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Impact and Process Evaluation of the 2016 Illinois Power Agency Residential Lighting Program

Final

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CADMUS

NAVIGANT

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1. Executive Summary

The goal of the Illinois Power Agency (IPA) Residential Lighting Program is the eventual transformation of the residential lighting market in Ameren Illinois Company (AIC) territory. The objective of the program is to increase residential customers' awareness and use of ENERGY STAR® (ES) lighting products by providing discounts and by undertaking marketing and outreach efforts at participating retailers. The discounts offered by the program and its retail and manufacturing partners bring the cost of ES lighting closer to that of less-efficient options. They encourage customers who are reluctant to pay full price for ES lighting to choose energy-efficient over standard lighting. During its 9 years, the program has discounted 27,654,662 energy-efficient light bulbs and fixtures. The Residential Lighting Program is implemented by CLEAResult and Energy Federation, Incorporated (EFI).

This report presents the results of Opinion Dynamics's evaluation of the Residential Lighting Program during its ninth year of operation (Program Year 9 [PY9]), which ran from June 2016 to May 2017.

Program Impacts

The Residential Lighting program completed its ninth successful year by providing discounts for 2,982,605 CFLs and LEDs across a wide range of product types and participating retailers. Overall, in PY9, the program achieved 116,888 MWh in ex post gross energy savings and 14.21 MW in ex post gross summer peak demand savings. These savings are based on the bulbs sold and installed in PY9 as well as bulbs sold in previous program years (namely PY7 and PY8) but not installed until PY9. The carryover savings method outlined in the Illinois Statewide Technical Reference Manual for Energy Efficiency Version 5.0 (IL-TRM V5.0) spreads program savings across the three years that customers take to install all the bulbs that they purchase.

To arrive at the ex post net savings, we applied NTGRs approved by the Illinois Stakeholder Advisory Group (SAG) for each program year to the sales made in that year. The program realized 68,075 MWh in ex post net energy savings and 8.29 MW in ex post net summer peak demand savings.

Program implementers track progress toward their net energy savings goals using per-unit values for each product type discounted through the program. We applied these per-unit values to bulb quantities in the sales data extract to represent ex ante gross savings. Using those savings as the denominator and ex post gross savings as the numerator, we calculated gross realization rate of 1.30. The program did not provide gross or net per-unit summer peak demand values; therefore, it was not possible for us to calculate gross and net demand realization rates as part of this evaluation.

Table 1 summarizes both gross and net impacts of the program.

Table 1. PY9 Residential Lighting Program Gross and Net Impacts

	Ex Ante Gross	Gross Realization Rate	Ex Post Gross	Net-to-Gross Ratio (NTGR)	Ex Post Net
Energy Savings (MWh)					
Total MWh	89,815	130%	116,888	0.63/0.58/0.60[a] 0.63/0.73[b] 0.47[c]	68,075
Demand Savings (MW)					
Total MW	--	--	14.21	0.63/0.58/0.60[a] 0.63/0.73[b] 0.47[c]	8.29

Note: Program staff provided only ex ante energy savings.
[a] NTGR = 0.63 for CFLs, 0.58 for omnidirectional LEDs, and 0.60 for specialty LEDs for PY9 purchases installed in PY9
[b] NTG = 0.63 for CFLs and 0.73 for LEDs for PY8 purchases installed in PY9.
[c] NTGR = 0.47 for all PY7 purchases installed in PY9.

Key Findings and Recommendations

The Residential Lighting Program ran smoothly in PY9, exceeding all of its goals for bulb sales and energy savings even though total bulb sales decreased by 16% from PY8. Program sales in PY9 shifted away dramatically from CFLs to LEDs. In PY9, 74% of all program sales were LEDs as compared to just 20% in PY8. The majority of program bulb sales were omnidirectional LEDs (62%), followed by standard CFLs (26%). Specialty LEDs represented a small portion of the program sales (12%).

Based on the results of the PY9 Residential Lighting Evaluation, the evaluation team offer the following key findings and recommendations for the program moving forward:

- **Key Finding #1:** The transformation of the lighting market in the AIC service territory continued at an accelerated pace with LEDs accounting for nearly all gains. Based on the results from the in-home lighting studies that Opinion Dynamics has conducted for AIC periodically, only 3% of AIC customers were using LEDs in 2012 compared to 50% in 2016. The average AIC home had LEDs in less than 1% of its light sockets in 2012 and now has them in 10%. The increase in LED saturation contributed to the overall increase in energy efficient (EE) lighting saturation rates of 49% in 2016, up from 38% in 2012. EE bulb usage is still highly varied across AIC households. In 2012, most AIC households had few EE bulbs in use whereas in 2016, an AIC household was equally likely to have few, some, or a lot of EE bulbs. In the past, the typical customer who was purchasing lighting at a retailer most likely had just a few or some EE bulbs. Today, the typical customer is equally likely for most of their bulbs to be EE as they are to be non-EE. Program opportunities continue to exist among certain customer segments, namely, older customers (55 years and older). EE lighting saturation in the homes of those customers is significantly lower than in the homes of their respective counterparts (45% vs. 50% for the 35-54 age group and 55% for the 18-34 age group).
  - **Recommendation:** With this EE bulb usage pattern, it is more challenging for the Residential Lighting Program to continue to impact the market with an upstream program design. With an upstream delivery model, the program will end up discounting the lighting purchases of many customers who already have high EE bulb saturation and would likely purchase them without a discount. The program should consider modifications to its upstream program design to increase the likelihood that it is reaching customers who have lower EE bulb saturation and who need the discount to encourage more EE bulb purchases. An online store could be an effective option as AIC could target program marketing to just the regions and customers that lag in EE bulb use.

- **Key Finding #2:** EE bulb saturation in reflector and specialty sockets has increased since 2014, but opportunity remains as it continues to be much lower than that of standard sockets. Of AIC homes with reflector sockets, one-third of those sockets (34%) have an EE bulb installed. Sockets that require another type of specialty bulb have even lower saturation; only 16% of specialty sockets have an EE bulb installed. LEDs are the new bulb of choice for these sockets. The increase in saturation between 2014 and 2016 is entirely due to LEDs. Reflectors sockets have more LEDs than CFLs, and specialty sockets have an equal number of the two bulb types. However, the most common technology installed in both of these socket types continues to be incandescents.
  - **Recommendation:** The program should shift its focus from standard LEDs to all types of specialty LEDs. Within the specialty category, reflector LEDs are gaining traction and the program should continue supporting these products. The program should greatly increase the number and type of other specialty products it supports as there has been little progress in this area.
- **Key Finding #3:** Customer knowledge of different lighting technologies is strong, and LEDs are the preferred bulb technology for most customers. As part of the consumer preference survey, we asked respondents to rate each lighting technology on seven different attributes, including cost, safety, and energy use. Customers understand that LEDs are the most energy efficient, best for the environment, and newest or most cutting-edge technology, and that CFLs are the next best option in these areas. The discrete choice survey that takes customers through a hypothetical shopping exercise revealed that AIC customers are generally not very price sensitive, especially when it comes to standard light bulbs. The analysis of the relative importance of the key light bulb attributes, such as price, technology, life, color, annual energy cost, and a presence of the ES label, shows that customers place greater importance on technology than price when it comes to standard products. Price matters more with reflectors and is the most important attribute relative to other attributes, followed by bulb life and technology. For both product types, customers are willing to pay more for ES LEDs suggesting they see the value that ES certification provides.
  - **Recommendation:** The residential lighting market appears to be to transforming, particularly for standard products. These changes suggest diminishing returns from future Residential Lighting program interventions. The program should consider shifting from a large scale upstream program to a targeted approach focusing on specialty products at the retail level and an online store that could make use of more targeted marketing. The program should monitor federal rulemaking and any other policy decisions, especially surrounding ESIA 2020, along with retailer and manufacturer behaviors in terms of manufacturing practices and shelf stocking trends to optimally scale down and ultimately end the program when less efficient lighting products disappear entirely from the market.

2. Program Summary and Evaluation Objectives

2.1 Program Summary

The Illinois Power Agency (IPA) Residential Lighting Program aims to transform the residential lighting market in Ameren Illinois (AIC) territory by increasing customers' awareness and use of ENERGY STAR® (ES) lighting. The program employs marketing and outreach efforts at participating retailers and community events and on the AIC website. It also partners with retailers and lighting manufacturers to sell ES lighting at a discount to bring the cost closer to that of less-efficient lighting options. These discounts encourage customers who are reluctant to pay full price for ES lighting to choose energy-efficient over standard lighting. Most products are sold at participating retailers throughout the AIC territory and include ES CFLs and LEDs.

Launched in August 2008, the program is implemented by CLEAResult and Energy Federation, Incorporated (EFI). During the program's nine years of operation, it has discounted 27,654,662 energy-efficient light bulbs and fixtures. This evaluation reviews the program's performance in PY9, which began in June 2016 and ended in May 2017.

2.2 Evaluation Objectives

The residential lighting market has been changing rapidly, with LED products becoming a dominant technology on store shelves, ES standards for LEDs becoming more relaxed[1], and LED prices, particularly for standard products, dropping dramatically. Our PY8 evaluation research showed that LEDs were the most common product on the retailer shelves and that more customers purchased LEDs than any other type of lighting technology. However, this research also showed that the market for LED specialty products was lagging behind that of standard bulbs with low-cost, less-efficient specialty bulbs still widely available on store shelves. With the rapidly changing marketplace and increasing adoption of LEDs, it is of critical importance to understand the market conditions in which the Residential Lighting program operates and identify areas of greatest impact in terms of program interventions. As such, the central objectives of the PY9 evaluation were to assess the performance of the Residential Lighting Program, the current state of the lighting market in AIC territory, and the impact of the program on that market, as well as to provide information to help the program determine where future efforts will have the most impact.

We designed the tasks to answer the following **impact-related** research questions:

1. What were the estimated gross energy and demand savings from this program?
2. What were the estimated net energy and demand savings from this program?
3. What are the average daily hours of use (HOU) and coincidence factors for LEDs?

[1] ES 2.0 Standards were effective January, 2017.
https://www.energystar.gov/sites/default/files/Lamps%20Version%202.0%20Updated%20Spec.pdf

Our evaluation also addressed the following **process-related** research questions:

1. Did the program change its design in PY9? If so, how and why and were those changes advantageous?
2. Was program implementation effective and smooth?
3. What was the format of customer outreach? How often did the outreach occur?
4. In what areas could the program improve to increase its overall effectiveness? What could the program do to help customers understand energy-efficient lighting options and how to save more energy?

A large portion of our evaluation research focused on the assessment of the residential lighting market, namely on the following research questions:

1. What is the penetration and saturation of lighting technologies by bulb type and room type? Does efficient lighting saturation lag behind for some uses compared to others?
2. How has the penetration and saturation of efficient lighting technologies changed over time in AIC territory? Does the degree of change vary by bulb type and room type?
3. What is the profile of AIC customers whose homes have high efficient lighting saturation rates compared to those whose homes do not? Has that profile changed in the past few years? Is the program reaching new users of energy-efficient lighting products?
4. What is customer level of knowledge and perceptions of the various lighting technologies?
5. What lighting attributes do customers consider when making lighting purchases? What are the barriers to purchasing efficient lighting? What is the relative impact of price, as compared to the other attributes, in customer lighting purchase decisions? How do energy efficient bulb sales change with changes in price? How can the program market efficient lighting to address the barriers? What is the anticipated maximum adoption of efficient lighting?

3. Evaluation Approach

PY9 evaluation activities included a range of data collection and analytical tasks. Table 2 summarizes the evaluation tasks that we conducted for PY9. Following the table, we detail our approach to each task.

Table 2. Summary of IPA Residential Lighting Program Evaluation Activities for PY9

Activity	PY9 Impact	PY9 Process	Forward Looking	Details
Program Staff In-Depth Interviews		✓	✓	Conducted an interview with program staff to gain detailed information on the step-by-step operational conditions and implementation efforts to gain an understanding of program design and delivery.
Program Data Review	✓			Verified program-reported savings.
Program Materials Review		✓		Reviewed program implementation plan and marketing and outreach materials.
Program Impact Analysis	✓			Calculate gross and net impacts using the IL-TRM V5.0 and SAG-approved NTGR values for PY9.
Statewide In-Home Lighting Inventory and Lighting Logger Study		✓	✓	Completed 146 lighting audits with AIC customers as part of a broader statewide study (total 288 site visits completed statewide). Collected information on the quantity and type of lighting in use and in storage in customer's homes. Deployed light loggers in a subset of 138 lighting audit homes statewide and 67 for AIC specifically. Collected lighting usage data to estimate HOU and coincidence factors.
Consumer Preference Study		✓	✓	Conducted a conjoint survey with 391 AIC customers. Used the results of the survey to assess customer preferences for different lighting features and to predict future lighting purchase behavior.

3.1.1 Program Staff In-Depth Interviews

We conducted a joint interview in August 2017 with the AIC staff member overseeing the program and CLEAResult staff responsible for implementing the program. We used structured interview questions to guide the interview in which we asked staff about their roles and responsibilities, program goals, marketing, data management, and quality assurance practices used in PY9.

3.1.2 Review of Program Data and Materials

The evaluation team conducted an extensive review of all available program data and materials, including marketing materials, field reports, and tracking databases.

3.1.3 In-Home Lighting Study and Consumer Preference Study

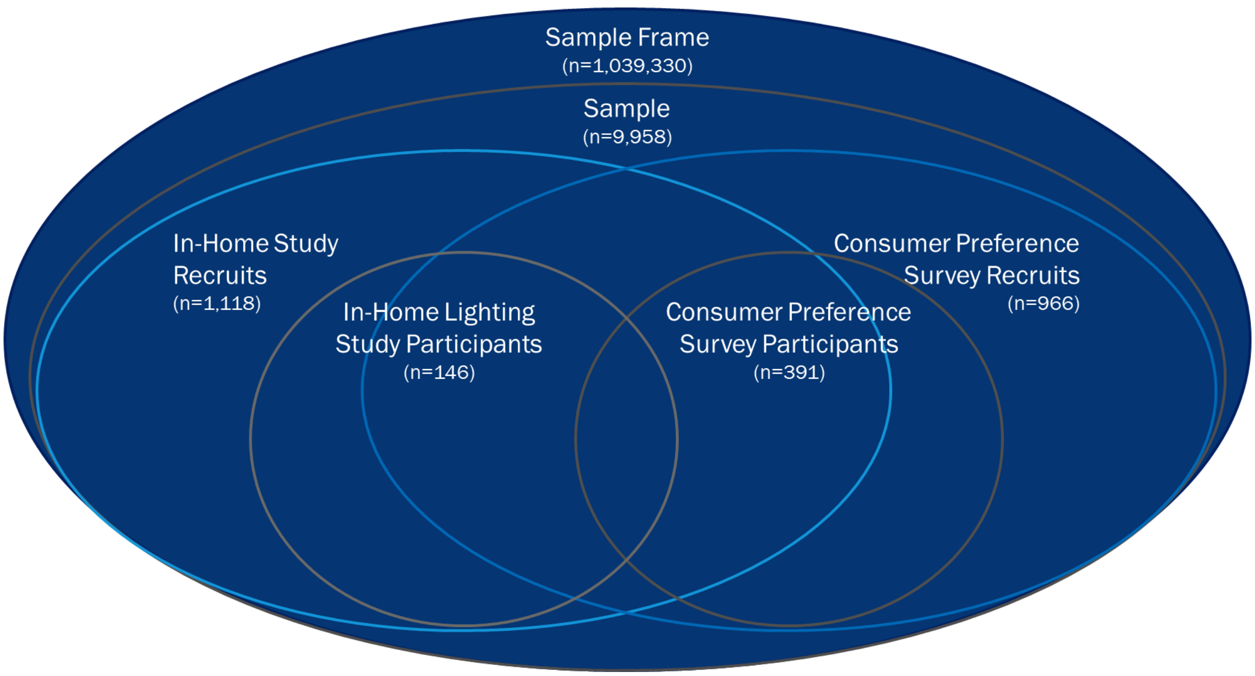
Overview of Approach

Opinion Dynamics completed a lighting inventory and logger study with a representative sample of AIC residential customers. This study was a part of a larger statewide research effort aimed at developing estimates of HOU and coincidence factors for LEDs. Other goals of the study include an analysis of penetration and saturation rates of the various lighting technologies and exploring lighting storage and installation patterns.

Along with the in-home study, we also completed a statewide discrete choice survey to understand consumer lighting preferences. To achieve fielding efficiencies, we used a single sample to recruit participants for this and the in-home study.

Figure 1 illustrates AIC-specific final sample sizes of the different data collection efforts and the relationship between them. From AIC's 1,039,330 residential electric customers, we drew a simple random sample of just under 10,000 customers. Slightly over 1,100 customers completed the recruitment survey *and* agreed to participate in the in-home study. From this group, we scheduled and completed in-home lighting inventories with 146 customers.[2] We recruited approximately 1,000 customers to participate in the lighting preference study. In spring of 2017, we provided the survey link to these recruits, and 391 of them subsequently completed the consumer preference survey.

Figure 1. Visualization of Data Collection Effort Sample Structure



For the larger statewide HOU study, we logged LEDs in 138 AIC and ComEd homes (67 were AIC homes). We will provide the results of this study in a separate deliverable.

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[2] We over-recruited participants because customers can change their minds when we call to schedule the in-home visit. It also may not be logistically possible to schedule visits with customers during the time the field team is in their area. Though we had intended to recruit more customers than we would include in the study, we had a higher response rate to the recruitment survey than we expected and ended up with a much greater number of recruits. We compared the observable characteristics of those that received an in-home audit to those that were recruited but ultimately did not participate in the study. We found no statistically significant differences between these two groups across a number of observable characteristics, including household type, house size, the total number of rooms, the total number of household members, the proportion of retirees, education levels, and household income.

Fielding Process and Timelines

We recruited customers to participate in the study by mailing them a letter that explained the study and encouraged them to complete a short recruitment survey. The letters provided a URL for customers to take the survey online, but those without internet could call our survey center to complete the survey with an interviewer. The recruitment survey allowed us to identify, pre-qualify, and recruit customers into the in-home lighting study, consumer preference study, or both studies. All customers were eligible for the in-home lighting inventory and consumer preference survey. Table 3 displays the dates of key study tasks.

Table 3. Study Timeline

Study Task	Dates
Recruitment Survey Fielded	November 2016 – January 2017
In-Home Lighting Inventories	December 2016 – February 2017
Consumer Preference Survey Fielded	April 2017 – May 2017

To encourage study participation, we provided incentives for the different phases of the project. Customers who participated in the in-home study received a $75 Visa gift card at the time of the lighting inventory. Customers who completed the lighting preference study were entered into a drawing to receive one of two $250 Visa gift cards.

Post-Stratification Weighting

We compared the participants in the in-home lighting study and discrete choice study to the general population of AIC customers[3] across a range of demographics and household characteristics to assess non-response bias and determine the need for post-stratification weights. Our analysis revealed that, relative to the population, both the in-home lighting and consumer preference study participant samples had a higher percentage of homeowners and customers residing in single-family properties. Because owned and single-family homes have more and different types of lighting in use compared to rented and multi-family homes, the results could be biased. We can correct for this bias by constructing and applying post-stratification weights during the analysis. With home ownership and housing type being correlated to each other, adjusting for one parameter would automatically adjust the other. As a result, we developed post-stratification weights to align both studies' samples with the population on home ownership. To ensure that we can draw meaningful comparisons across years for the in-home lighting study, namely comparisons of the current study to the ones completed in 2016, 2014, and 2012, we weighted the previous years' data by home ownership as well.

Table 4 summarizes the post-stratification weights we applied to each study's participants.

[3] We obtained AIC population characteristics from the U.S. Census Bureau's 2010–2015 American Community Survey (ACS).

Table 4. In-Home Study Post-Stratification Weights

Home Ownership	2016 In-Home Study		2014 In-Home Study		2012 In-Home Study		Consumer Preference Survey	
	n	Weight	n	Weight	n	Weight	n	Weight
Own	107	0.95	133	1.14	153	1.04	310	0.88
Rent	37	1.14	82	0.77	73	0.91	77	1.47
Unknown	2	1.00	10	1.00	0	1.00	4	1.00

Source: Opinion Dynamics analysis.

In-Home Lighting Study Data Collection and Analytical Activities

During each home visit, the auditor recorded the quantity and type of lighting installed in the interior and exterior of each home. For each light socket, the auditor recorded the socket type (e.g., screw, pin, etc.), light switch control type (e.g., on/off, dimmer, etc.), bulb technology (e.g., CFL, LED), shape (e.g., A-lamp, reflector, globe, etc.), fixture type (e.g., table lamp, recessed ceiling fixture, etc.), and room type (e.g., bedroom, kitchen, etc.). The auditor also recorded information about all lighting found in storage but not in use. We collected information on all bulbs installed inside and outside of AIC homes. All results presented in this report are based on both interior and exterior bulbs unless otherwise noted.

Our analysis included descriptive statistics of the penetration and saturation rates by technology, room type, bulb type, and customer segment. We make comparisons of lighting penetration and saturation to in-home lighting inventories that the evaluation team conducted in 2010, 2012, and 2014 where appropriate. We also performed regression analysis to better understand the drivers of efficient bulb saturation. Finally, a distinct component of our analysis included developing estimates of in-service rates for efficient products based on the information on the installed bulbs and bulbs in storage.

Consumer Preference Study Data Collection and Analytical Activities

We designed and administered our consumer preference study as a discrete choice online survey. The discrete choice method relies on customer-stated preferences and utilizes a random experimental design to measure the trade-offs between various product attributes, both price and non-price. While this method relies on customer self-report, it is superior to directly asking customers what product attributes are most important to them and what they would be willing to pay for a specific product. By having respondents consider the attributes of competing products simultaneously and select a product they would purchase, we mimic the actual shopping experience. Customers' product selections "reveal" the true effect of each attribute on the customer purchase decision.

As part of the survey, we presented respondents with a series of lighting product options that differed on key attributes, including price (choice sets). The discrete choice design ensured random assignment of the various attributes to products in each choice set. For each choice set, we asked respondents to select the product that they would purchase, including an option to not purchase anything. Prior to showing customers the choice sets, we provided a series of instructions that noted that the product characteristics might differ from what they were used to seeing in stores and to make choices as if actually shopping for light bulbs. As part of the design, we restricted certain attributes to specific products in order to avoid unrealistic combinations. More specifically, we restricted the appearance of the ES logo to just CFLs and LEDs. Table 5 contains the range of products that we presented to respondents. Appendix E contains example screenshots from the discrete choice survey.

We deployed two distinct discrete choice modules: one for standard light bulbs and one for reflectors. At the outset of the survey, we asked respondents if they had recessed lighting in their homes. Those who did, were randomly assigned into either the reflector or the standard light bulb discrete choice module. Customers who did not have reflectors in their homes were assigned to the standard light bulb module. We did this to set up a more realistic decision-making environment for respondents (i.e., asking about lighting products that they have in their home) and to improve our ability to generalize our findings beyond the sample. For both the standard and reflector light bulbs, we varied product attributes 12 times and asked respondents what they would purchase each time.

Table 5. Product Attributes and Levels for Standard and Reflectors Bulb Modules

Attributes	Attribute Levels	
Standard Module		
Price	$0.60, $2.90, $5.20, $7.50, $9.80	None
Technology	CFL, LED, Incandescent	
Bulb life	1, 3, 5, 10, 15 and 25 years	
Annual energy cost	$1.00, $1.75, $5.00, and $7.25	
Light color	Warm/Soft White, Cool/Bright White, and Natural/Daylight	
ENERGY STAR rating	"ENERGY STAR rated" (only shown for CFLs and LEDs) or "Not ENERGY STAR rated"	
Reflector Module		
Price	$2.00, $6.00, $10.00, $14.00, $18.00	None
Technology	CFL, LED, Incandescent	
Bulb life	1, 3, 5, 10, 15 and 25 years	
Annual energy cost	$1.25, $2.00, $5.25, and $7.75	
Light color	Warm/Soft White, Cool/Bright White, and Natural/Daylight	
ENERGY STAR rating	"ENERGY STAR rated" (only shown for CFLs and LEDs) or "Not ENERGY STAR rated"	

We designed and fielded our survey using Sawtooth's SSI Web software and used Hierarchical Bayes (HB) modeling to estimate utilities for each of the attributes and develop price elasticities. To estimate market shares at various market scenarios and product configurations, we imported HB-modeled estimates into Sawtooth's market simulator software (Sawtooth Software Market Research Tools [SMRT]), enabling us to predict market shares under varying market conditions.

3.1.4 Impact Analysis

As part of the impact analysis, we estimated both gross and net impact savings from the program activity in PY9. This section details the approach and inputs used in the impact analysis.

Gross Impacts

The evaluation team calculated gross electric and demand savings for PY9 using the program-tracking database and applying algorithms and savings assumptions based on the Illinois Statewide Technical Reference Manual Version 5.0 (IL-TRM V5.0). Gross impact savings analysis included the calculation of carryover savings from the previous program years. Those are savings from the products purchased in the previous years but assumed to be installed in PY9.

The IL-TRM V5.0 outlines a carryover savings method to account for bulbs that are purchased and stored for later use. The method assumes that 2% of program bulbs will never be installed, but the remaining 98% will be installed within 3 years. As a result, PY9 savings come from bulbs *installed* in PY9 but that could have been *purchased* in PY7, PY8, or PY9.

Equation 1. Carryover Savings Formula – Energy Savings

$$\text{Realized PY9 Energy Savings} = \Delta\,\text{kWh} \times (\text{Units Purchased PY9 and Installed in PY9} + \text{Units Purchased PY8 and Installed in PY9} + \text{Units Purchased PY7 and Installed in PY9})$$

Equation 2. Carryover Savings Formula – Demand Savings

$$\text{Realized PY9 Demand Savings} = \Delta\,\text{kW} \times (\text{Units Purchased PY9 and Installed in PY9} + \text{Units Purchased PY8 and Installed in PY9} + \text{Units Purchased PY7 and Installed in PY9})$$

Per the IL-TRM V5.0, first-year in-service rate (ISR) varies by bulb type. We took those varying first-year ISRs into account when estimating carryover savings. Table 6 below provides an installation trajectory by bulb type

Table 6. Installation Rate Trajectory by Bulb Type

Bulb Type	First Year (YR1)	Second Year (YR2)	Third Year (YR3)	Final
Standard CFLs	73.2%	13.4%	11.4%	98.0%
Specialty CFLs	73.2%	13.4%	11.4%	98.0%
Omnidirectional LEDs	95.0%	1.6%	1.4%	98.0%
Specialty LEDs	95.0%	1.6%	1.4%	98.0%

Source: IL-TRM V5.0.

Equation 3 and Equation 4 below detail the algorithms used to calculate per bulb energy and demand savings from the program-discounted bulbs.

We estimated energy savings for each of the three years during which PY9 program bulbs are estimated to be installed. We applied the installation rate of the respective year as presented in Table 6 above.

The savings assumptions in the IL-TRM V5.0 vary depending on the customer and bulb type purchased. Based on the in-store customer intercept interviews completed as part of the PY8 evaluation, the evaluation team determined that 6% of program-discounted bulbs are installed in commercial spaces, which have greater HOU and different waste heat factors. The remaining 94% of program-discounted bulbs are installed in residential settings. To estimate energy savings, the evaluation team weighted the savings by the number of bulbs installed in residential homes and commercial spaces.

Due to the upstream nature of the program, AIC cannot limit the sales of program-discounted bulbs to AIC customers. At the same time, AIC customers can go to retailers in neighboring jurisdictions and purchase utility-discounted bulbs. Through our in-store customer research conducted in PY8, the evaluation team estimated that 13% of AIC-discounted bulbs were sold to non-AIC customers. Through secondary research that we conducted in PY7, the evaluation team estimated that AIC customers purchased and installed the equivalent

5% of AIC PY7 sales from other utility programs in Illinois, Indiana, and Missouri. Based on our estimates of both factors, we applied an overall leakage rate of 8% to gross.

Equation 3. First-Year Per Bulb Energy and Demand Savings Algorithm

$$Year\ 1\ \Delta\ kWh = \mathrm{LA} \times\ 0.94 \times \left[\frac{(Base\ Watt - Bulb\ Watt)}{1000} \times ISR_{res,yr1} \times HOU_{res} \times WHFe_{res}\right]$$

$$+ \mathrm{LA} \times 0.06 \times \left[\frac{(Base\ Watt - Bulb\ Watt)}{1000} \times ISR_{com,yr1} \times HOU_{com} \times WHFe_{com}\right]$$

$$Year\ 1\ \Delta\ kW = LA \times 0.94 \times \left[\frac{(Base\ Watt - Bulb\ Watt)}{1000} \times ISR_{res,yr1} \times WHFd_{res} \times CF_{res}\right] +$$

$$LA \times 0.06 \times \left[\frac{(Base\ Watt - Bulb\ Watt)}{1000} \times ISR_{com,yr1} \times WHFd_{com} \times CF_{com}\right]$$

Where:

$Year\ 1\ \Delta\ kWh$=Per-bulb energy savings from PY9 program bulbs installed in the first year

$Year\ 1\ \Delta\ kW$=Per-bulb summer peak demand savings from PY9 program bulbs installed in the first year

LA = Leakage adjustment equal to (1 − leakage rate) or (1 − %Leakage)

0.94 = Residential install rate

0.06 = Commercial install rate

$Base\ Watt$ = EISA-compliant base wattage

$Bulb\ Watt$ = Actual wattage of installed bulb

ISR = First year in-service rate

HOU = Hours of use

$WHFe$ = Waste heat factor for energy savings

$WHFd$ = Waste heat factor for demand savings

CF = Summer peak coincidence factor

Res = Residential values

Com = Commercial values

We provide more detail on the savings assumptions for each quantity in Appendix A.

Similarly, to calculate savings for PY9 purchases that will be installed during the next 2 years, we simply apply the in-service rate (ISR) for year 2 and year 3.

Equation 4. Future Years Per Bulb Energy and Demand Savings Algorithm

$$Year\ 2\ \Delta\ kWh = LA \times 0.94 \times \left[\frac{(Base\ Watt - Bulb\ Watt)}{1000} \times ISR_{res,yr2} \times HOU_{res} \times WHFe_{res}\right] +$$

$$LA \times 0.06 \times \left[\frac{(Base\ Watt - Bulb\ Watt)}{1000} \times ISR_{com,yr2} \times HOU_{com} \times WHFe_{com}\right]$$

$$Year\ 2\ \Delta\ kW = LA \times 0.94 \times \left[\frac{(Base\ Watt - Bulb\ Watt)}{1000} \times ISR_{res,yr2} \times WHFd_{res} \times CF_{res}\right] +$$

$$LA \times 0.06 \times \left[\frac{(Base\ Watt - Bulb\ Watt)}{1000} \times ISR_{com,yr2} \times WHFd_{com} \times CF_{com}\right]$$

$$Year\ 3\ \Delta\ kWh = LA \times 0.94 \times \left[\frac{(Base\ Watt - Bulb\ Watt)}{1000} \times ISR_{res,yr3} \times HOU_{res} \times WHFe_{res}\right] + LA \times 0.06 \times \left[\frac{(Base\ Watt - Bulb\ Watt)}{1000} \times ISR_{com,yr3} \times HOU_{com} \times WHFe_{com}\right]$$

$$Year\ 3\ \Delta\ kW = LA \times 0.94 \times \left[\frac{(Base\ Watt - Bulb\ Watt)}{1000} \times ISR_{res,yr3} \times WHFd_{res} \times CF_{res}\right] + LA \times 0.06 \times \left[\frac{(Base\ Watt - Bulb\ Watt)}{1000} \times ISR_{com,yr3} \times WHFd_{com} \times CF_{com}\right]$$

Where:

$Year\ 2\ \Delta\ kWh$=Per-bulb energy savings from PY9 program bulbs installed in the second year
$Year\ 2\ \Delta\ kW$=Per-bulb summer peak demand savings from PY9 program bulbs installed in the second year
$Year\ 3\ \Delta\ kWh$=Per-bulb energy savings from PY9 program bulbs installed in the third year
$Year\ 3\ \Delta\ kW$=Per-bulb summer peak demand savings from PY9 program bulbs installed in the third year
LA = Leakage adjustment equal to (1 − leakage rate) or (1 − %Leakage)
0.94 = Residential install rate
0.06 = Commercial install rate
$Base\ Watt$ = EISA-compliant base wattage
$Bulb\ Watt$ = Actual wattage of installed bulb
ISR = First year in-service rate
HOU = Hours of use
$WHFe$ = Waste heat factor for energy savings
$WHFd$ = Waste heat factor for demand savings
CF = Summer peak coincidence factor
Res = Residential values
Com = Commercial values

Net Impacts

The evaluation team applied net-to-gross ratios (NTGRs) approved by the Illinois SAG to PY9 program savings as well as the carryover savings. The PY9 CFL NTGR comes from in-store customer intercept interviews that we conducted for AIC as part of the PY6 evaluation. The PY9 LED NTGRs come from the in-store intercept interviews that we conducted for ComEd as part of its PY8 evaluation.[4] Note that consistent with the IL-TRM V5.0, when calculating carryover net savings, we applied the approved NTGRs for the year of purchase. Table 7 summarizes the NTGRs used in the net impact analysis.

Table 7. SAG-Approved NTGRs

<table>
<tr><th>Measure Type</th><th>PY9 Electric NTGR</th><th>PY8 Electric NTGR</th><th>PY7 Electric NTGR</th></tr>
<tr><td>Standard CFLs</td><td>0.63</td><td>0.63</td><td rowspan="4">0.47</td></tr>
<tr><td>Specialty CFLs</td><td>N/A</td><td>N/A</td></tr>
<tr><td>Omnidirectional LEDs</td><td>0.58</td><td rowspan="2">0.73</td></tr>
<tr><td>Specialty LEDs</td><td>0.60</td></tr>
</table>

Summary of Input Sources

Table 8 summarizes the data sources for key variables in the ex post gross and net energy and demand savings estimation.

Table 8. Summary of Ex Post Savings Assumptions and Sources

Parameter	Source of Savings Assumption
Program Sales	PY9 Sales Data
Base Watts	2016 IL-TRM 5.0
CFL Watts	PY9 Sales Data (Measure Descriptions)
Residential vs. Commercial Installations	PY8 In-Store Intercepts
Leakage Out	PY8 In-Store Intercepts
Leakage In	PY7 Residential Lighting Evaluation Analysis
HOU	2016 IL-TRM 5.0
Installation Rate	2016 IL-TRM 5.0
Waste Heat Energy Factor	2016 IL-TRM 5.0
Waste Heat Demand Factor	2016 IL-TRM 5.0
Summer Peak CF	2016 IL-TRM 5.0
NTGR	PY6 AIC In-Store Intercepts for CFLs PY8 ComEd In-Store Intercepts for LEDs

[4] Opinion Dynamics conducted in-store intercepts in PY8 and estimated an LED NTGR, but the research was completed after the deadline for use in the PY9 evaluation.

3.2 Sources and Mitigation of Error

Table 9 provides a summary of the possible sources of error associated with data collected for the Residential Lighting Program evaluation. We discuss each item in detail below.

Table 9. Possible Sources of Error

Research Task	Survey Error		Non-Survey Error
	Sampling	Non-Sampling	
Statewide In-Home Lighting Study	• Yes	• Measurement error • Non-response and self-selection bias	• Data processing error
Consumer Preference Study	• Yes		• Data processing error • Modeling error • Heteroskedasticity
Gross Savings Calculations	• N/A	• N/A	• Data processing error
Net Savings Calculations	• N/A	• N/A	• Data processing error

The evaluation team took a number of steps to mitigate potential sources of error throughout the planning and implementation of the PY9 evaluation.

Survey Error

- **Sampling Error**
  - The evaluation team designed the in-home audit sample to achieve 90% confidence and +/-10% relative precision. We completed site visits in the homes of 146 customers out of a population of AIC's 1,039,330 residential electric customers. At the 90% confidence level, we achieved a precision of +/- 7% assuming a coefficient of variation of 0.50. The actual precision of each survey question depends on the variance of the responses to each question.
  - We designed the consumer preferences sample to achieve 90% confidence and +/-10% relative precision. We surveyed 391 customers out of a population of 1,039,330 residential electric customers. At the 90% confidence level, we achieved a precision of +/- 4% assuming a coefficient of variation of 0.50. The actual precision of each survey question depends on the variance of the responses to each question.
- **Non-Sampling Error**
  - **Measurement Error:** We addressed the validity and reliability of customer survey and onsite data through multiple strategies. First, we relied on the experience of the evaluation team to create questions that, at face value, measure the idea or construct that they are intended to measure. We reviewed the questions to ensure that we did not ask double-barreled questions (i.e., questions that ask about two subjects, but with only one response) or loaded questions (i.e., questions that are slanted one way or another). We also checked the logical flow of the questions so as not to confuse respondents, which would decrease reliability. Key members of the evaluation team, as well as AIC and ICC staff, reviewed all survey instruments. As part of the onsite data collection specifically, we deployed a thorough training process to ensure accuracy and consistency of question interpretation and data entry.

- **Non-Response and Self-Selection Bias:** To ensure that we could generalize the in-home lighting study results based on a sample to the target population, we used incentives to encourage participation from all types of customers. We offered $75 Visa gift cards to each customer who qualified and participated in the study. Customers who participated in the consumer preferences study were entered into a drawing for one of two $250 Visa gift cards. Providing an incentive and encouragement to participate helps reduce the degree to which certain types of customers are more likely to "self-select" for participation, which would introduce non-response bias. Despite these efforts, we detected some slight systematic non-response bias in the results, which we corrected with post-stratification weights.

- **Data Processing Error:** The evaluation team addressed processing error by using established data cleaning and analysis quality control processes and procedures. Experienced project managers oversaw the work of analytic staff and conducted checks of their work to catch any data processing errors. We also had analytic code for many data cleaning and processing tasks that flag errors.

Non-Survey Error

- Data Processing Error
  - **Gross Savings Calculations:** We applied the IL-TRM V5.0 calculations to the sales data in the tracking database to calculate gross impacts. To minimize data processing error, a separate member of the evaluation team reviewed all calculations to verify accuracy.
  - **Net Savings Calculations:** We applied the prospective, PY9, SAG-approved NTGR to estimate net impacts of the program in PY9. To minimize data processing error, a separate member of the evaluation team reviewed all calculations to verify accuracy.
- Modeling error
  - For the statistical models used in the consumer preferences study, the evaluation team addressed modeling error in several ways. First, the use of a choice-based conjoint research design enabled us to produce unbiased estimates because product attribute levels are randomized across respondents. Second, to produce group-level estimates of attribute importance and price sensitivity, we used a hierarchical Bayes Regression model (Sawtooth Software Technical Paper, 2009), which leverages Markov Chain Monte Carlo simulations to ensure convergence on stable coefficient estimates.

4. Detailed Findings

The IPA Residential Lighting Program aims to transform the residential lighting market in AIC territory by increasing customers' awareness and use of ES lighting. The program employs marketing and outreach efforts at participating retailers and community events and on the AIC website. It also partners with retailers and lighting manufacturers to sell ES lighting at a discount in order to bring the cost closer to that of less-efficient lighting options. These discounts encourage customers who are reluctant to pay full price for ES lighting to choose energy-efficient over standard lighting. Most products are sold at participating retailers throughout AIC territory and include ES CFLs and LEDs.

Launched in August 2008, the program is implemented by CLEAResult and EFI. During the program's nine years of operation, it has discounted 27,654,662 energy-efficient light bulbs and fixtures. This evaluation reviews the program's performance in PY9, which began in June 2016 and ended in May 2017.

4.1 Process Findings

4.1.1 Program Design and Implementation

The Residential Lighting Program ran smoothly in PY9. As in prior years, the program met its goals in terms of energy savings, achieving 108% of the program's energy savings goal. The program's design and implementation were largely similar to PY8 and included discounts across a range of ES LED products at point-of-sale, marketing and educational efforts in-store and through other channels, and extensive training and retail support. The program continued to offer discounts on standard CFL products as well in PY9.

CLEAResult field representatives remained an integral part of program implementation. Seven field representatives provided support to participating retail stores across AIC territory in PY9. Representatives regularly visited their assigned retailers to ensure that products and promotional materials were displayed properly, to train store staff (e.g., sales associates, cashiers, managers), and to conduct in-store lighting demonstrations that educate customers. Field staff visited each retail location at least once a month, with the top-selling locations receiving weekly visits. The field representative supervisor reviewed staff work using quality assurance scorecards, and all retail visits were documented by the program implementer.

Due to the rapid change of the lighting market, the program shifted away from set budget allocations for specific bulb types to a more flexible process, where sales of specific bulb types were not constrained by pre-determined budget caps. This change allowed the program implementer to adjust program incentives based on market dynamics.

4.1.2 Program Data

The program-tracking data included all of the information necessary to calculate ex post savings using the method outlined in the IL-TRM V5.0. Program administrators track progress toward their net savings goals using per-unit values for each product type discounted through the program. The net per-unit values were used to set savings goals in the CLEAResult contract but may not reflect the per-unit savings that would result from application of the IL-TRM V5.0 savings assumptions.[5] As we show in the Section 4.2.4, the ex post net per-unit savings are slightly higher than the ex ante net savings.

4.1.3 Program Marketing, Outreach, and Training

Program marketing and outreach activities in PY9 were similar to those in the previous years, with program marketing focused on point-of purchase marketing and educational materials at participating retailers, retailer visits, and in-store demonstration events.

PY9 program materials featured a new design, which field representatives distributed to participating retailers over the course of PY9 (see Figure 2). Certain Home Depots and independent retailers featured large program elliptical displays at times during PY9.

Figure 2. Example of In-Store Marketing Collateral

Field representatives' visits to participating stores were among the key ways the program interacted with customers. During those visits, field representatives conducted customer outreach, trained store staff about the program, and adjusted program marketing and collateral. To ensure store visit quality, the senior field representative conducted follow-up visits to select stores over the course of PY9. Throughout PY9, program field representatives completed a total of 8,088 store visits, engaged a total of 4,219 customers and 12,159 retailer staff, an average of more than 350 customers and 1,000 employees per month.

In-store demonstrations were another way to educate customers about energy efficient lighting options. The demonstrations were held to coincide with the peak lighting sales season (September through May). During the demonstrations, field representatives discussed bulb features and details of the discount program and, in some cases, referred customers to the AIC website for more information about other energy efficiency programs for their home or business. Field representatives completed a total of 80 demonstrations during the peak sales period. In addition to the demonstrations, the program administered nine special events during the month of October, including trade-in opportunities for non-energy efficient bulbs.

[5] Program administrators also estimated savings using TRM assumptions for tracking purposes, but these values were not the official program savings values.

4.1.4 Lighting Usage

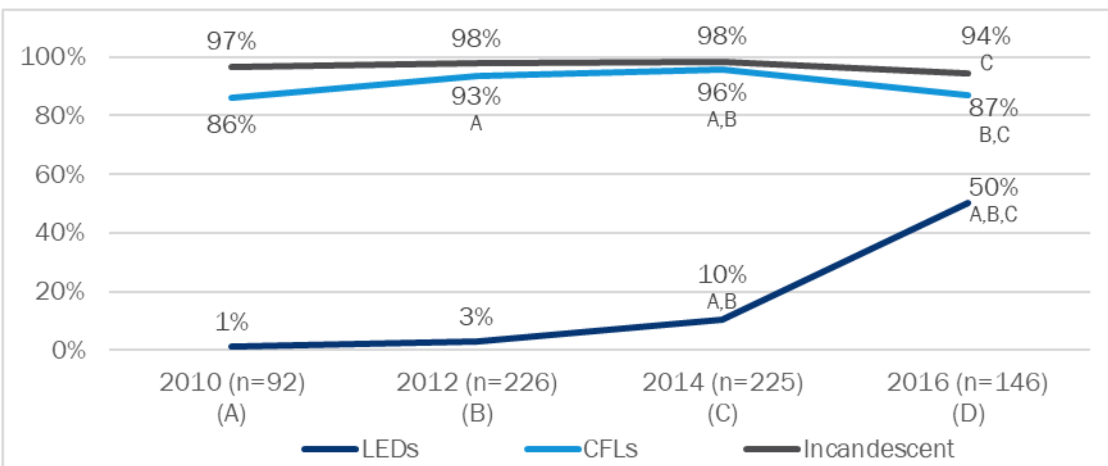
The results of the AIC customer lighting inventory study provide detailed information about how AIC customers are using lighting in their homes and long-term program effects. Overall, the results show that AIC customers are making increased use of energy efficient (EE) light bulbs. LEDs have become the preferred product and are responsible for the increased use of EE bulbs across all bulb types, but particularly in the reflector and specialty categories.

Lighting Penetration

The penetration of EE bulbs has been consistently high since 2010 when we conducted the first AIC in-home lighting study. However, there has been a dramatic increase in the use of LEDs since 2014. LED penetration (the percentage of homes with at least one LED installed) increased from 10% to 50% between 2014 and 2016. At the same time, fewer homes have at least one CFL installed dropping from 96% in 2014 to 87% in 2016. Combined, nearly all AIC customers (94%) had at least one CFL or LED installed in their homes in 2016.

Despite more AIC customers using LEDs, nearly all customers (94%) still have at least one incandescent bulb in use.[6] Given that most customers tend to replace bulbs when they burn out, it is not surprising that we found incandescent bulbs in most homes. Less efficient bulbs will likely remain in sockets that are not used that frequently as they are less likely to burn out and customers may feel that it does not make financial sense to replace working bulbs that are rarely used. While incandescent bulbs may not disappear entirely for some time, as we will see in the next section, their prevalence is declining. Figure 3 provides penetration rates by bulb type over the past several years.

Figure 3. Lighting Penetration Rates, 2010 – 2016



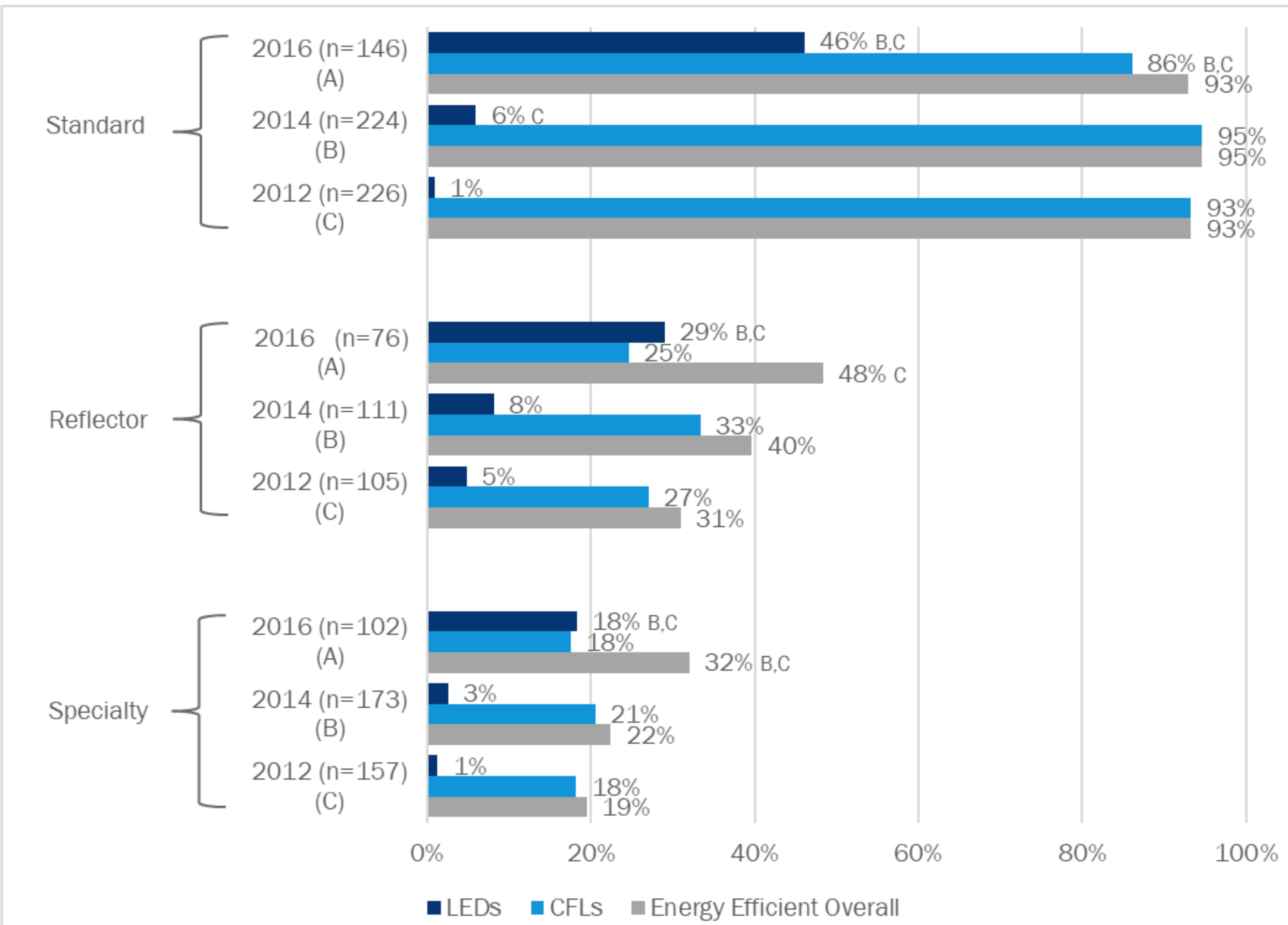
Note: Letter codes denote significant difference between years at the 0.1 alpha level.

[6] For this analysis, we combined traditional incandescent bulbs with EISA-compliant halogens. The bulbs look nearly identical so it is difficult to distinguish between the two technologies without removing many bulbs from their sockets during the audit, which we did not do for safety and time reasons. Therefore, separate results for incandescents and halogens would not be reliable. We refer to both bulb types as incandescents throughout this report.

Penetration by Bulb Type

EE bulb penetration varies by bulb type. All customers have light sockets that require a standard light bulb and nearly all have at least one standard EE bulb. While penetration of EE bulbs in reflector or specialty sockets has increased over time, it still lags standard sockets (see Figure 4).[7] For example, 48% of customers with reflector bulbs in their home have at least one EE reflector installed compared to 93% for standard bulbs. LEDs are the reason for the increase in EE reflector and specialty penetration. LED penetration has increased for both reflector and specialty sockets since 2014 and is now equal to or exceeds CFL penetration. Reflector and specialty CFL penetration has decreased slightly, though the decline is not statistically significant due to the smaller number of homes with these bulbs types.

Figure 4. Efficient Bulb Penetration by Bulb Type, 2012 – 2016



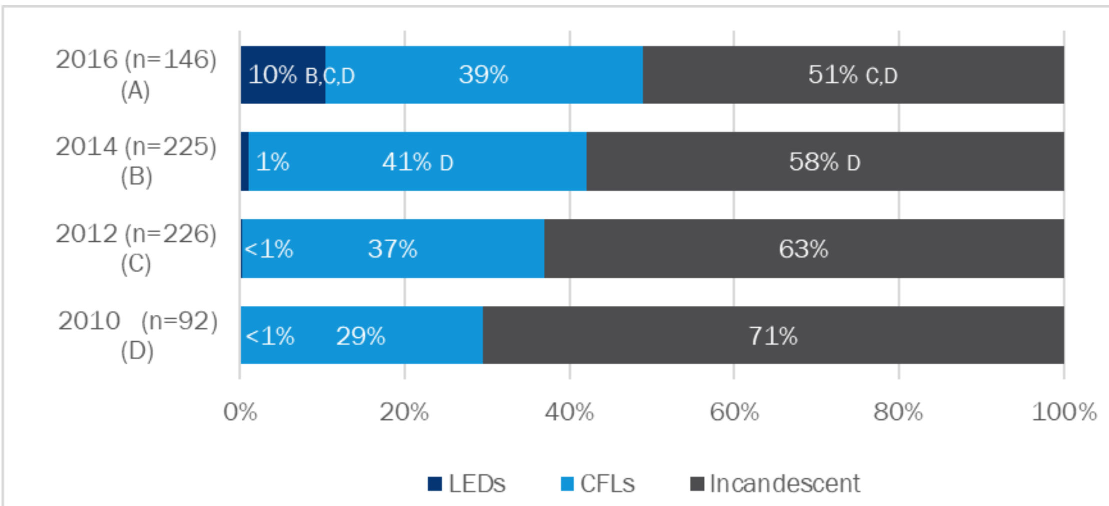
Note: Letter codes denote significant difference between years at the 0.1 alpha level.

[7] Standard bulbs are A-lamps and spirals if the bulb is a CFL. The Residential Lighting Program classifies all other bulbs as specialty bulbs, including reflectors. We report the results for reflectors separately from other specialty bulbs for this analysis because reflectors are the specialty bulb most frequently discounted through the residential lighting program. A specialty socket is one that had a specialty

Lighting Saturation

Use of EE light bulbs has increased dramatically since the first AIC lighting audit in 2010. In 2016, nearly half of the light sockets in the average AIC customer home (49%) contained an EE bulb compared to 29% in 2010. The recent growth in efficient bulb use between 2014 and 2016 is due entirely to the increased use of LEDs, though CFL saturation still exceeds LED saturation (39% compared to 10%). The average home had LEDs in only 1% of its light sockets in 2014 and now has them in 10%. Although CFL saturation in 2016 is not statistically different from 2014 (41% compared to 39%), as CFLs disappear from store shelves, this two percentage point drop in CFL saturation may represent the beginning of a decline in CFL use. Figure 5 provides saturation rates by bulb technology for the past several years.

Figure 5. Lighting Saturation Rates, 2010 – 2016

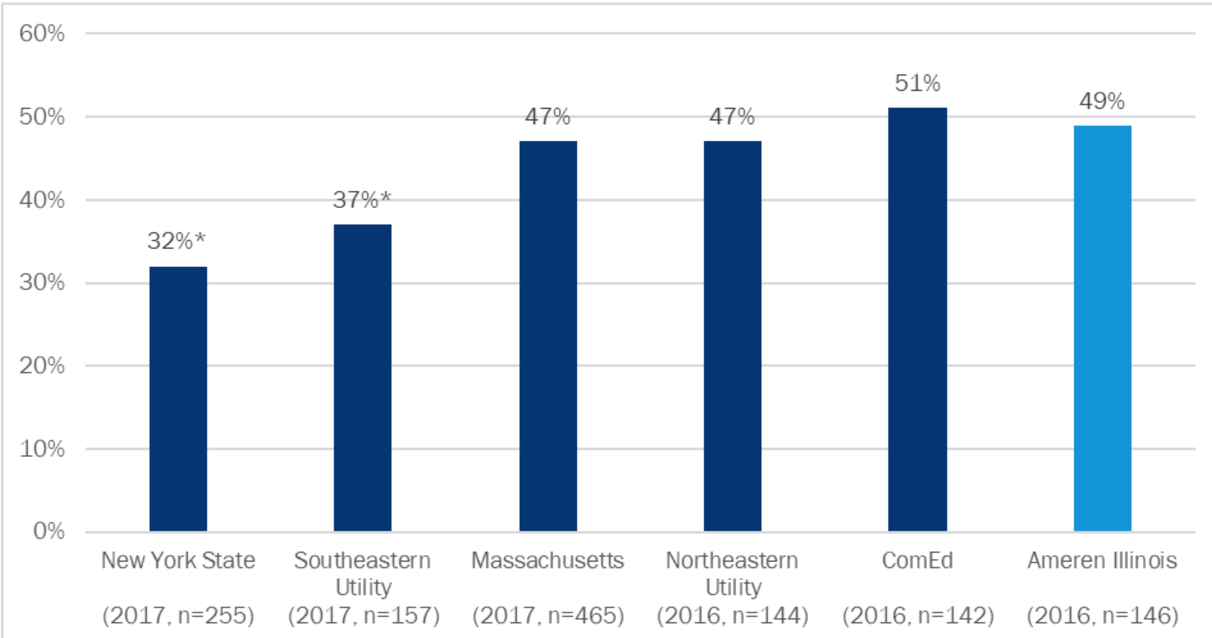


Note: Letter codes denote significant difference between years at the 0.1 alpha level.

In both 2012 and 2014, we compared EE bulb saturation rates in AIC territory to other jurisdictions and found the rates in AIC territory to be among the highest. We updated this analysis for 2016 and found that AIC's EE bulb saturation rate remains high relative to other programs, though most differences are not statistically significant. Figure 6 provides saturation rates of EE bulbs across various parts of the country.

bulb of any technology installed (i.e., incandescent, CFL, etc.). A standard socket is one that had a standard bulb of any technology installed. Although a resident could, in the future, install a standard bulb in a specialty socket and vice versa, our analysis assumes the resident has chosen the most appropriate bulb for the socket and will continue to use that same type of bulb.

Figure 6. Energy Efficient Bulb Saturation in Different Areas of the United States



Source: Home audits conducted by Opinion Dynamics and publicly available reports[8]
*Difference between AIC and utility is significant at the 0.1 alpha level.

Saturation by Socket and Room Type

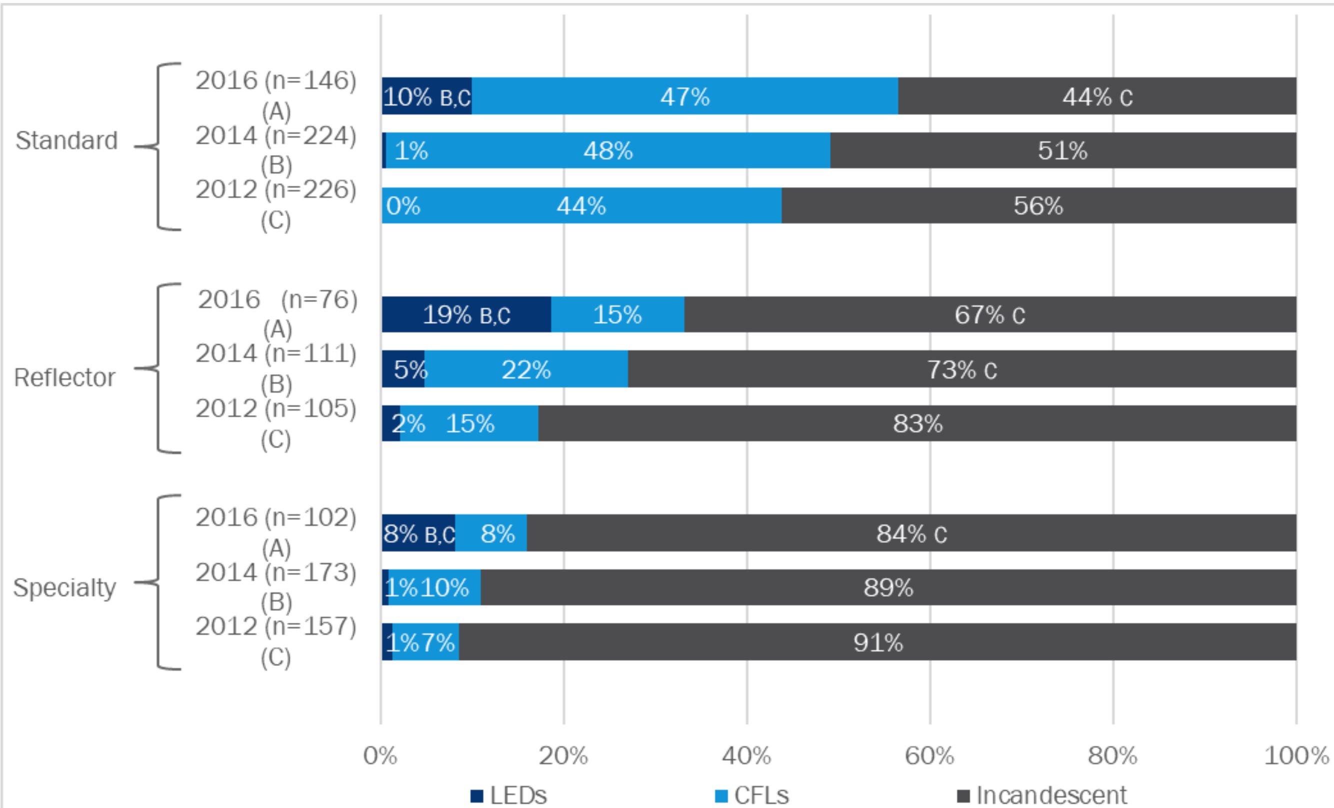
During its nine years, the Residential Lighting Program has provided incentives for standard, specialty, and reflector CFLs and LEDs, though the large majority of program-discounted bulbs have been standard bulbs. While the relative percentage of discounts for standard versus specialty/reflector bulbs has varied across the years, standard bulbs have never made up fewer than 80% of bulbs discounted through the program. This program emphasis has been appropriate since nearly three-quarters of light sockets in the typical AIC home are standard sockets (73% in 2016). Not surprisingly, we have consistently found that EE bulb saturation for standard bulbs has been much higher than that of specialty bulbs in our past lighting audit studies. Our 2016 results show a similar pattern (see Figure 7). The average home has an EE bulb installed in over half (57%) of its standard light sockets. LED saturation in standard sockets increased from 1% to 10% between 2014 and 2016, but there still are close to five times as many CFLs (47% saturation) installed compared to LEDs. CFLs are the most common standard bulb installed in AIC customer homes.

EE bulb saturation in reflector and specialty sockets has increased since 2014, but a lot of opportunity remains as it continues to be much lower than that of standard sockets. Of AIC homes with reflector sockets, one-third of those sockets (34%) have an EE bulb installed. Sockets that require another type of specialty bulb have even lower saturation; only 16% of specialty sockets have an EE bulb installed. LEDs are the new bulb of choice for these sockets. The increase in saturation of EE bulbs between 2014 and 2016 is entirely due to LEDs.

[8] Massachusetts and New York numbers are drawn from 2015-2016 Lighting Market Assessment, Consumer Survey, and On-Site Saturation Study. Submitted to the Electric and Gas Program Administrators of Massachusetts, August 8, 2016 by NMR Group.

Reflectors sockets have more LEDs than CFLs, and specialty sockets have an equal number of the two bulb types. However, the most common technology installed in both socket types continues to be incandescents.

Figure 7. Energy Efficient Bulb Saturation by Socket Type, 2012 – 2016

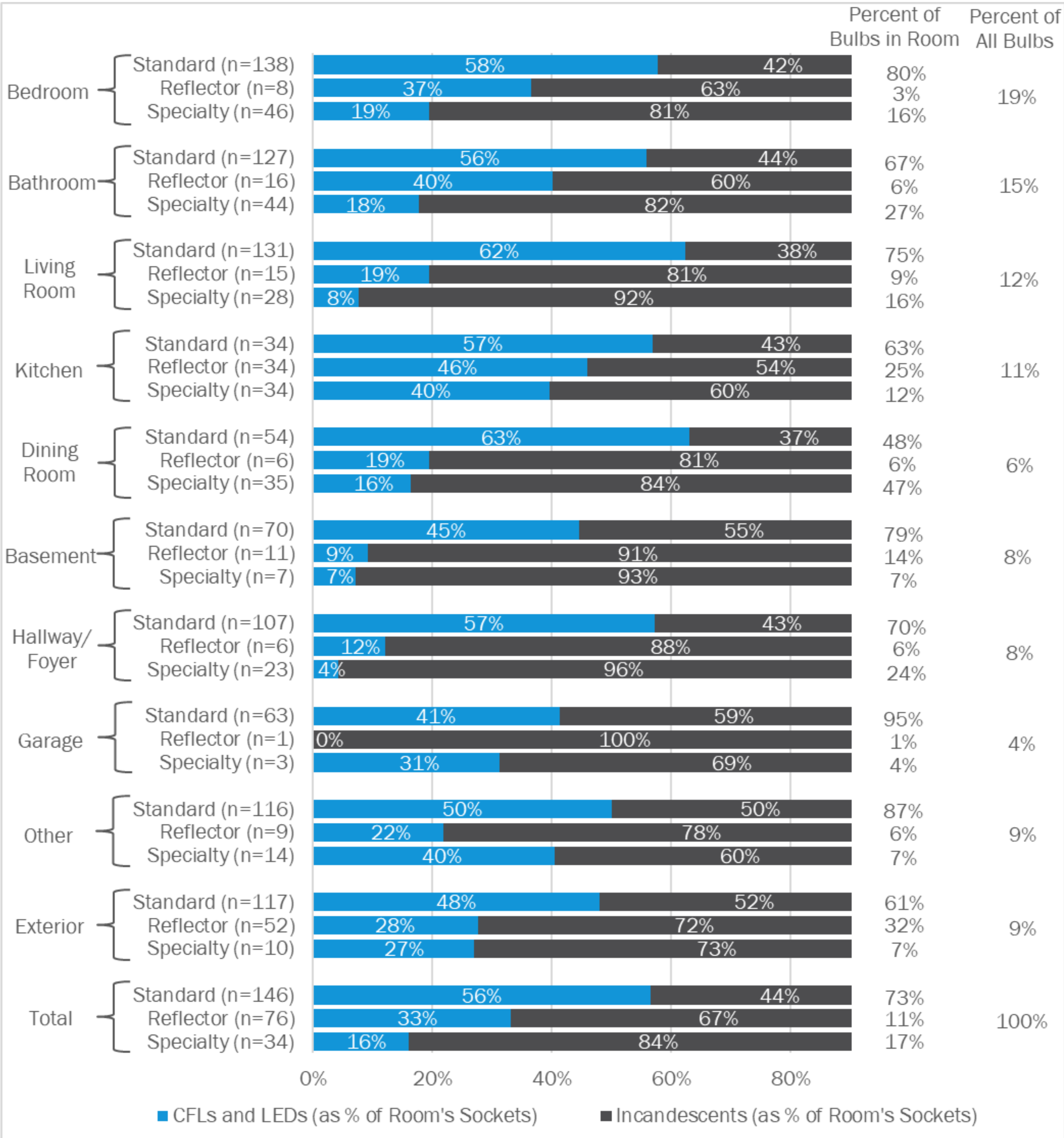


Note: Letter codes denote significant difference between years at the 0.1 alpha level.

AIC customers use different types of bulbs and technologies depending on the room type (see Figure 8). For example, kitchens are the most advanced room in terms of the lighting in use. Kitchens have a higher percentage of reflector bulbs compared to any other interior room and the highest EE reflector saturation rate. Customers also make use of more reflectors for their exterior lighting, but the EE saturation rate of these bulbs lags kitchens. Dining rooms and bathrooms have the highest percentage of specialty bulbs in use, but only a small percentage of these bulbs are EE. Customers are more likely to use standard bulbs in their bedrooms, living rooms, garages, and basements. Living rooms have the highest EE saturation rate followed closely by bedrooms. Most customers have yet to upgrade the standard bulbs in their basements and garages to EE bulbs.

Exterior lighting, dining rooms, and bathrooms represent some the remaining opportunities for the residential lighting program. Garages and basements may provide some opportunities as well, though these bulbs likely have lower HOU so the savings benefit would be lower. We will tie these results to the HOU of each room type in a separate deliverable that reports the HOU study results, which will help us assess whether customers are more likely to use EE bulbs in rooms that have the greatest HOU. We will provide revised recommendations based on the prevalence of different bulb types, EE saturation, and HOU in that report.

Figure 8. Energy Efficient Bulb Saturation by Socket and Room Type, 2012 – 2016



Saturation by Customer Segment

The evaluation team compared the distribution of EE bulb saturation rates from 2012 through 2016 to better understand the range of efficient bulb usage among AIC customers and how it has changed. EE usage remains highly varied across AIC households though, over time, we see the distribution shift from being skewed to the right where the tail of the distribution is on the right to a uniform distribution where the distribution is relatively flat (see Figure 9). In 2012, most AIC households had few EE bulbs in use whereas in 2016, an AIC household was equally likely to have few, some, or a lot of EE bulbs. With this EE bulb usage pattern, it is more challenging for the Residential Lighting Program to continue to impact the market with an upstream program design. In the past, the typical customer who was purchasing lighting at a retailer most likely had just a few or some EE bulbs. Today, the typical customer is equally likely for most of their bulbs to be EE as they are to be non-EE. With an upstream delivery model, the program will end up discounting the lighting purchases of many customers who already have high EE bulb saturation and would likely purchase them without a discount. The challenge going forward will be to identify and target customers who have lower EE bulb saturation and who need the discount to encourage more EE bulb purchases.

We compared EE bulb penetration and saturation across different demographic groups to help identify the types of customers that the program should target. We found few statistically significant differences due to the smaller sample sizes of subgroups. However, consistent with the study we conducted in 2014, it appears that homeowners, customers living in single family homes, better educated customers, and older customers have lower EE bulb saturation rates than their counterparts. We suspected that some of these differences might be due to differences in the home sizes and bulb types used by these different demographic groups. That is, owned homes tend to be larger than rented, multi-family homes, and owned homes tend to have more reflector and specialty sockets. We have seen that EE bulb saturation in these sockets lags standard sockets. As shown in Table 10, homes with more light sockets have lower EE bulb saturation rates than other homes. Homes with a greater percentage of sockets that require a reflector or specialty bulb also have lower EE bulb saturation.

To examine these differences even further, we ran a multivariate regression predicting EE bulb saturation by respondent demographics, the total number of light sockets in the home, and the percentage of light sockets that use a reflector or specialty bulb. The model results show that most demographic variables are not significantly related to EE bulb saturation. The one demographic variable that is significant is age, which has a negative association with EE bulb saturation rates, even when controlling for education, number of sockets, percentage of bulbs that are reflector or specialty, and home size. In addition, the number of light sockets is not significantly related to EE bulb saturation, but the percentage of reflector or specialty sockets is (i.e., the type of sockets in a home is a better predictor of EE bulb saturation than the number of sockets). In summary, households headed by older adults and that have a higher percentage of specialty light sockets have lower EE bulb saturation rates than other households.

Figure 9. Distribution of Energy Efficient Bulb Saturation, 2012 – 2016

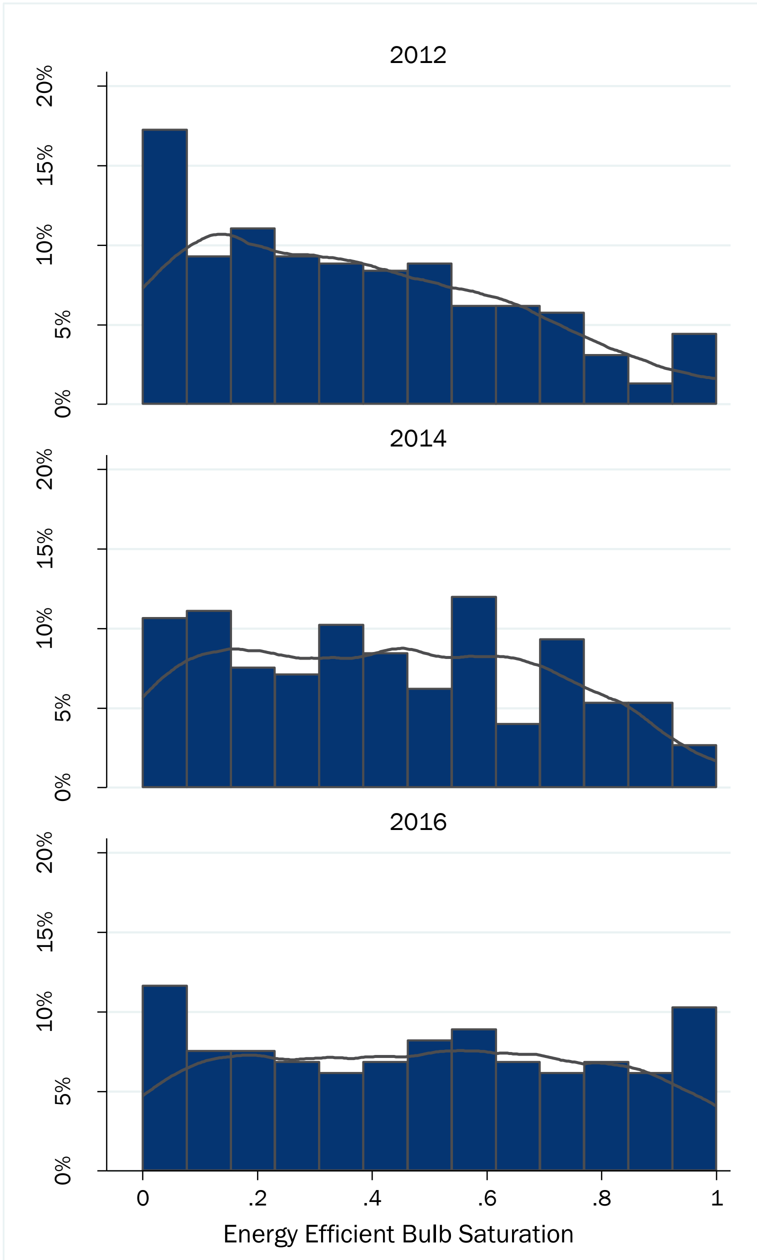


Table 10. EE Bulb Penetration and Saturation Rates by Select Demographic Categories

Demographic Characteristic	n	CFL/LED Penetration	CFL/LED Saturation
Home Type			
Single-family (A)	117	94%	46%
Multifamily (B)	10	89%	66%
Other/mobile (C)	19	95%	58%
Home Ownership			
Own (A)	107	95%	47%
Rent (B)	37	89%	53%
Annual Household Income			
Less than $50,000 (A)	82	94%	53%
$50,000 – less than $75,000 (B)	24	87%	40%
$75,000 or more (C)	37	97%	44%
Education			
High school or less (A)	41	94%	53%
Some college/technical/trade (B)	55	87% [C]	40%
College grad (or more) (C)	50	97%	44%
Age of Respondent			
18 – 34 years old (A)	28	89%	55%
35 – 54 years old (B)	43	95%	50%
55+ years old (C)	74	95%	45%
Employment			
Employed (A)	88	91%	50%
Unemployed (B)	6	100%	74%
Retired/not looking (C)	52	98%	45%
Square Footage			
Less than 1,000 square feet (A)	31	87% [C]	53%
1,001 - 2,000 square feet (B)	71	94%	50%
Greater than 2,000 square feet (C)	44	98%	43%
Total Bulb Count			
First Quartile (6 – 23 bulbs) (A)	38	87%	60%
Second Quartile (24 - 37 bulbs) (B)	36	97%	45%
Third Quartile (38 - 58 bulbs) (C)	36	95%	43%
Fourth Quartile (59 - 142 bulbs) (D)	36	97%	44%
Specialty Bulb Count			
First Quartile (0 - 2 bulbs) (A)	40	85% [B,D]	59% [D]
Second Quartile (3 - 8 bulbs) (B)	36	100% [C]	52%
Third Quartile (9 - 16 bulbs) (C)	34	91% [D]	48%
Fourth Quartile (17 - 80 bulbs) (D)	36	100%	34%

Note: Letter codes denote significant difference between subgroups at the 0.1 alpha level.

Lighting Controls

Although the Residential Lighting Program has only discounted light bulbs, lighting controls are another potential area for energy savings (see Table 11). We recorded the control type of each lighting switch inside AIC customer homes and found that simple “on/off” switches are the most common type of switch (93%) and that these switches control a large majority of bulbs (92%). Three-way switches are the next most common type of switch, followed by dimmable switches. Less than 1% of switches were occupancy or motion sensors.[9] These results suggest that lighting controls could be a source of savings for AIC in the future.

Table 11. Distribution of Control Types in 2016

Control Type	n	Percent of Homes	Percent of Switches	Percent of Bulbs
On-Off	146	100%	93%	92%
3-Way	39	26%	4%	5%
Dimmable	21	14%	1%	2%
Timer	19	13%	1%	1%
4-Way	3	2%	<1%	<1%
Motion/Occupancy Sensor	3	2%	<1%	<1%
Other	2	1%	<1%	<1%
Total	**146**	**100%**	**100%**	**100%**

LED Purchase and Installation Behavior

During the in-home audit, field technicians asked customers with LEDs installed several questions about their purchase and installation of those LEDs. LEDs are a new bulb technology for many customers. Nearly two-thirds of customers installed their first LEDs within the past year (64%).[10] Table 12 provides the number of survey participants who reported installing their first LED in each year.

Table 12. Distribution of Customers’ First LED Installations

First LED Installed	n	%
2013 or earlier	3	4%
2014	5	7%
2015	16	24%
2016-17	43	64%
Total	**67**	**100%**

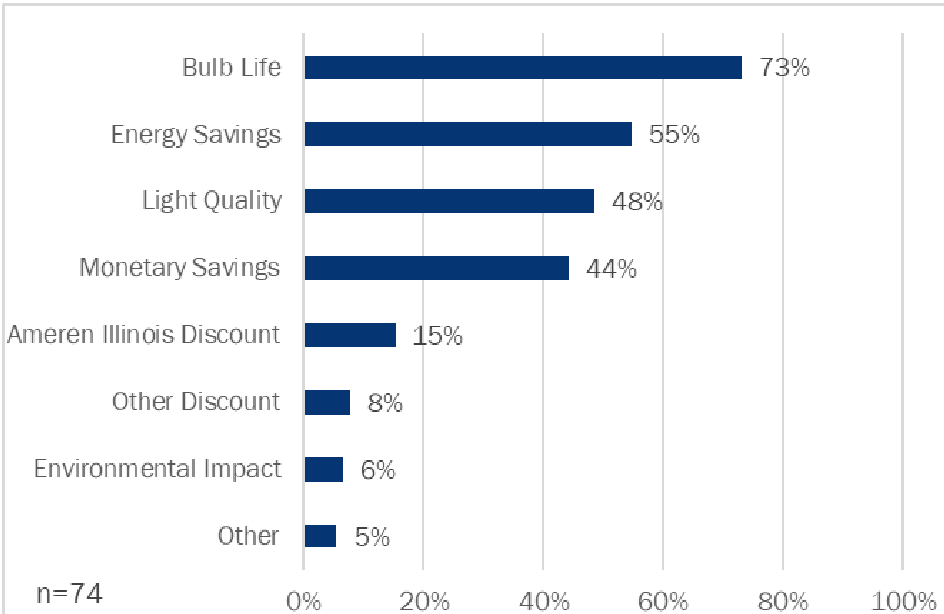
We asked customers why they purchased LEDs over another bulb technology. The top four reasons given were the longer bulb life (73%) followed by the energy savings (55%), light quality (48%), and monetary savings (44%).

[9] We did not record switch types for bulbs installed outside the homes so it is possible that a greater percentage of exterior bulbs are on switches with motion sensors.

[10] The audits were conducted between December 2016 and February 2017 so any response of 2016 or 2017 is roughly the past year.

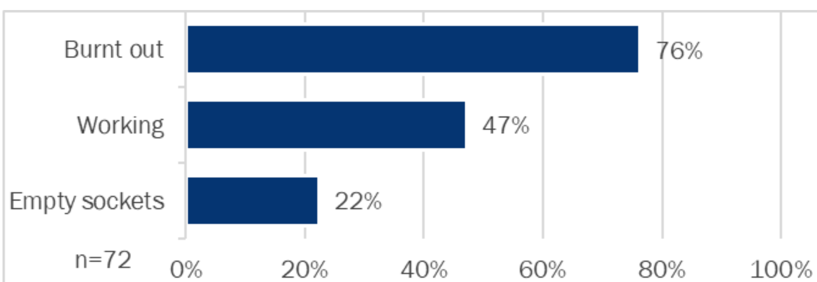
A smaller number of customers (15%) volunteered that the AIC discount caused them to purchase the LEDs (see Figure 10).

Figure 10. Reasons for Purchasing LEDs Over Another Bulb Technology



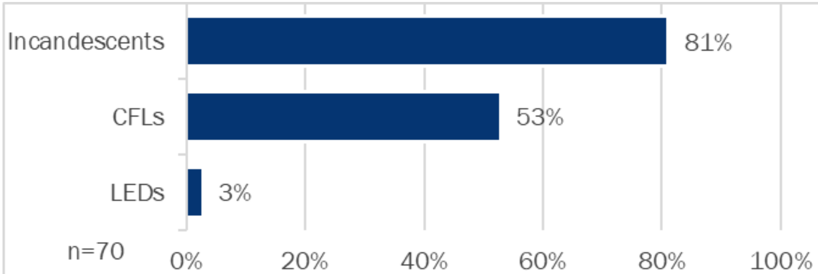
We asked customers about the types of bulbs they replaced with LEDs (see Figure 11). Customers replaced both burnt out and working light bulbs. Replacing burnt out light bulbs was more common. Smaller numbers also installed LEDs in previously empty sockets.

Figure 11. Socket Status Prior to Most Recent LED Installation



Customers also replaced multiple bulb types, sometimes more than one type. A large majority said that they replaced incandescents (81%) while just over half (53%) replaced CFLs. A very small number replaced LEDs (3%), probably because they had previously purchased the wrong light color or brightness (see Figure 12).

Figure 12. Type of Bulb Replaced by Most Recent LED Installation

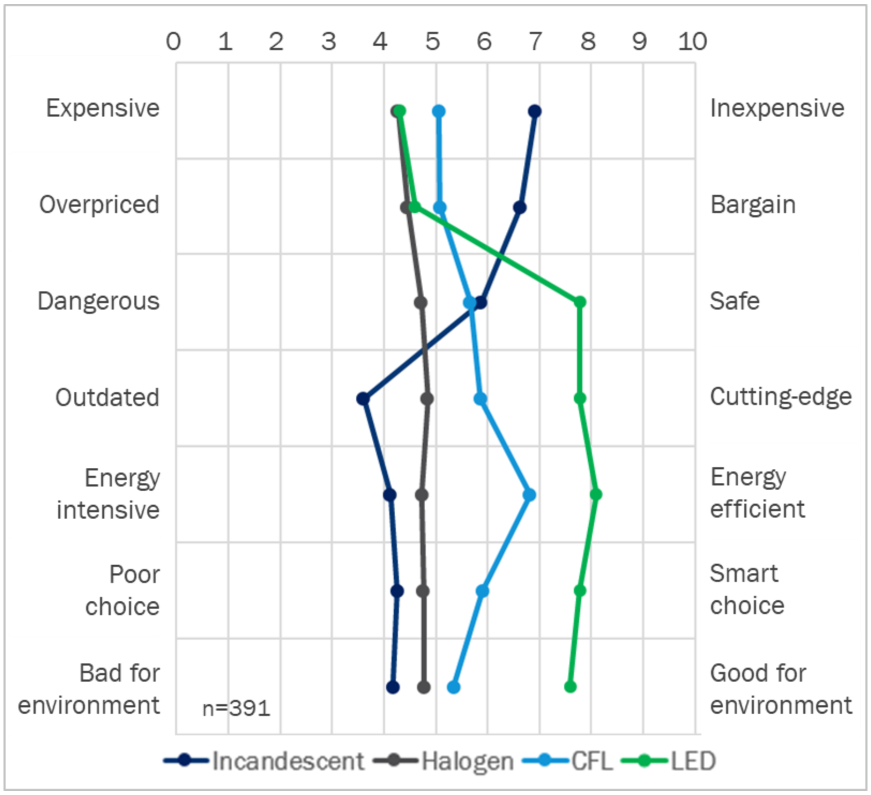


LEDs, particularly standard bulbs, are increasingly sold in multi-packs so it is likely that customers buy more than they need right away and put some in storage until a bulb burns out. To determine the prevalence of this behavior, field technicians recorded information about LEDs that they found in storage. Among customers with standard LEDs, 40% had at least one standard LED in storage and 73% of standard LEDs were installed. Customers were less likely to have specialty or reflector bulbs in storage. Among customers with specialty or reflector LEDs, only 11% had at least one of those bulbs in storage and 93% of specialty and reflector LEDs were installed.

Product Perceptions

As part of the consumer preferences survey, we asked respondents to rate each lighting technology on seven different attributes, including cost, safety, and energy use. The responses indicate that customers have a firm understanding of the different bulb technologies (see Figure 13). For example, customers understand that LEDs are the most energy efficient, best for the environment, and newest or most cutting-edge technology and that CFLs are the next best option in these areas. They also know that LEDs are among the most expensive products available and correctly identify incandescents as the oldest, cheapest, and least energy efficient option. The only signs of misunderstanding are with halogens, which customers on average perceive to be as expensive as LEDs.

Figure 13. Customer Perceptions of Available Lighting Technologies

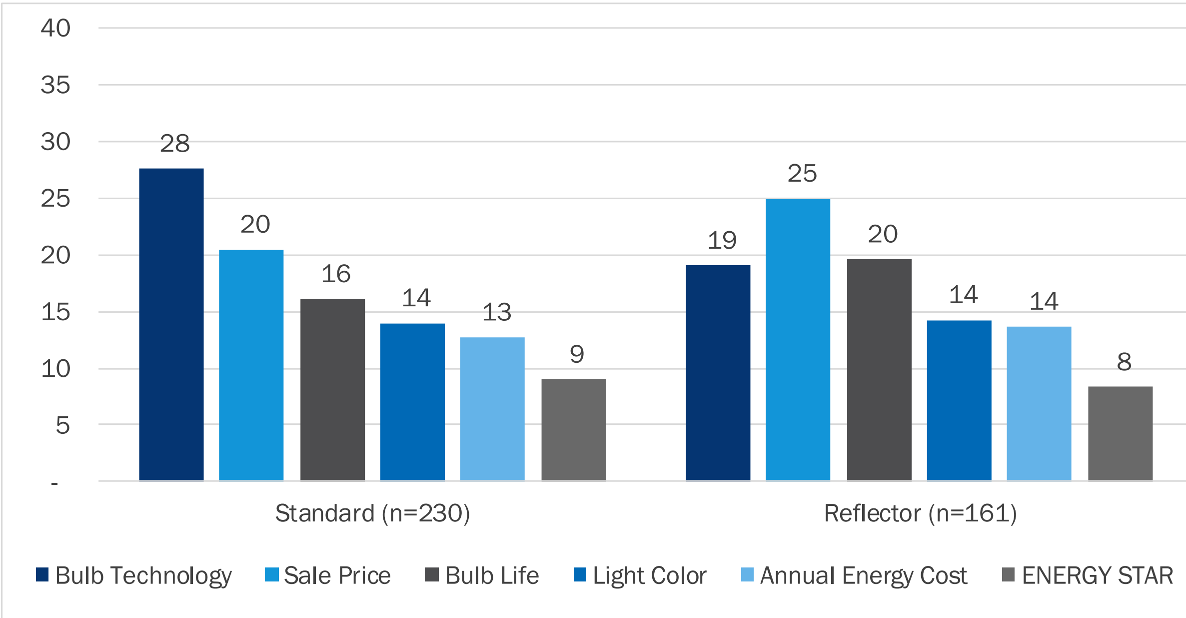


Lighting Preferences

As part of the customer preference study, we administered a discrete choice survey to examine the relative importance of different product attributes and to assess customers' price sensitivity towards energy-efficient lighting products. Because of the notable differences in product application and pricing, we modeled results separately for standard bulbs and reflector bulbs.

Figure 14 provides relative importance scores for key product attributes. As can be seen in the figure, bulb technology and price are the top two attributes for standard and reflector products alike, followed by bulb life, light color, and annual energy cost. ES certification is the least important attribute. Bulb technology is of greater relative importance to customers when shopping for standard products, while price is of greater importance when shopping for reflector products. This difference in attribute importance may be due to the higher cost of reflector bulbs and therefore higher sensitivity to price when shopping for reflectors.[11]

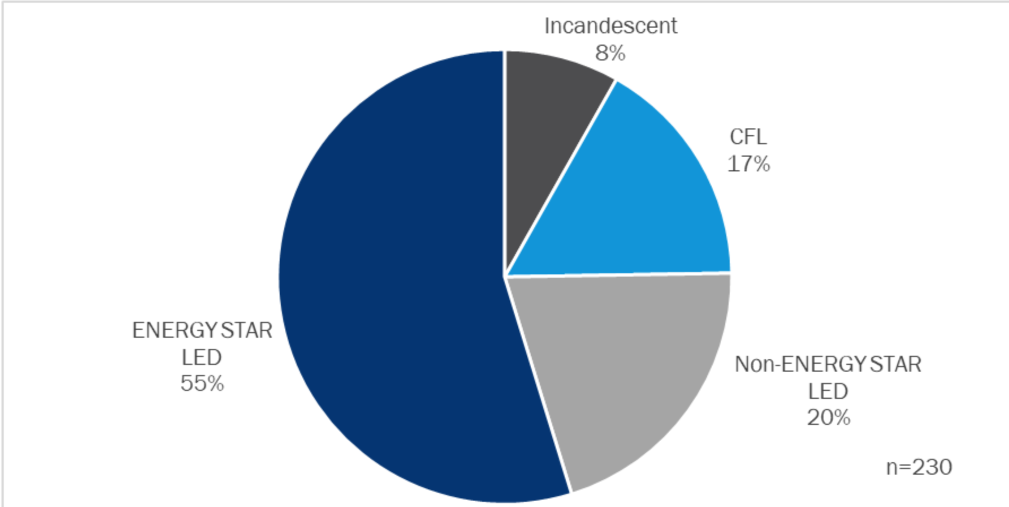
Figure 14. Relative Importance of Attributes by Bulb Type



In addition to modeling the relative importance of the different bulb attributes, the discrete choice survey allowed us to simulate market shares for the different bulb technologies within the standard and reflector product categories. Figure 15 shows the market shares for standard products. The results suggest that customers prefer LEDs over other technologies at current market prices and with typical bulb attributes for each technology, such as bulb life, light color, and annual energy cost. ES LEDs would capture 55% of standard bulb sales, and non-ES LEDs would account for another 20%. Together, ES and non-ES LEDs account for close to three-quarters of sales (75%). CFLs make up approximately one fifth of sales (17%), and incandescents account for the remaining 8% of lighting sales.

[11] Please note that the importance score of each attribute for a product type is expressed in relative terms to the other attributes for that product and should not be compared across product types.

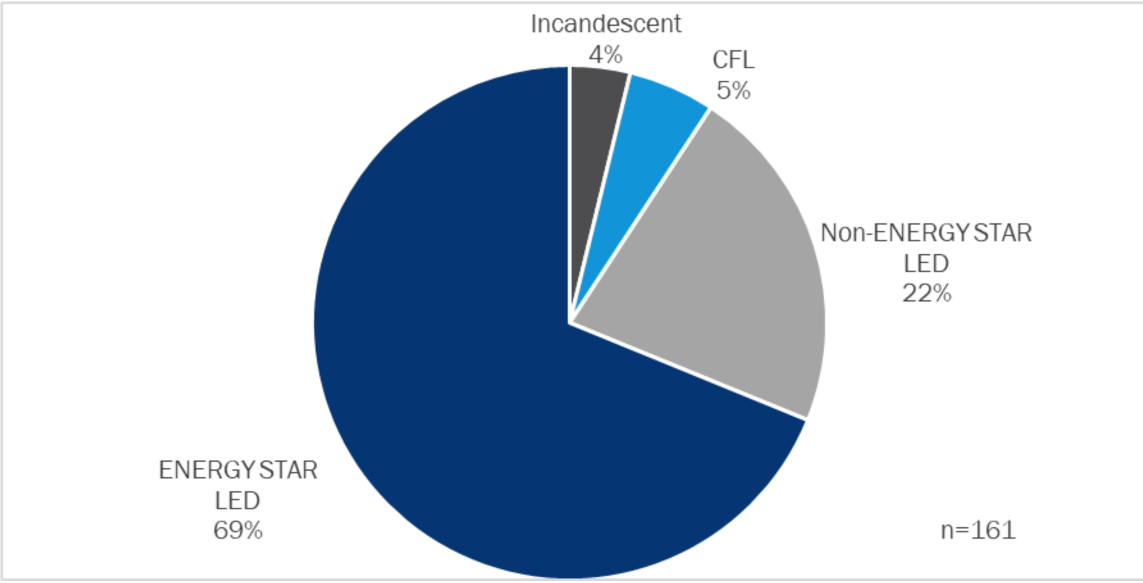
Figure 15. Standard Lighting Product Market Shares at Current Market Conditions



Simulator Inputs	Product 1	Product 2	Product 3	Product 4
Technology	Incandescent	CFL	Non-ES LED	ES LED
Sale price	$1.98	$3.17	$2.96	$4.90
Bulb life	1	5	10	15
Annual energy cost	$7.25	$1.75	$1.00	$1.00
Light color	Warm	Warm	Warm	Warm
ENERGY STAR	Non-ES	Non-ES	Non-ES	ES

Figure 16 shows the modeled market shares for the reflector products. The results show that ES LEDs dominate reflector sales at current market prices and with typical product attributes. As can be seen in the figure, ES LEDs account for 69% of sales, and non-ES account for another fifth of sales (22%). The cumulative LED market share in the reflector category is over 90%. CFLs account for 5% of bulb sales and incandescent account for the remaining 4%.

Figure 16. Reflector Lighting Product Market Shares at Current Market Conditions



Simulator Inputs	Product 1	Product 2	Product 3	Product 4
Technology	Incandescent	CFL	Non-ES LED	ES LED
Sale price	$4.39	$5.96	$5.54	$6.36
Bulb life	1	5	10	15
Annual energy cost	$7.75	$2.00	$1.25	$1.25
Light color	Warm	Warm	Warm	Warm
ENERGY STAR	Non-ES	Non-ES	Non-ES	ES

In addition to understanding the relative importance of the attributes and modeling lighting market shares at current market conditions, we examined how changes in the price of ES LEDs, holding all other attributes constant, impacted ES LED market share. We estimated price elasticity curves for different lighting product configurations across standard and reflector products. We define price elasticity as:

$$\frac{\%\Delta\ Quantiy}{\%\Delta\ Price}$$

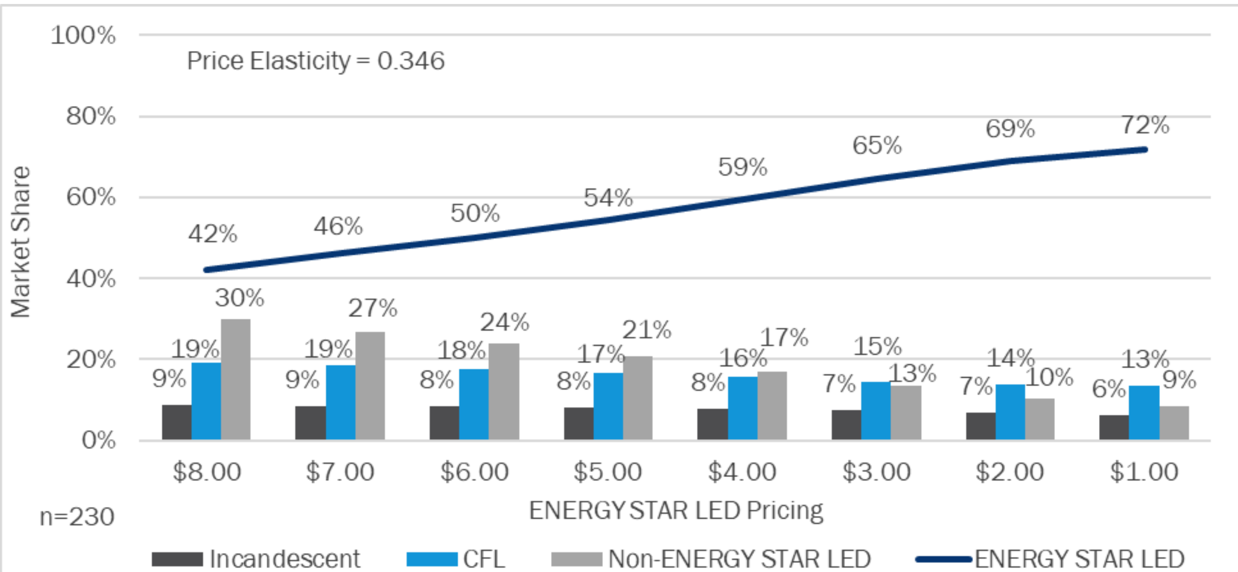
We show price elasticity as a number. For example, a price elasticity equal to 0.50 means that for every 10% drop in price, there will be 5% increase in market share.[12] We ran multiple price sensitivity scenarios.

Figure 17 shows the results of the price sensitivity analysis for standard ES LEDs. The upward-sloping line reflects the change in ES LED market share as the price decreases. The bars below the line represent the market shares for an average-priced non-ES LED, CFL, and incandescent bulb at each ES LED price point.

[12] An elasticity (in absolute value) closer to 0 is considered low or relatively inelastic, while an elasticity closer to or greater than 1 is considered high or relatively elastic (Simon and Blume, 1994).

The results show price that sensitivity for standard ES LEDs is relatively low at 0.346, which indicates that for every 10% decrease in bulb price, the market share of ES LEDs will increase only by 3.5%. ES LEDs have the greatest market share at all price points. At $8 per bulb, ES LEDs lead all bulb technologies with 42% of the market. For this analysis, we held the price of non-ES LEDs constant at $2.96 per bulb. When ES LEDs are $8 per bulb, 30% of customers will purchase a non-ES LED instead. The greater market share for ES LEDs suggests that some customers see value in the ES certification. As the price of ES LEDs drops from $8 to $1 per bulb, market share increases to 72% with most of the increase in market share coming at the expense of non-ES LEDs. The market share for non-ES LEDs drops from 30% to 9%. We also hold CFLs and incandescents constant at their current market prices, $3.17 and $1.98 respectively. Even with ES LEDs at $1 per bulb, a few customers will pay more to purchase CFLs (9%) or incandescents (6%), suggesting that some people may be more comfortable sticking with a technology they know.

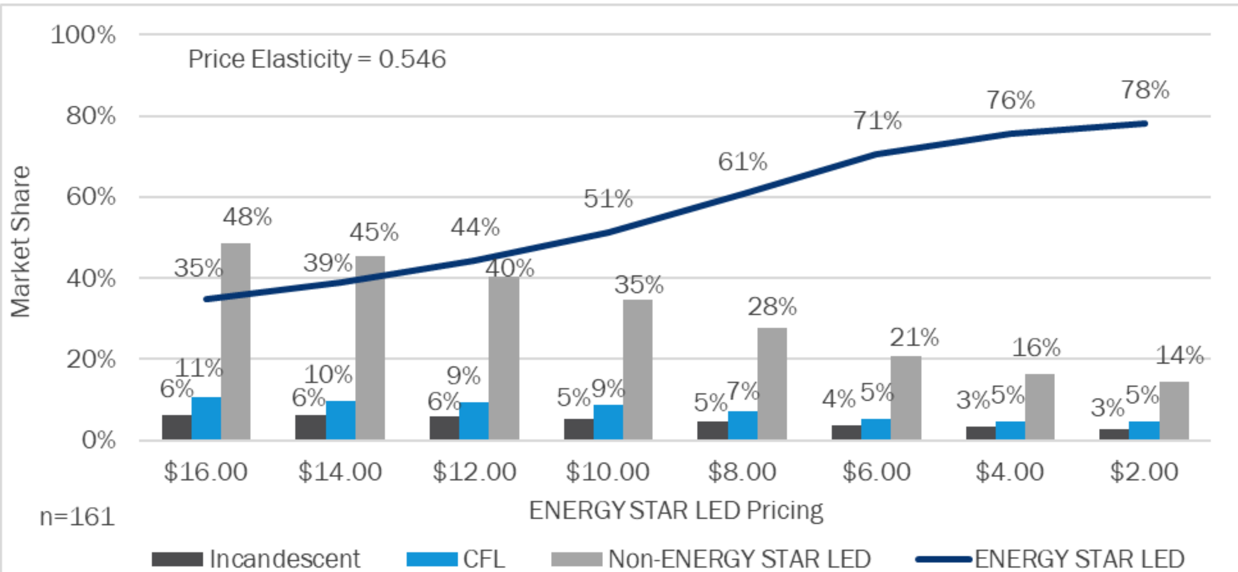
Figure 17. Price Sensitivity and Average Price Elasticity for Standard ES LEDs



Simulator Inputs	Product 1	Product 2	Product 3	Product 4
Technology	Incandescent	CFL	Non-ES LED	ES LED
Sale price	$1.98	$3.17	$2.96	**Varied**
Bulb life	1	5	10	15
Annual energy cost	$7.25	$1.75	$1.00	$1.00
Light color	Warm	Warm	Warm	Warm
ENERGY STAR	Non-ES	Non-ES	Non-ES	ES

Compared to the standard ES LEDs, reflector ES LEDs are considerably more price elastic. The price elasticity for reflector ES LEDs is 0.546, which indicates that for every 10% decrease in bulb price, LED market share will increase by 5.46% (see Figure 18). At the highest price point of $16 for an ES LED, more customers would purchase a non-ES LED at $5.54 per bulb than an ES LED. However, as we saw with ES standard bulbs, there is value in the ES label. As the price of reflector ES LEDs declines, market share increases so that at $12 per bulb, reflector ES LEDs have largest market share compared to all other technologies. As reflector ES LED market share increases, it pulls disproportionately from non-ES LEDs, though the market share of CFLs and incandescents drops as well to very low levels.

Figure 18. Price Sensitivity and Average Price Elasticity for ES Reflector LEDs



Simulator Inputs	Product 1	Product 2	Product 3	Product 4
Technology	Incandescent	CFL	Non-ES LED	ES LED
Sale price	$4.39	$5.96	$5.54	**Varied**
Bulb life	1	5	10	15
Annual energy cost	$7.75	$2.00	$1.25	$1.25
Light color	Warm	Warm	Warm	Warm
ENERGY STAR	Non-ES	Non-ES	Non-ES	ES

These results suggest that customers are willing to pay more for LEDs, both ES and non-ES. The discrete choice survey was a hypothetical shopping experience so that it is possible that customers in an actual store setting might make different choices and simply purchase the least expensive product. However, combined with the in-home study results that show increasing use of LEDs and the survey results showing strong customer knowledge of the benefits of LED bulbs, the residential lighting market appears to be transforming.

4.2 Impact Assessment

4.2.1 Program Data Verification

For PY9, AIC provided two parallel components of program-tracking data: a raw sales data extract to be treated as final PY9 sales data and a goal-tracking worksheet that included per-unit net energy savings assumptions drawn from CLEAResult's contractual statement of work (SOW). The SOW specifies a deemed savings value for each of three primary product categories: standard CFLs, standard LEDs, and specialty LEDs.

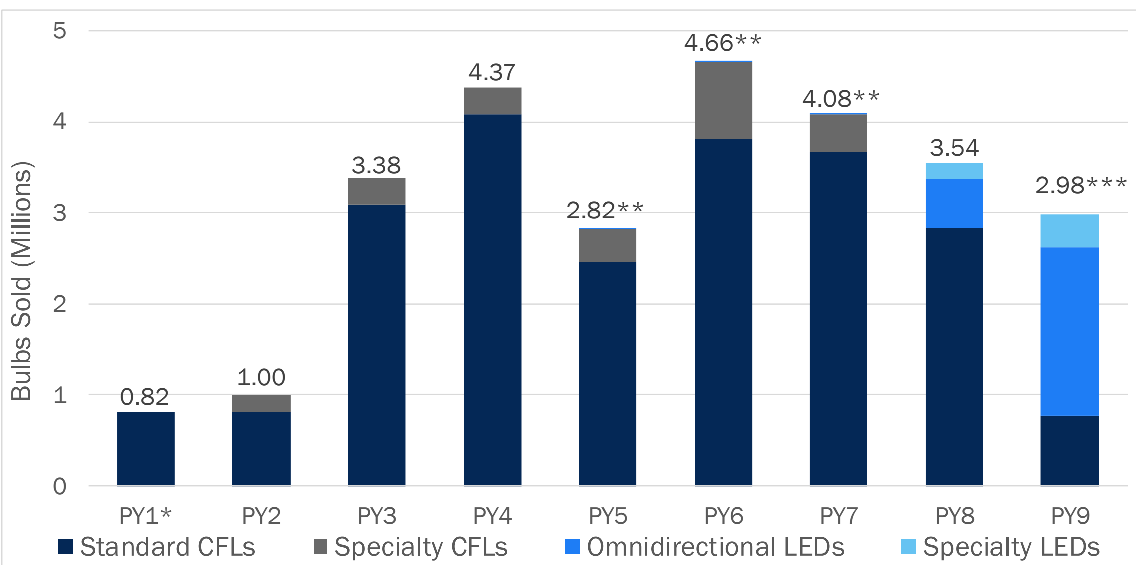
We verified program participation by examining the product sales data for product eligibility and time of sale. Our review of the program-tracking data found that all product sales were made during the eligible time-period and for eligible products. We also cross-checked bulb specifications with product descriptions and corrected some small discrepancies.

Program implementers track progress toward their savings goals using per-unit SOW savings values for each product type discounted through the program. We applied these per-unit values to bulb quantities in the sales data extract to represent ex ante kWh savings. The SOW did not contain summer peak demand savings values; therefore, it was not possible for us to calculate gross and net ex ante summer peak demand savings or realization rates for these savings as part of this evaluation.

4.2.2 Program Participation

The Residential Lighting Program sold a total of 2,982,605 bulbs in PY9 at participating retail stores. This reflects a 16% decrease from PY8. CFL products went from representing the majority of sales in PY8 to just over a quarter (26%) of all program-discounted products in PY9. Figure 19 shows program sales from PY1 through PY9. The figure shows increasing sales of bulbs until PY4, a significant drop in PY5 due to a reduction in program goals, a rebound to the increasing sales trajectory pattern in PY6, and subsequent decreases in PY8 and PY9.

Figure 19. Total Bulbs Sold, PY1–PY9



* We do not have a record of the number of CFLs sold by type for PY1.

** Indicates LEDs were sold but the quantity is too small for the bar to be visible.

Table 13 provides additional detail on the shifting landscape of program-discounted bulb sales over the course of last three years. Program sales of omnidirectional LEDs increased nearly four-fold from 15% in PY8 to 62% in PY9. The relative share of specialty LED sales tripled between PY8 and PY9, but those bulbs continued to account for a small share of program sales (12%). Standard CFLs accounted for just over a quarter of sales (26%) in PY9. The program stopped offering discounts on specialty CFLs in PY7.

Table 13. Bulb Sales by Type, PY7–PY9

Bulb Type	PY7		PY8		PY9	
	#	%	#	%	#	%
Standard CFLs	3,671,575	90%	2,838,498	80%	772,799	26%
Specialty CFLs	404,285	10%	0	0%	0	0%
Omnidirectional LEDs	480	0%	534,289	15%	1,847,239	62%
Specialty LEDs	0	0%	171,384	5%	362,567	12%
Total	**4,076,340**	**100%**	**3,544,171**	**100%**	**2,982,605**	**100%**

Sales by Store Category

Over the course of PY9, the program engaged over 20 retailers across 429 storefronts. Big Box retailers and DIY stores remained the dominant sources of program sales, cumulatively accounting for 81% of bulb sales. (see Table 14). The program, however, engaged 34 independent grocery stores, 21 hardware stores, and 58 discount stores as part of the program.

Table 14. Bulb Sales by Retailer Type

Retailer Type	PY7		PY8		PY9	
	Bulbs	% of Sales	Bulbs	% of Sales	Bulbs	% of Sales
Big Box[a]	2,296,820	56%	2,014,277	57%	1,548,712	52%
DIY	1,128,519	28%	1,004,652	28%	876,615	29%
Discount	324,801	8%	279,838	8%	229,798	8%
Drug Store	37,512	1%	45,500	1%	8,000	0%
Grocery Store	165,248	4%	66,856	2%	63,420	2%
Independent Grocery	N/A	N/A	17,080	<1%	29,638	1%
Independent Hardware	122,345	3%	115,968	3%	226,422	8%
Online Store	1,095	< 1%	N/A	N/A	N/A	N/A
Total	**4,076,340**	**100%**	**3,544,171**	**100%**	**2,982,605**	**100%**

[a] Includes warehouse retailers.

Sales by Wattage

In PY9, 60-watt equivalent standard bulbs accounted for the majority of products discounted through the program (77% of LED sales and of 91% CFL sales). Specialty LEDs in the 600 to 950 lumen range were the next most frequently sold product in terms of sales, accounting for over a third of program sales (36%). High wattage LEDs (100-watt equivalent and higher) accounted for a very small percentage of program sales.

Table 15. Program Bulb Sales by Type and Wattage

Lumen Range	LEDs		CFLs	
	Number Sold	% of Sales	Number Sold	% of Sales
Omnidirectional/ Standard	**1,284,621**	**84%**	**772,799**	**100%**
< 310	87	0%	0	0%
310–749	59,675	3%	1,210	0%
750–1,049	1,705,715	77%	702,645	91%
1,050–1,489	31,295	1%	9,711	1%
1,490–2,599	50,467	2%	58,782	8%
> 2,600	0	0%	451	0%
Specialty	**925,185**	**42%**	**N/A**	**N/A**
<600	103,296	5%	N/A	N/A
600 - 950	794,101	36%	N/A	N/A
950 - 1,400	18,327	1%	N/A	N/A
>1,400	9,461	0%	N/A	N/A
Total	**2,209,806**	**100%**	**772,799**	**100%**

4.2.3 Gross Impacts

Table 16 outlines the ex post gross savings for the PY9 Residential Lighting Program. As can be seen in the table, the program achieved 116,888 MWh in ex post gross energy savings and 14.21 MW in ex post gross summer peak demand savings. Because some bulbs sold are stored for later use, an installation adjustment factor or ISR is required to calculate the gross savings achieved in PY9. We used the method outlined in the IL-TRM V5.0 that banks savings from a portion of sales for application in future years. The ex post gross savings achieved in PY9 therefore include a combination of bulb sales from PY7, PY8, and PY9 that were installed in PY9. Appendix A contains additional details about the savings assumptions we used to calculate program savings in PY9.

The gross realization rate for PY9 is 1.30 and is based on dividing the total PY9 ex post gross savings by PY9/Year 1 ex ante gross savings. Because carryover savings were a part of ex post gross savings but not a part of the ex-ante savings, the program had a high realization rate. The program implementation team uses per-unit ex ante savings of 18.48 kWh for CFLs, 29.53 for omnidirectional LEDs, and 57.85 for specialty LEDs.[13] The evaluation team does not have an insight into the underlying assumptions that went into the per-unit savings values and cannot point to the reasons that may drive additional differences between the PY9 ex ante and ex post savings. The program implementation team did not calculate ex ante summer peak demand savings. As such, we are unable to develop the gross realization rate for those savings.

Table 16. PY9 Residential Lighting Program Gross Impacts

Sales Year / Install Year	Energy (MWh)		Demand (MW)	
	Ex Ante	Ex Post	Ex Ante	Ex Post
PY7 / Year 3	-	14,957	-	1.84
PY8 / Year 2	-	13,463	-	1.80
PY9 / Year 1	89,815	88,468	-	10.57
Total PY9 Gross Savings	89,815	116,888	-	14.21
PY9 Achieved Gross Realization Rate	1.30		-	

Note: Realization Rate = Ex Post Value / Ex Ante Value.

Table 17 provides the savings values from sales made in PY9 that are claimed in PY9 and the savings that will carry over to PY10 and PY11 due to their later installation. As discussed earlier, the IL-TRM V5.0 method assumes that 98% of bulb will be installed within 3 years and 2% of bulbs will never be installed.

Table 17. PY9 Residential Lighting Gross Impacts for PY9–PY11

Measure	Energy (MWh)			Demand (MW)		
	PY9	PY10	PY11	PY9	PY10	PY11
Standard CFLs	18,032	3,391	2,883	2.37	0.45	0.39
Omnidirectional LEDs	54,647	892	784	6.31	0.10	0.09

[13] Note that we back-calculated these values by dividing per-unit ex ante net savings by associated NTG ratios provided in the SOW.

Measure	Energy (MWh)			Demand (MW)		
	PY9	PY10	PY11	PY9	PY10	PY11
Specialty LEDs	15,789	711	608	1.89	0.11	0.09
Total	**88,468**	**4,994**	**4,275**	**10.57**	**0.66**	**0.57**

4.2.4 Net Impacts

PY9 ex post net savings is comprised of sales from PY7, PY8, and PY9. To calculate ex post net savings, we applied NTGRs approved by the SAG for each program year to the sales made in that year. We applied the SOW net per-unit savings to bulb quantities in the sales data extract to represent ex ante net kWh savings. Table 18 details ex ante and ex post net energy and summer peak demand savings. As can be seen in the table, the program achieved 68,075 in summer ex post net MWh savings and 8.29 in ex post net MW savings. The net realization rate around the net energy savings is 1.28. One reason that ex ante net savings are less than ex post net savings is that the program did not track and claim PY7 and PY8 bulb sales installed during PY9. Because the program did not provide information about the source of the per-unit values it uses to estimate savings, it is not possible to determine why ex post net savings is larger than ex ante net beyond the application of carry over savings. The program implementation team did not calculate ex-ante net summer peak demand savings. As such, we were unable to develop the realization rate for demand savings.

Table 18. PY9 Residential Lighting Program Net Energy Impacts

Sales Year / Install Year	Energy (MWh)		Demand (MW)	
	Ex Ante	Ex Post	Ex Ante	Ex Post
PY7 / Year 3	N/A	7,030	N/A	0.86
PY8 / Year 2	N/A	8,517	N/A	1.14
PY9 / Year 1	53,223	52,529	N/A	6.29
Total PY9 Net Savings	53,223	68,075	-	8.29
PY9 Achieved Net Realization Rate	1.28		-	

Note: Realization Rate = Ex Post Value / Ex Ante Value.

Table 19 shows per-unit net ex ante and ex post energy savings by bulb type from the PY9 bulb sales.

Table 19. Deemed Energy Savings Comparison for PY9 Sales

Measure	Ex Ante Net kWh Savings per Bulb	Ex Post Net kWh Savings per Bulb
Standard CFLs	11.64	14.70
Omnidirectional LEDs	17.13	17.16
Specialty LEDs	34.71	26.13

5. Conclusions and Recommendations

The Residential Lighting Program ran smoothly in PY9, exceeding all of its goals for bulb sales and energy savings. The program had a net realization rate of 1.28 for energy savings.

We conducted an in-home lighting audit of AIC customers' homes and a consumer lighting preference study. Combined, these studies provide results that suggest that the residential lighting market continues to transform at a rapid pace with LEDs leading the way.

Within this context, we provide the following key findings and recommendations for program improvement:

- **Key Finding #1:** The transformation of the lighting market in the AIC service territory continued at an accelerated pace with LEDs accounting for nearly all of the gains. Based on the results from the in-home lighting studies that Opinion Dynamics has conducted for AIC periodically, only 3% of AIC customers were using LEDs in 2012 compared to 50% in 2016. The average AIC home had LEDs in less than 1% of its light sockets in 2012 and now has them in 10%. The increase in LED saturation contributed to the overall increase in EE lighting saturation rates of 49% in 2016, up from 38% in 2012. EE bulb usage is still highly varied across AIC households. In 2012, most AIC households had few EE bulbs in use whereas in 2016, an AIC household was equally likely to have few, some, or a lot of EE bulbs. In the past, the typical customer who was purchasing lighting at a retailer most likely had just a few or some EE bulbs. Today, the typical customer is equally likely for most of their bulbs to be EE as they are to be non-EE. Program opportunities continue to exist among certain customer segments, namely, older customers (55 years and older). EE lighting saturation in the homes of those customers is significantly lower than in the homes of their respective counterparts (45% vs. 50% for the 35-54 age group and 55% for the 18-34 age group).
  - **Recommendation:** With this EE bulb usage pattern, it is more challenging for the Residential Lighting Program to continue to impact the market with an upstream program design. With an upstream delivery model, the program will end up discounting the lighting purchases of many customers who already have high EE bulb saturation and would likely purchase them without a discount. The program should consider modifications to its upstream program design to increase the likelihood that it is reaching customers who have lower EE bulb saturation and who need the discount to encourage more EE bulb purchases. An online store could be an effective option as AIC could target program marketing to just the regions and customers that lag in EE bulb use.
- **Key Finding #2:** EE bulb saturation in reflector and specialty sockets has increased since 2014, but opportunity remains as it continues to be much lower than that of standard sockets. Of AIC homes with reflector sockets, one-third of those sockets (34%) have an EE bulb installed. Sockets that require another type of specialty bulb have even lower saturation; only 16% of specialty sockets have an EE bulb installed. LEDs are the new bulb of choice for these sockets. The increase in saturation between 2014 and 2016 is entirely due to LEDs. Reflectors sockets have more LEDs than CFLs, and specialty sockets have an equal number of the two bulb types. However, the most common technology installed in both of these socket types continues to be incandescents.
  - **Recommendation:** The program should shift its focus from standard LEDs to all types of specialty LEDs. Within the specialty category, reflector LEDs are gaining traction and the program should continue supporting these products. The program should greatly increase the number and type of other specialty products it supports as there has been little progress in this area.

- **Key Finding #3:** Customer knowledge of different lighting technologies is strong, and LEDs are the preferred bulb technology for most customers. As part of the consumer preference survey, we asked respondents to rate each lighting technology on seven different attributes, including cost, safety, and energy use. Customers understand that LEDs are the most energy efficient, best for the environment, and newest or most cutting-edge technology, and that CFLs are the next best option in these areas. The discrete choice survey that takes customers through a hypothetical shopping exercise revealed that AIC customers are generally not very price sensitive, especially when it comes to standard light bulbs. The analysis of the relative importance of the key light bulb attributes, such as price, technology, life, color, annual energy cost, and a presence of the ES label, shows that customers place greater importance on technology than price when it comes to standard products. Price matters more with reflectors and is the most important attribute relative to other attributes, followed by bulb life and technology. For both product types, customers are willing to pay more for ES LEDs suggesting they see the value that ES certification provides.
  - **Recommendation:** The residential lighting market appears to be nearing transformation, particularly for standard products. These changes suggest diminishing returns from future Residential Lighting Program interventions. The program should consider shifting from a large scale upstream program to a targeted approach focusing on specialty products at the retail level and an online store that could make use of more targeted marketing. The program should monitor federal rulemaking and any other policy decisions, especially surrounding ESIA 2020, along with retailer and manufacturer behaviors in terms of manufacturing practices and shelf stocking trends to optimally scale down and ultimately end the program when less efficient lighting products disappear entirely from the market.

Appendix A. Gross Impact Assumptions

In this appendix, we provide details on the savings assumptions used to estimate ex post gross electric and demand savings.

Base Wattage – EISA Compliance

The baseline wattages in the IL-TRM V5.0 vary depending on the bulb type. Baseline wattages for general service CFLs and omnidirectional LEDs are based on the lumen output and account for the EISA 2017 efficiency standards, where appropriate (see Table 20 below).

Table 20. Baseline Wattages for Calculation of Gross Savings after EISA for General Service CFLs and Omnidirectional LEDs

Lumen Range	Base Wattage
250–309	25
310–749	29
750–1,049	43
1,050–1,489	53
1,490–2,600	72
2,601–2,999	150
3,000–5,279	200
5,280–6,209	300

The baseline wattages for directional LEDs vary depending on the directional bulb type and lumen range and account for the Department of Energy (DOE) energy efficiency standards for incandescent reflector lamps and any appropriate exemptions to the standards. Table 21 specifies the baseline wattages we used in our savings calculations for directional LEDs.

Table 21. Baseline Wattages for Calculation of Gross Savings for Directional LEDs

Bulb Type	Lumen Range	Base Wattage
R, ER, BR with medium screw bases w/ diameter >2.25" (*see exceptions below)	420-472	40
	473-524	45
	525-714	50
	715-937	65
	938-1,259	75
	1,260-1,399	90
	1,400-1,739	100
	1,740-2,174	120
	2,175-2,624	150
	2,625-2,999	175
	3,000-4,500	200

Bulb Type	Lumen Range	Base Wattage
*R, BR, and ER with medium screw bases w/ diameter <=2.25"	400-449	40
	450-499	45
	500-649	50
	650-1,199	65
*ER30, BR30, BR40, or ER40	400-449	40
	450-499	45
	500-649	50
*BR30, BR40, or ER40	650-1,419	65
*R20	400-449	40
	450-719	45
*All reflector lamps below lumen ranges specified above	200-299	20
	300-399	30

For specialty LEDs, we varied baseline wattages based on the specialty bulb type. Specialty bulbs are exempt from the first phase of EISA 2007, therefore the baseline wattages are based on incandescent products of equivalent lumen output. Table 22 details baseline wattages used to calculate savings for specialty LEDs.

Table 22. Baseline Wattages for Calculation of Gross Savings for Specialty LEDs

Bulb Type	Lumen Range	Base Wattage
3-Way	250-449	25
	450-799	40
	800-1,099	60
	1,100-1,599	75
	1,600-1,999	100
	2,000-2,549	125
	2,550-2,999	150
Globe (medium and intermediate bases less than 750 lumens)	90-179	10
	180-249	15
	250-349	25
	350-749	40
Decorative	70-89	10

Bulb Type	Lumen Range	Base Wattage
(Shapes B, BA, C, CA, DC, F, G, medium and intermediate bases less than 750 lumens)	90-149	15
	150-299	25
	300-749	40
Globe (candelabra bases less than 1050 lumens)	90-179	10
	180-249	15
	250-349	25
	350-499	40
	500-1,049	60
Decorative (Shapes B, BA, C, CA, DC, F, G, candelabra bases less than 1050 lumens)	70-89	10
	90-149	15
	150-299	25
	300-499	40
	500-1,049	60

The program-tracking data provided the lumens per bulb, and the evaluation team was able to match and verify the program-tracked base wattages using Table 20.

Hours of Use

For the 94% of bulbs sold to residential customers, we applied the residential HOU assumptions, and for the 6% of bulbs sold to commercial entities we applied the commercial HOU assumptions from the IL-TRM V5.0 (see Table 23). The TRM provides different residential HOU assumptions for different bulb types as well as for exterior and interior installations. Where applicable and possible, we used custom HOU by product type and installation location. For specialty products specifically we applied a generic interior HOU value of 847.

For commercial HOU, one value is provided for exterior installations and another is given for installations that could be either indoors or outdoors. We applied the latter assumption to exterior downlight bulbs and the former to all other bulb types.

Table 23. Illinois Statewide TRM Version 5.0 HOU Assumptions

Bulb Type	Residential	Commercial
CFL		
Standard	847	3,612
LED		
Omnidirectional	847	3,612
Reflector (BR/R)	891	3,612
Reflector (PAR)	891	3,612
Reflector (Exterior)	2,475	4,903
Specialty (CMB/CSB)	1,190	3,612
Specialty (G25/G16C)	639	3,612
Specialty (3-way)	850	3,612

Waste Heat Factors

The IL-TRM V5.0 provides different waste heat factor values for different installation locations. For energy savings, we used a waste heat factor of 1.06 for the 94% of bulbs that were installed in residential locations and 1.09 for the 6% that were installed in commercial locations.[14] For demand savings, we used a waste heat factor of 1.11 for the 94% of bulbs that were installed in residential locations and 1.36 for the 6% that were installed in commercial locations. Bulb types that customers would normally install in exterior locations take on a value of 1.00 because these bulbs do not affect the heated areas of a building. Table 24 outlines waste heat factor assumptions by installation location and bulb type.

[14] The TRM provides a large variety of waste heat factors for commercial installations based on building type. Because we do not know the installation locations of bulbs sold to commercial customers, we followed the TRM guidelines and chose the WHFe for unknown buildings.

Table 24. Illinois Statewide TRM Version 5.0 Waste Heat Factor Assumptions

Bulb Type	Residential		Commercial	
	WHFe	WHFd	WHFe	WHFd
CFL				
Standard	1.06	1.11	1.09	1.36
LED				
Omnidirectional	1.06	1.11	1.09	1.36
Reflector (BR/R)	1.06	1.11	1.09	1.36
Reflector (PAR)	1.06	1.11	1.09	1.36
Reflector (Exterior)	1.00	1.00	1.00	1.00
Specialty (CMB/CSB)	1.06	1.11	1.09	1.36
Specialty (G25/G16C)	1.06	1.11	1.09	1.36
Specialty (3-way)	1.06	1.11	1.09	1.36

Coincidence Factors

The IL-TRM V5.0 provides peak CFs based on bulb type and installation location. For the 94% of bulbs sold to residential customers, we applied the residential factors and, for the remaining 6%, we applied the commercial factors (see Table 25).

Table 25. Illinois Statewide TRM Version 5.0 Coincidence Factor Assumptions

Bulb Type	Residential	Commercial
CFL		
Standard	0.081	0.660
LED		
Omnidirectional	0.081	0.660
Reflector (BR/R)	0.091	0.660
Reflector (PAR)	0.094	0.660
Reflector (Exterior)	0.273	0.000
Specialty (CMB/CSB)	0.121	0.660
Specialty (G25/G16C)	0.075	0.660
Specialty (3-way)	0.078	0.660

Appendix B. Inputs for Future Planning

As part of the in-home lighting study, we captured information on the light bulbs in storage to provide updated in-service rate values.

In-Service Rate

As part of the in-home lighting inventory, we included bulbs in storage in the scope of our data collection. The quantity of bulbs in storage relative to the total number of bulbs found in the home provides an estimate of first-year ISR. Table 26 contains first-year ISR derived as part of this study as well as the ISR trajectory for standard LEDs and specialty LEDs. We developed the ISR trajectory based on the carryover method outlined in IL-TRM V5.0, which assumes that 98% of all bulbs will be installed within 3 years of purchase with 55% of bulbs remaining after the first year installed in year two and 45% installed in year three. As can be seen in the table, the overall first-year ISR for LEDs is 77%. First-year ISR for specialty LEDs is considerably higher than for standard LEDs (93% vs. 73%).

Table 26. LED Residential In-Service Rates

Bulb Type	n	First Year ISR	Second Year ISR	Third Year ISR	Cumulative ISR
Standard LEDs	69	73%	14%	11%	98%
Specialty LEDs	38	93%	3%	2%	98%
Overall LEDs	**76**	**77%**	**11%**	**9%**	**98%**

Appendix C. Other Cost-Effectiveness Inputs

Heating Penalty Methods

The heating penalty represents the increase in gas usage because of the additional space heating needed due to the reduction of waste heat generated by the more-efficient lighting.[15] The penalty is used in the analysis of program cost-effectiveness. The IL-TRM V5.0 provides different algorithms to calculate the heat penalty for residential and commercial installations.

For residential homes:

$$Year\ 1\ \Delta\ Therms = LA \times 0.94 \times \left[\frac{(Base\ Watt - Bulb\ Watt)}{1000} \times ISR_{res,yr1} \times HOU_{res} \times HF_{res} \times 0.03412\right] \Big/ \eta Heat$$

Where:

LA = Leakage adjustment equal to (1 − leakage rate) or (1 − %Leakage)
0.94 = Residential install rate
Base Watt = EISA-compliant base wattage
Bulb Watt = Actual wattage of installed bulb
ISR = First year ISR
HOU = Hours of use
HF = Heating factor or percentage of light savings that must be heated
0.03412 = Conversion factor from kWh to Therms
ŋHeat = Efficiency of heating system.

For commercial facilities:

$$Year\ 1\ \Delta\ Therms = LA \times 0.06 \times \frac{(Base\ Watt - Bulb\ Watt)}{1000} \times ISR_{com,yr1} \times HOU_{com} \times IFTherms_{com}$$

Where:

LA = Leakage adjustment equal to (1 − leakage rate) or (1 − %Leakage)
0.06 = Commercial install rate
Base Watt = EISA-compliant base wattage
Bulb Watt = Actual wattage of installed bulb
ISR = First year ISR
HOU = Hours of use
IFTherms = Lighting-HVAC integration factor for gas-heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting

To calculate the weighted program heat penalty, we apply both the residential and commercial savings algorithms outlined in the IL-TRM V4.0 and multiply them by the probability of being installed in each location. Our weighted savings equation is:

[15] We follow the direction of the IL-TRM V4.0 and assume all homes are gas heated because we do not have information on the heating fuel of customers' homes. Thus, we calculate only a gas-heating penalty.

$$Year\ 1\ \Delta\ Therms = LA \times 0.94 \times \left[\frac{(Base\ Watt - Bulb\ Watt)}{1000} \times ISR_{res,yr1} \times HOU_{res} \times HF_{res} \times 0.03412\right] \Big/ \eta Heat$$

$$+ LA \times 0.06 \times \left[\frac{(Base\ Watt - Bulb\ Watt)}{1000} \times ISR_{com,yr1} \times HOU_{com} \times IFTherms_{com}\right]$$

Where:

LA = Leakage adjustment equal to (1 − leakage rate) or (1 − %Leakage)
Base Watt = EISA-compliant base wattage
Bulb Watt = Actual wattage of installed bulb
ISR = First year ISR
HOU = Hours of use
WHFe = Waste heat factor for energy savings
Res = Residential values
Com = Commercial values

To calculate the heating penalty for PY8 purchases that will be installed during the next 2 years, we simply apply the ISR for year 2 and year 3 and modify the base wattage if necessary:

$$Year\ 2\ \Delta\ Therms\ Heat\ Penalty$$
$$= LA \times 0.94 \times \left[\frac{(Base\ Watt - Bulb\ Watt)}{1000} \times ISR_{res,yr2} \times HOU_{res} \times HF_{res} \times 0.03412\right] \Big/ \eta Heat +$$
$$LA \times 0.06 \times \left[\frac{(Base\ Watt - Bulb\ Watt)}{1000} \times ISR_{com,yr2} \times HOU_{com} \times IFTherms_{com}\right]$$

$$Year\ 3\ \Delta\ Therms\ Heat\ Penalty$$
$$= LA \times 0.94 \times \left[\frac{(Base\ Watt - Bulb\ Watt)}{1000} \times ISR_{res,yr3} \times HOU_{res} \times HF_{res} \times 0.03412\right] \Big/ \eta Heat +$$
$$LA \times 0.06 \times \left[\frac{(Base\ Watt - Bulb\ Watt)}{1000} \times ISR_{com,yr3} \times HOU_{com} \times IFTherms_{com}\right]$$

Heat Penalty-Related Factors

The heating factors represent the increased gas space heating needed due to the reduction of waste heat generated by the more-efficient lighting. The IL-TRM V4.0 provides different factors based on installation location.

Table 27. Heating Penalty Factors for Calculating Gas Heat

Bulb Type	Ex Post Residential	Ex Post Commercial
	Heating Factor	Lighting-HVAC Integration Factor
Standard		
Standard	0.49	0.014

Bulb Type	Ex Post Residential	Ex Post Commercial
	Heating Factor	Lighting-HVAC Integration Factor
Specialty		
A-lamp	0.49	0.014
Bug Light	0.00	0.000
Candelabra	0.49	0.014
Dimmable Spiral	0.49	0.014
Exterior Reflector	0.00	0.000
Globe	0.49	0.014
High-Output Spiral	0.49	0.014
Interior Reflector	0.49	0.014
Post Light	0.49	0.014
Three-Way	0.49	0.014
LEDs		
A-lamp	0.49	0.014

Heating Penalty Results

The gas-heating penalty that results from the additional space heating needed due to the reduction of waste heat generated by more-efficient lighting is shown in Table 28.

Table 28. Gas Heating Penalty

Measure	Heating Penalty (Therms)		
	PY9	PY10	PY11
Standard CFLs	-396,005	-74,314	-63,178
Omnidirectional LEDs	-1,215,879	-19,908	-17,488
Specialty LEDs	-352,529	-15,358	-13,152
Total	**-1,964,414**	**-109,580**	**-93,819**

Appendix D. Program Savings by Funding Source

PY9 savings for the Residential Lighting Program are comprised of bulbs sold in PY7, PY8, and PY9 and installed in PY9. The program funded by both AIC and the IPA in PY7, and entirely by the IPA in PY8 and PY9. Tables Table 29 and

Table 30 provides PY9 gross and net savings by the year the bulbs were sold and the funding source.

Table 29. PY9 Gross Impacts by Bulb Sales Year and Funding Source

Program Year	AIC (8-103)		IPA		Total	
	kWh	kW	kWh	kW	kWh	kW
PY7	13,587	1.67	1,370	0.16	14,957	1.84
PY8	-	-	13,463	1.80	13,463	1.80
PY9			88,468	10.57	88,468	10.57
Total	**13,587**	**1.67**	**103,300**	**12.53**	**116,888**	**14.21**

Table 30. PY9 Net Impacts by Bulb Sales Year and Funding Source

Program Year	AIC (8-103)		IPA		Total	
	kWh	kW	kWh	kW	kWh	kW
PY7	6,386	0.79	644	0.08	7,030	0.86
PY8			8,517	1.14	8,517	1.14
PY9			52,529	6.29	52,529	6.29
Total	**6,386**	**0.79**	**61,689**	**7.50**	**68,075**	**8.29**

Appendix E. Consumer Preferences Study Design

Standard Design

Design Summary

- 60 wattage assumption
- 4 options + "none" per choice set
- 12 total choice sets (including two fixed for quality assurance)

Table 31. Standard Design Attributes and Possible Values

Attributes	Levels	
Price	$0.60, $2.90, $5.20, $7.50, $9.80	None
Technology	Incandescent, CFL, or LED	
Bulb life	1, 3, 5, 10, 15, or 25 years	
Annual energy cost	$1.00, $1.75, $5.25, $7.25	
Light color	Warm/Soft, Cool/Bright, or Natural/Daylight	
ENERGY STAR rating	"ENERGY STAR rated" (LEDs only) or "Not ENERGY STAR rated"	

Survey Introduction

We'd like you to imagine that you need to purchase a standard light bulb for a frequently used light fixture. The fixture may look something like this.

For the next series of questions, we will show you 4 light bulb options on each page and ask you to choose which you would purchase. If you would not purchase any of the four, please select "none".

Each set of choices will look something like this:

Assume that all bulbs shown are standard, screw-in, 60-watt equivalent bulbs. We will ask you to make 12 separate purchase decisions.

When making your selections, please:

- Do not compare products between screens. Only choose between products shown on the same screen.
- If you would not realistically purchase any of the products shown, select "NONE".
- Respond as though you are spending your own money, even though no real money is involved.
- Imagine that all products you see are available for purchase, even though some options may be unrealistic.

Finally, remember, there are no right or wrong answers. We are looking to best understand how **you** purchase light bulbs.

Reflector Design

Design Summary

- 65 wattage assumption
- 4 options + "none" per choice set
- 12 total choice sets (including two fixed for quality assurance)

Table 32. Reflector Design Attributes and Possible Values

Attributes	Levels	
Price	$2.00, $6.00, $10.00, $14.00, or $18.00	None
Technology	Incandescent, CFL, or LED	
Bulb life	1, 3, 5, 10, 15, or 25 years	
Annual energy cost	$1.25, $2.00, $5.25, $7.75	
Light color	Warm/Soft, Cool/Bright, or Natural/Daylight	
ENERGY STAR rating	"ENERGY STAR rated" (LEDs only) or "Not ENERGY STAR rated"	

Survey Introduction

We'd like you to imagine that you need to purchase a standard light bulb for a frequently used light fixture. The fixture may look something like this.

For the next series of questions, we will show you 4 light bulb options on each page and ask you to choose which you would purchase. If you would not purchase any of the four, please select "none".

Each set of choices will look something like this:

Price	**$2.90**	**$0.60**	**$9.80**	**$7.50**	
Bulb Type	LED	CFL	CFL	Incandescent	NONE: I wouldn't choose any of these.
Bulb Life	25 years	1 year	3 years	15 years	
Yearly Energy Cost	$7.25	$5.00	$1.75	$1.00	
Light Color	Cool/Bright White	Warm/Soft White	Warm/Soft White	Natural/ Daylight	
ENERGY STAR Rating	ENERGY STAR rated	Not ENERGY STAR rated	Not ENERGY STAR rated	Not ENERGY STAR rated	
	○	○	○	○	○

Assume that all bulbs shown are reflector, screw-in, 65-watt equivalent bulbs. We will ask you to make 12 separate purchase decisions.

When making your selections, please:

- Do not compare products between screens. Only choose between products shown on the same screen.
- If you would not realistically purchase any of the products shown, select "NONE".
- Respond as though you are spending your own money, even though no real money is involved.
- Imagine that all products you see are available for purchase, even though some options may be unrealistic.

Finally, remember, there are no right or wrong answers. We are looking to best understand how **you** purchase light bulbs.

Appendix F. Data Collection Instruments

In-Home Study
Recruiter Instrument

In-Home Study
Deployment Instrum

In-Home Study
Retrieval Instrument

Consumer
Preferences Survey I

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