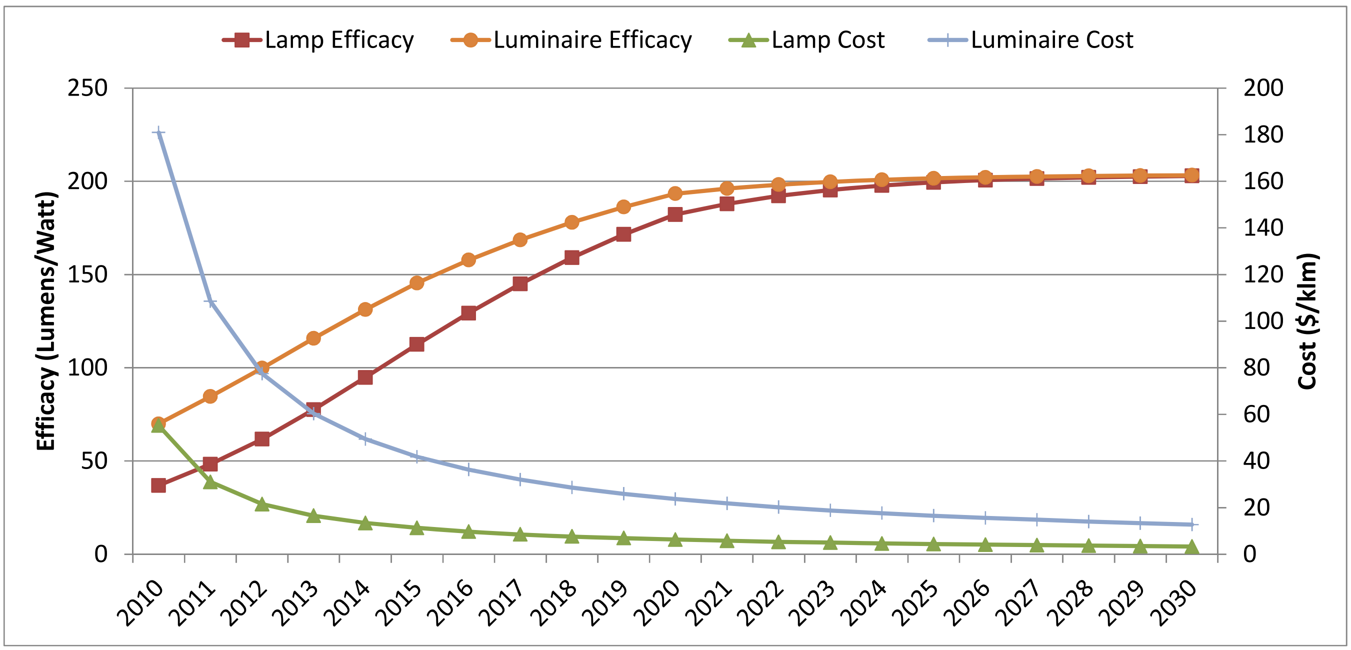


Figure 3. LED Efficacy Improvement

Price. While manufacturers have been working to increase LED efficiency through design improvements, they have also brought down costs through improved manufacturing techniques and economies of scale. According to a Navigant study for the Department of Energy (DOE), prices per kilolumen will drop from $55 in 2010 to $11.25 in 2015, and $6.26 in 2020 (see Figure 3 and Table 2).

Table 2. LED Price Projection ($/klm)

Product	2010	2015	2020	2025	2030
Lamp	55.16	11.25	6.28	4.36	3.34
Luminaire	180.88	41.81	23.69	16.55	12.73

Source: Navigant 2012a

[2] Efficacy is defined as lumens per Watt where lumens are a measure of light output.

Sales. Although CFLs have become quite common, there still appear to be plenty of sockets that contain incandescents (D&R International 2010).[3] A Navigant study for DOE in 2012 found that roughly half of the residential lighting energy use comes from incandescent bulbs (Navigant 2012a).

The Philips lamps division now claims that 25 percent of their sales come from LEDs and they expect that to increase to 50 percent in two years (Barringer 2013). LEDs are expected to represent 36 percent of lumen-hours sales by 2020 and 74 percent by 2030 (see Figure 4) (Navigant 2012a).

In an in-store intercept survey in Illinois in 2012, we found that 28 percent were either purchasing a LED or indicated they had installed an LED bulb in their home (Navigant 2013). In Ohio, 8 percent of respondents said they had LEDs installed in their homes in 2012 (Navigant 2013b). However, the choices in LED bulbs are still relatively limited. A shelf surveys in Illinois in 2012 found that overall LED availability in the 75 to 100-Watt incandescent equivalent range is still quite limited (Navigant 2013).

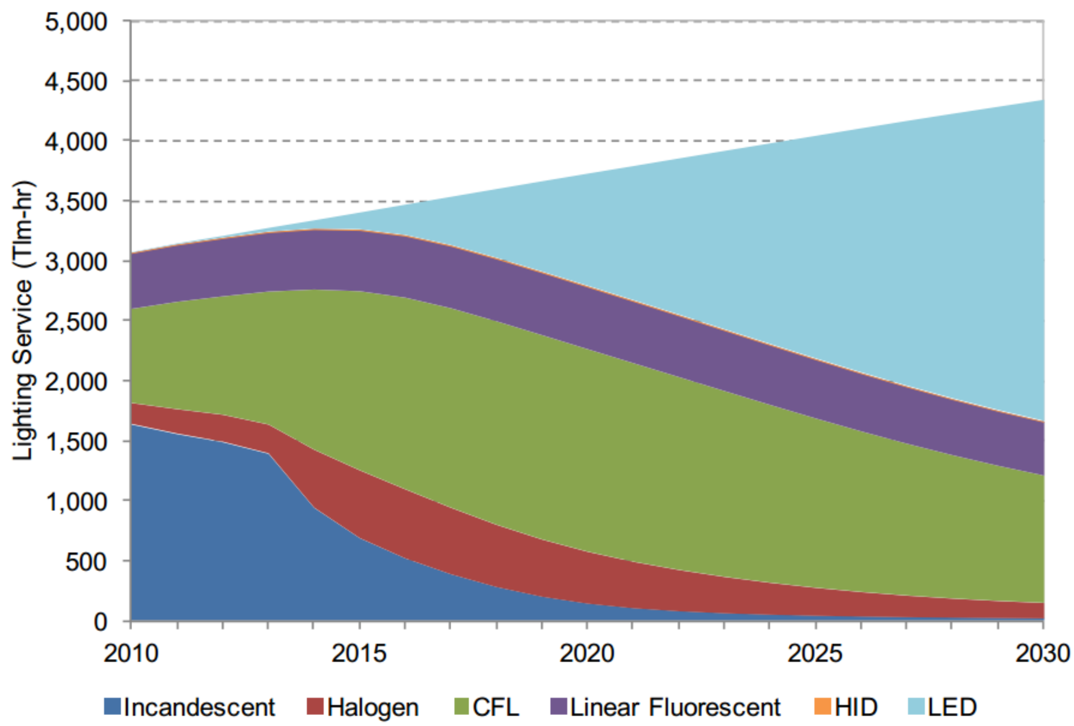


Figure 4. Residential Lighting Service Forecast, 2010 to 2030

Trends

Trends in popular opinion provide more context for the future of residential lighting programs. There was quite a bit of publicity and reaction to the EISA standards, not all of it positive. How has this debate affected public attitudes toward energy efficiency and efficient lighting? Was there any meaningful pushback in attitudes in a way that would affect residential lighting programs?

Internet search engines keep track of search queries entered by users over time. Google allow queries into their data through Google Trends[4]. Searches in Google Trends on terms related to residential lighting and energy efficiency provide insight into the ebb and flow of public opinion.

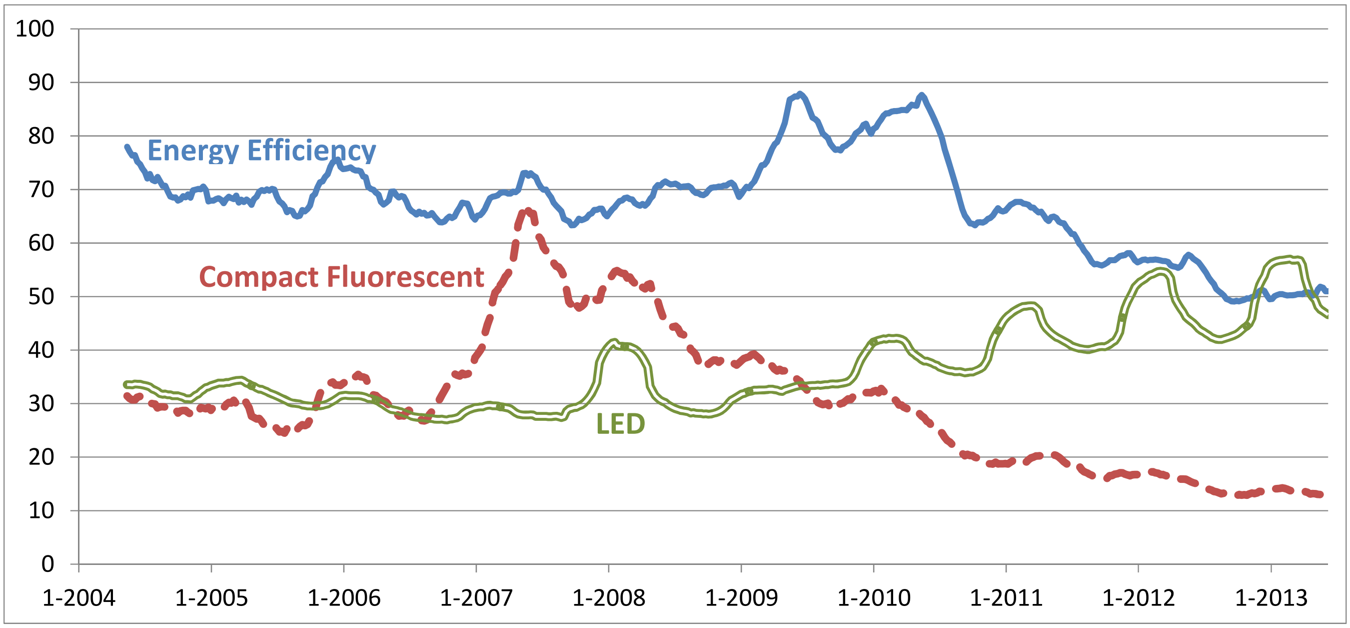
Searches for "Energy Efficiency" varied substantially week to week but the overall trend was relatively flat from 2004 to 2008, when EISA was being debated and passed (see Figure 5). In 2009 and

[3] D&R International found in 2010 that "more than 70 percent of the sockets that can hold CFLs remain unfilled." (D&R International p17)

4 https://www.google.com/trends/

2010, energy efficiency searches saw an upswing but then around June 2010 such searches began a long slow descent that continues today. The decline in “energy efficiency” searches is coincident with the recession and slow recovery. This could reflect a retreat from interest in any investment, including in energy efficiency, in uncertain times. Or it could reflect a continued and perhaps accelerated decline in interest in energy efficiency.

Searches for “compact fluorescent” increase from 2004 to a peak in 2007, coinciding with the passage of EISA and then decline to a level below 2004 at present. The start of this decline predates the recession. While interest in CFLs seems to be waning in recent years, interest in LEDs has been growing substantially since late 2008. Interest shows a cyclical pattern with peaks toward the end of the year. This is perhaps correlated with holiday sales of decorative LED lights.



20 week moving average. The number 100 represents the peak search interest.

Figure 5. Trends in Web Searches

Program Design Issues

In light of these market dynamics, residential lighting program managers must adjust their program designs to help move the market along toward more efficient bulbs and higher socket saturation while at the same time avoid claiming savings that would have happened in the absence of the program. This task is now much more difficult than it was a few years ago but some significant opportunities remain.

Cost Effectiveness. Residential lighting programs are typically very cost effective. However, because EISA is changing the baseline it is reducing per bulb savings from program bulbs and, all else equal, this will put downward pressure on residential lighting program cost effectiveness. With the price of LEDs now significantly lower than it was a few years ago, it is now possible that programs that once focused exclusively on CFLs could change their emphasis to LEDs without risking their cost effectiveness. How that plays out depends on a variety of factors, but the longer life of LEDs ought to help in the TRC calculation.

Free ridership. With EISA-compliant halogens more expensive than the incandescents they replaced, and with declining CFL prices, the cost difference between CFLs and their least efficient competitor has declined. That difference can be as little as $0.75 per bulb. Given that, small energy efficiency program incentives may have little effect and raise the risk of high free ridership. Incentives large enough to reduce the final cost of CFLS to noticeably lower than halogens may mitigate that risk. On the other hand, the price difference between LEDs and halogens is still rather substantial, which might give programs plenty of room to have a meaningful impact with their rebates.

Bulb Type. Historically, most program bulb sales have been in standard sizes and types and specialty bulbs have formed only a small percent of savings. In ComEd's territory in 2012, we found that 86 percent of respondents who purchased standard CFLs bought program bulbs, while only 63 percent of specialty CFL purchases were program bulbs (Navigant 2013). For AEP Ohio, we found that 85 percent of residential customers were familiar with CFLs, but less than 50 percent were familiar with specialty CFL bulbs (from 42 percent for dimmable CFLs to 46 percent for 3-way or floodlight CFLs) (Navigant 2013b). Part of the reason for this divergence could be the relatively sparse choice of CFL specialty bulbs that meet customers' expectations for features and appearance (Forrester 2013). This could change as LED specialty bulbs start spreading.

Encouraging customers to purchase specialty CFL and LED bulbs might improve a program's overall impact and cost effectiveness. Average per-bulb savings can be higher for specialty bulbs since their baseline may be lower since their incandescent counterparts are unaffected by EISA. However, it is worth noting that part of this increase in gross savings could be offset if free ridership is higher on specialty bulbs, as we found in ComEd territory (although it was only slightly higher).

Manufacturers can produce a value based LED to bring down their cost, but in doing so risk producing a product that will not live up to expectations (Forrester 2013). Energy efficiency program designers will want to ensure the products they support are of a high quality, perhaps relying on the ENERGY STAR certification, so that they increase their customer's odds of having a positive experience.

Education. Programs may be able to improve their effectiveness by improving the material they provide at the point of purchase and the education they do with customers. In ComEd's territory, we found that half the intercept respondents buying specialty bulbs said the information materials were not influential. The declining frequency of web searches on "compact fluorescent" may indicate there is room to re-engage customers with messages on CFLs. The strong seasonality of interest in LEDs may point to an opportunity to piggyback a broader LED education campaign on holiday light LED messages.

When customers purchase CFLs or LEDs, but put them on the shelf instead of installing them, near-term program savings suffer. Programs could improve that situation by educating customers more to encourage them to take out functioning incandescents and replacing them with program bulbs, rather than waiting for an existing bulb to burn out. That will improve the baseline and perhaps improve the net-to-gross ratio. Pilot programs in ComEd and AEP Ohio are testing that theory. In ComEd's territory, 39 percent of CFL purchasers planned to remove an incandescent (Navigant 2013). In Ohio, 28 percent of purchasers were waiting to buy CFLs until installed lamps burned out (Navigant 2013b).

Savings Calculation. Finally, when considering adding LEDs to a residential lighting program, utilities should ensure that they are appropriately calculating per-bulb savings. We have found that some LED savings calculations do not properly take into account the fact that many LED bulbs provide more directional light than their incandescent or CFL equivalent. That means that comparing lumens has to be done carefully. We recommend that the delta Watts calculation should be made from a look-up table that includes bulb type. The current Energy Star draft specification for lamps[5] takes this approach. Using a lumen-based method that also relies on bulb shape provides a more robust means of establishing base Wattage equivalents across all bulb types, especially specialty CFLs and LEDs. Because lumen output is a measure of the total light produced in all directions from a source, bulbs such as reflectors (and LEDs in general) that focus light in a single direction require a different lumen mapping than a standard CFL (Navigant 2013).

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[5]http://www.energystar.gov/ia/partners/prod_development/new_specs/downloads/lamps/V1.0_Draft_2_Specification.pdf?4749-8e30

Evaluation

Residential lighting program evaluators also face a more difficult task than a few years ago as they examine decision-making and technology features in a complex, fast moving market.

Gross Savings. While there are not many variables in the equation for calculating gross program energy and demand savings from residential lighting (i.e., delta Watts * hours of use * installation rate), programs do not typically have just one bulb type and each bulb type requires unique values for each of these variables.

Baseline. EISA is changing the baseline by eliminating standard incandescent bulbs that used to form the baseline. EISA first affected 100 Watt incandescents as they had to meet their new standard in January 2012. However, bulbs manufactured before that date could continue to be sold. That meant that some customers continued to have the choice of buying non-compliant bulbs well into 2012. In that case, what is the baseline? The same issue arose with the 75 Watt standard that came into effect at the beginning of 2013. In Illinois, program years start June 1 and the statewide Technical Reference Manual requires using the EISA standard for the baseline at the beginning of each program year. Thus it essentially allows six months for the existing inventory to be depleted to the point where the baseline should shift. The 2012 evaluation of the AEP Ohio program used results from a shelf survey to calculate the percent of 100 W incandescents that could still be considered baseline.

Incandescents, CFLs, and LEDs come in a variety of shapes and produce a variety of lumens of output. Calculating the change in Watts from the inefficient baseline to the program-supported bulb is best done with a lookup table that maps bulb types and sizes (in lumens) to their baseline Wattage. The new ENERGY STAR draft specification for lamps[6] includes such a mapping. Because lumen output is a measure of the total light produced in all directions from a source, bulbs such as reflectors (and LEDs in general) that focus light in a single direction require a different lumen mapping than a standard CFL. We also recommend working with the program implementation team to ensure that bulb type and lumens are recorded in the program tracking system.

Installation Rate. CLFs and LEDs are unlike most other program supported measures in that the customer may buy more bulbs than they currently need and place the rest in storage. When are the savings from those bulbs in storage counted? The technical reality is that electricity is only saved when those bulbs are installed. That implies carrying over savings from one year to the next as bulbs in storage make their way into lamps. In Illinois, Ohio, and California, at least, policy calls for counting savings when the bulbs are installed. For ComEd, evaluation research supported a 33.3 percent installation rate in subsequent years meaning all bulbs are eventually assumed installed. California[7] and Ohio (Navigant 2013b) assume 99 percent of the bulbs are installed over three years. As a practical matter, though, since we can assume (and we have evidence to support it) that almost all bulbs get installed eventually, is it worth the bother to carry the savings forward? That would be a question for the policy makers.

Net Savings. Many residential lighting programs are upstream buy-down programs where the program pays manufacturers or retailers reduce the retail price of the bulbs. In those cases, the program does not know who the participants are. They deal with the market actors up stream and never see the end users. How can the evaluation find those participants to ask questions needed for the evaluation? Navigant's evaluation teams have tried a number of approaches[8] and have come to the conclusion that in-store intercepts were the best route.

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[6] http://www.energystar.gov/ia/partners/prod_development/new_specs/downloads/lamps/V1.0_Draft_2_Specification.pdf?4749-8e30

[7] KEMA. 2010 "Final Evaluation Report: Upstream Lighting Program" CALMAC ID CPU 0015.01. Retrieved from: http://www.calmac.org/publications/FinalUpstreamLightingEvaluationReport%5FVol1%5FCALMAC%5F3%2Epdf

[8] For ComEd, Navigant tried 1. Customer Self-Reported NTGR via a general population telephone survey and in-store intercept participant surveys, 2. Supplier Self-Reported NTGR (via in-depth interviews with lighting manufacturers and

Process Evaluation. Process evaluation is bedeviled by the problem mentioned above – knowing who the participants are and there, too, in-store intercepts seem the most viable, although expensive, approach to collecting process data. Three things are worth watching closely in process evaluations over the coming years: First, what do program participants really know about their lighting choices? Do they understand the distinction between the various choices? Has the energy efficiency program helped them navigate through the confusion? Second, do customers understand lumens? Is that becoming a relevant construct in their purchase decision? Is anything besides Watts entering their decision? Third, given the concern that corners might be cut to produce less expensive LEDs, program evaluations should watch for trends in satisfaction with LEDs over time and by type and manufacturer to provide warning, if need be, of potential dissatisfaction driven by the technology and its features.

Summary and Conclusions

Utility energy efficiency programs have successfully spurred substantial energy savings through residential lighting energy efficiency programs over the past few years. However, they face significant challenges in the coming years and program managers must be prepared to adjust to new realities if their programs are to continue to be relevant. The residential lighting market has seen significant changes in the past few years and is due to see more in the coming years as LEDs start to make major inroads. These changes and the EISA standards have significantly narrowed the field of play for residential program energy savings but there remains much potential for actively helping the market continue to evolve.

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