R1615 Light Emitting Diode Net-to-Gross Evaluation

DRAFT

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SUBMITTED TO:
Bob Wirtshafter, Lisa Skumatz, and Ralph Prahl, EEB Consultants

SUBMITTED BY:
NMR Group, Inc.

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ES Executive Summary

The Connecticut Energy Efficiency Board (EEB) contracted NMR Group, Inc., (NMR) with subcontractors DNV GL and The Cadmus Group (the evaluation team), to estimate net-to-gross (NTG) ratios for light emitting diodes (LEDs) in 2015 and predict prospective ratios through 2018 and beyond for the Retail Products Program.

RESULTS

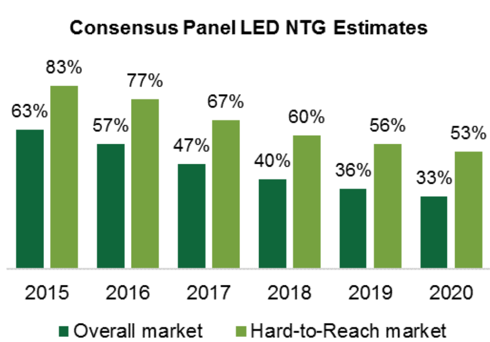
The study undertook five tasks: in-depth interviews with suppliers and program staff, sales data modeling, demand elasticity modeling, benchmarking, and a consensus panel. These efforts were carried out between August 2016 and February 2017—a time of political uncertainty, with implications for lighting efficiency standards and programs. Some of the findings presented in this report hinge on federal rulemaking, political appointments, and funding of public agencies. This report attempts to note if the certainty of results is particularly tenuous given the political climate and if they should be interpreted with caution.

Recommended Net-to-Gross Estimates

Based on results from the five research tasks the R1615 study makes the following recommendations:

- ***Retrospective LED NTG ratios for all non-hard-to-reach (HTR) LEDs (inclusive of standard [A-line], reflector, and other specialty bulbs) of 63% for 2015 and 57% for 2016.***
- ***Placeholder prospective LED NTG ratios of 47% for 2017, 40% for 2018, 36% for 2019, and 33% for 2020, with the caveat that these numbers be re-evaluated in the near future due uncertain market dynamics and rapid change.***
- ***HTR channel LED NTG ratios of: 83% for 2015, 77% for 2016, and 67% for 2017, 60% for 2018, 56% for 2019, and 53% for 2020.***

These recommendations come from the consensus panel which engaged lighting experts who first estimated NTG values based on R1615 primary and secondary-research tasks and their knowledge of the industry. They later participated in a consensus building process to develop these final recommendations. The panel took place a couple of months after the presidential election but in the early days of the new administration (January and February 2017). Thus, a fair amount of uncertainty remains about the future of the market and if and how the new administration might respond to previously legislated increases for lighting efficiency standards in 2020 (under the Energy Independence and Security Act [EISA] of 2007) and a Department of Energy (DOE) rule to expand the general service lamps to include reflectors and other bulb types. As such, the panel recommends that the prospective estimates beyond 2017 be reevaluated ideally in 2017/2018 and no later than 2019.



The non-HTR recommended NTG estimates are lower than the current value assumed in the 2017 *Connecticut Program Savings Documentation*, which stipulates an LED NTG of 82%.[1] The PSD value was derived from the R86 lighting NTG study conducted in 2014 and 2015, *Connecticut Residential LED Market Assessment and Lighting Net-to-Gross Overall,*[2] **but the consensus panelists believe the lighting market has changed substantially enough since the completion of that study to warrant an adjustment to the PSD to reflect the newly recommended prospective NTG ratios**. Panelists agreed that HTR channels, such as discount stores, are more price sensitive, and therefore demonstrate higher NTG ratios.

The consensus panel considered developing separate NTG ratios for reflector bulbs. However, after reviewing the available retrospective and prospective estimates in the face of uncertainty about adoption of the EISA, the expanded definition of general service lamps, and the fact that panelists' annual estimates only demonstrated differences of five percentage points or less,[3] the panelists concurred that the evidence does not support separate reflector NTG ratios.

Evaluated Net-to-Gross Estimates

The study relied on three empirical approaches to estimate LED NTG ratios, which, together with the results of the benchmarking exploration described below, fed into the consensus panel process. These included supplier interviews (n=16), sales data modeling (based on 17 states with varying levels of LED program activity), and demand elasticity modeling (drawing on program data from the Retail Products Program). Table 1 presents the results of the R1615 efforts.

Table 1: Estimated and Recommended LED NTG Estimates

Source	Retrospective[1]		Prospective				
	2015	2016	2017	2018	2019	2020	2021
% of CT Lighting Strategy 2015 Program Bulbs	100%	100%	-	-	-	-	-
2016 to 2018 PSD	82%	82%	-	-	-	-	-
In-depth supplier interviews	61%	61%	40%		38%		35%
Sales data modeling	70%	70%	-	-	-	-	-
Demand elasticity modeling[2]	61%	61%	-	-	-	-	-
Consensus panel / Recommended	**63%**	**57%**	**47%**	**40%**	**36%**	**33%**	**-**

[1] The in-depth interviews addressed 2015-2016 estimates together, while the sales data and demand elasticity modeling addressed only 2015. The consensus panel recommended separate estimates for 2015 and 2016.
[2] Because the model includes only program data, the estimate is net-of-freeriders, which excludes spillover.

Retrospective NTG. Supplier interviews yielded a retrospective NTG ratio of 61% for 2015 and 2016, demand elasticity modeling estimated a net-of-freeridership (which excludes spillover) for 2015 of 61%,

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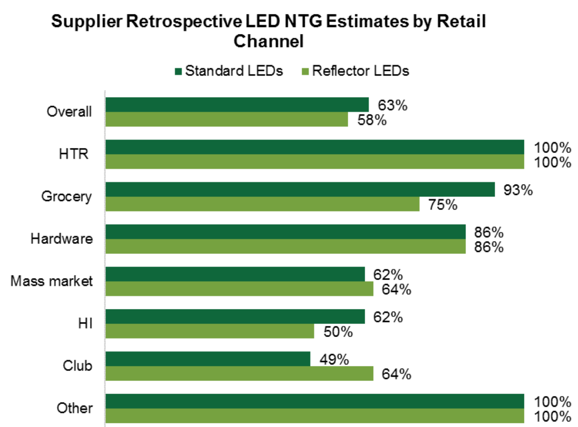
[1] http://www.ct.gov/deep/lib/deep/energy/conserloadmgmt/2016_2018_CLM_PLAN_FINAL.pdf.
[2] http://www.energizect.com/sites/default/files/CT%20Residental%20LED%20Lighting%20Market%20Assessment%20and%20Lighting%20NTG%20%28R86%29_Final%20Report_06.19.15.pdf.
[3] For example, their 2015 estimate for standard LEDs was 66% and their estimate for reflector LEDs was 62%.

and sales data modeling resulted in the highest NTG ratio of 70% for 2015. The consensus panel relied more heavily on the supplier interview and demand elasticity modeling results, expressing some concerns about the methodology of the sales data modeling level of robustness.

Prospective NTG. Suppliers expected program rebates will continue to be valuable in the future because they provide first cost decreases. They also emphasized that the rapidly increasing sales of LEDs independent of the program will make the program less influential. Suppliers estimated steadily decreasing prospective NTG ratios of 40% in 2017, 38% in 2019, and 35% in 2021. As mentioned, the consensus panel recommended placeholder NTG ratios on somewhat similar estimates, steadily decreasing from 47% in 2017 to 33% in 2020.

Bulb type. Suppliers and demand elasticity modeling estimated lower retrospective NTG ratios for reflector LEDs than standard LEDs. Suppliers predicted the opposite relationship in 2017 and 2019, but ultimately attributed a higher prospective NTG ratio for standard LEDs than reflector LEDs in 2021. The consensus panel discussed several theories of why reflector and specialty NTG ratios may be lower than for standard LEDs, such as the affinity between LEDs and the characteristics of reflectors (such as long life and, for many, dimmability), the poor performance of reflector CFLs leading consumers to LEDs as the energy-efficient choice, reflector LEDs have been on the market longer than standard LEDs, reflector LEDs are currently at price parity with halogen reflectors, and halogen reflectors were never perceived as high quality. Nonetheless, the lack of specific evidence supporting these theories, the small differences in standard and reflector/specialty NTG estimates (5% or less), and that LEDs only represented 13% of program LED sales in 2015 led the panel to recommend using the same NTG for standard and reflector bulbs.



Retail channel. Suppliers estimated higher NTG ratios for HTR channels than other channels, a finding that underlied the consensus panel's decision to recommend consistently higher HTR NTG estimates. Demand elasticity modeling also made estimates by retail channel, but sample sizes for HTR channels were too small to isolate for analysis.

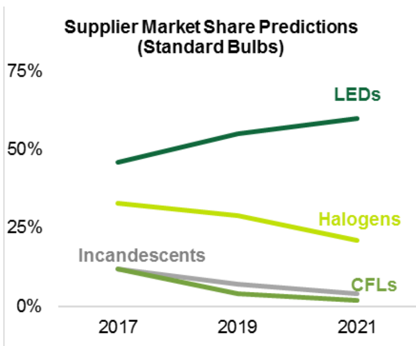
Comparison to Other Net-to-Gross Ratio Estimates

R1615's benchmarking effort revealed that research for comparable programs have resulted in retrospective LED NTG ratios for the years of 2012 to 2015 ranging from 73% to 100%, with a median value of 85%. The data from other jurisdictions do not display a clear pattern of increase or decrease over time. Ultimately, the consensus panel determined that all benchmarking studies were too dated or geographically distant to strongly factor into their considerations.

Market Trends and Predictions

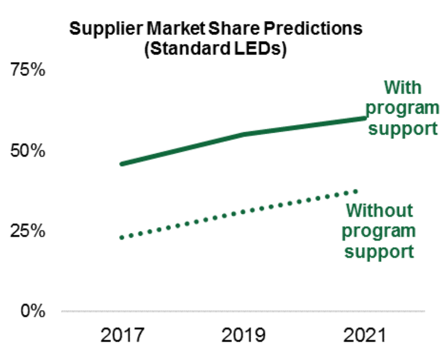
The study also gathered information on market trends that may affect NTG ratios through 2021, including past market share trends and predictions of future market share, the ENERGY STAR 2.0 specification, and the program decision to phase out CFLs by early 2017.

Aggregated sales data show that halogens and CFLs currently dominate the residential market, yet LED market share has been on the rise. Connecticut residents were most likely to have purchased halogen bulbs in 2015. Similar to the nation as a whole and its neighboring states, Connecticut's sales of LEDs among a subset of retailers sharply increased in recent years. Suppliers projected that regionally in 2021, LEDs would represent 60% of the standard bulb market and 54% of the reflector bulb market. Meanwhile, they anticipated that all other bulb types would decrease in market share.



When it came to speculating on the impacts of non-program factors, suppliers expected that EISA 2020 would usher the decrease in halogen sales and increase in LED sales. They anticipated that ENERGY STAR 2.0 will 1) cause CFL sales to gradually decrease because the specification excludes most CFLs which, in part, has slowed manufacturers' production of them, and 2) stimulate LED sales to increase, with some suggesting LEDs and halogens will take the place of CFLs. Additionally, they predicted that ENERGY STAR 2.0 coupled with EISA 2020 will greatly curtail CFL sales and significantly decrease CFL market share.

Nonetheless, suppliers emphasized that program support in the next several years will remain vital to LEDs' steadily increasing dominance in the regional market. For example, they hypothesized that, LEDs would only account for 38% of the standard bulb market in 2021 without program support (versus 60% with program support). Suppliers did not believe that the program's phase-out of CFLs would make their sales decline faster than they already are, but suppliers did recognize that the decline in CFLs would create a potential gap in the market for a low-price, energy efficient alternative to incandescents and halogens. They speculated that program support for LEDs will increase the likelihood that consumers would choose LEDs over halogens and incandescents in the absence of CFLs.



Conclusions and Recommendations

Retrospective and Prospective Net-to-Gross

The consensus panel first estimated NTG values based on R1615 primary and secondary-research tasks and their knowledge of the industry and later came to consensus on recommendations. Panelists predicted that the future LED market will grow independent of program support and estimated steady

NTG declines from 2015 to 2020. After careful consideration, they determined that the level of uncertainty and quickly moving variables necessitated reevaluating the prospective estimates in the near future. Panelists explained that HTR channels are more price sensitive, and therefore demonstrate higher NTG ratios.

- **Recommendation.** The study recommends using the NTG ratios resulting from the consensus panel: for non-HTR LEDs overall (inclusive of standard [A-line], reflector, and other specialty bulbs): 63% for 2015, 57% for 2016, 47% for 2017, 40% for 2018, 36% for 2019, and 33% for 2020. Prospective estimates should be reevaluated next year or by 2019 at the latest. The consensus panel suggests measuring the HTR channel by adding 20 percentage points annually to attribute to the HTR channel: 83% for 2015, 77% for 2016, and 67% for 2017, 60% for 2018, 56% for 2019, and 53% for 2020.

Retail Channels

Big box stores, including home improvement (HI), mass market, and club stores, composed over 90% of program sales so the relatively high freeridership estimated by suppliers drove suppliers' relatively low NTG estimates. The consensus panel results aligned with supplier interview results that higher NTG ratios should be associated with the HTR channels, yet HTR channels composed a small share of program sales.

- **Recommendation.** Further targeting the HTR channel has the potential to increase the program's cost effectiveness. The program should continue incentivizing lower-priced ENERGY STAR-qualified LEDs at HTR retailers. It may also wish to test the cost effectiveness of including higher-priced LEDs with specialty features such as those with dimmability and high color-rendering index in the HTR channel.

Program Implementation

The demand elasticity data relied on data detailing in-store promotional events and merchandising displays. Field staff collected these data when visiting stores to ensure compliance with retailer contractual agreements: 1) verifying prices and shelf signs that indicated products were included as part of the program and 2) tracking off-shelf merchandising displays of program bulbs (e.g., clip strips, end caps, pallet displays).

- **Recommendation.** Improving the level of detail in the tracking of in-store merchandising displays (ideally product model number or brand and bulb type) would increase the likelihood of identifying the impact this program component has on program sales.

Section 1 Introduction

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The Connecticut EEB contracted the evaluation team to estimate retrospective and prospective LED NTG ratios from 2015 through 2018 or beyond for the Retail Products Program, which largely supports light bulbs and light fixtures. The study, known as R1615, produced LED NTG estimates for 2015 through 2020.

1.1 Background

The EEB completed a lighting NTG study in 2014 and 2015 (R86), which provided estimates of NTG or net-of-freerider ratios for standard and specialty compact fluorescent lamps (CFLs) and LEDs (treated as one category) for 2013.[4] The R86 study recommended applying a CFL NTG of 51% and LED NTG of 82% for 2013 and 2014; the *Connecticut Program Savings Documentation* for the 2017 program year lists a NTG of 82% in keeping with the study, though it lists a NTG of 74% for CFLs.[5]

Since the completion of that study, Eversource and the United Illuminating Company (UI) released the *2016-2018 Electric and Natural Gas Conservation & Load Management Plan* (2016 to 2018 CL&M Plan). The plan called for the continued phasing out of CFLs from program offerings in 2016 and 2017, while shifting support to both standard and specialty LEDs. However, after the Connecticut Department of Energy and Environmental Protection (DEEP) approved the plan, ENERGY STAR® released Lamp Specification 2.0. Very few CFLs meet the criteria (the exact number is uncertain, but market intelligence suggests that number is fewer than ten models); this prompted the Companies to adjust their Lighting Strategy to phase out CFLs in early 2017, coincident with the implementation of the ENERGY STAR implementation date. By Spring 2017, the Companies anticipate supporting only standard and specialty LEDs.

The C&LM plan also called for supporting lighting products in multiple retail channels, including those considered as serving HTR consumers who are less likely to purchase or use energy-efficient bulbs mostly due to cost barriers.

Table 2 lists the unit and saving goals for the Retail Products Program as well as the percentage the program represents of all residential savings. The plan does not differentiate the number of CFLs and LEDs, specialty and standard products, or retail channels to be supported in each year. The table makes clear that the Companies will still rely heavily on the Retail Products Program to achieve a significant share of residential savings over the 2016 to 2018 program cycle, but they do anticipate the savings falling precipitously in 2018.

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[4] NMR, Cadmus, DNV GL. *R86: Connecticut Residential LED Market Assessment and Lighting Net-to-Gross Overall*. 2015. http://www.energizect.com/sites/default/files/CT%20Residental%20LED%20Lighting%20Market%20Assessment%20and%20Lighting%20NTG%20%28R86%29_Final%20Report_06.19.15.pdf.

[5] The 2017 PSD refers to these values as *net realization percentages*, but the formula is the same as that for NTG estimates: *(100% - freeridership) + spillover = NTG*. The PSD does not associate spillover with LEDs or CFLs; the freeridership rates assigned to them are therefore 18% and 26%, respectively (page 315).

The reason for the decline stems from the assumption *at the time the plan was written* that the next phase of the Energy Independence and Security Act (EISA), to be implemented in January 2020, will essentially make LED bulbs the new baseline. It also assumed that the continued LED price decreases would lead to a higher natural adoption rate prior to 2020. The decrease in savings also reflects a reduction in claimed Delta Watts, the result of the introduction of lower wattage general service halogens and a greater number of CFL to CFL and CFL to LED replacements (rather than assuming all CFLs and LEDs replace incandescent or halogen bulbs). Together, these assumptions have implications on the *current* bulb lifetime the Companies can claim for bulbs sold: if the assumed baseline wattage for 2020 approached that of the program bulbs being offered, then the program may not be able to factor post-2019 savings into their cost effectiveness tests. Stressing that nothing is certain in this dynamic market, it is possible that legislative and market changes may lead to the cessation of a retail-based residential lighting program in the next program cycle.

Table 2: Retail Products Unit and Savings Goals 2015 to 2018

(2016 to 2018 CL&M Plan)

Company	2015	2016	2017	2018
Units				
Eversource	2,211,792	2,684,921	2,631,667	2,435,933
UI	605,963	671,181	670,385	601,615
Total	2,817,755	3,356,102	3,302,052	3,037,548
Annual MWh Savings				
Eversource	51,420	67,192	62,020	53,967
UI	13,648	16,539	15,794	13,304
Total	65,068	83,731	77,814	67,271
Percentage of Residential Savings				
Eversource	40%	58%	53%	42%
UI	65%	60%	59%	51%
Total	43%	58%	54%	44%

The evaluation began with the supposition that four important developments in the lighting market since the approval of the three-year C&LM plan may have an impact on the Companies' residential retail lighting plans for the 2016 to 2018 cycle. Knowledge of these developments informs the interpretation of the NTG and market share trends discussed in this report, but the study focuses greatest attention on the ENERGY STAR Lamp 2.0 specification due to its immediate effect on program offerings and market trends.

1. **ENERGY STAR Lamp 2.0 Specification**:[6] As mentioned earlier, ENERGY STAR released its final Lamp 2.0 Specification, and it has important implications for ENERGY STAR qualification for both CFLs and LEDs. The specification adjusts measure life and efficacy requirements, among other factors, but the most important

[6] During the drafting of this report, the administration's proposed budget called for the elimination of ENERGY STAR (see https://www.bloomberg.com/graphics/2017-trump-budget/). Given that the budget remains a proposal at this time (March 17, 2017), we have not addressed this issue in the report.

implications are these: very few CFLs will meet the new standard as of January 2017, and some low-cost LEDs (see more below) now qualify for ENERGY STAR. The Department of Energy (DOE) allowed LEDs qualified under the new specification to be labeled and sold as ENERGY STAR starting in Summer 2017. Program staff reported during in-depth interviews that they have added these newly qualified LEDs to the product mix and will phase CFLs out of the program early in 2017.

2. **Value-line LEDs:** A variety of non-ENERGY STAR qualified LEDs had been around for a few years, but the shelf space devoted to them skyrocketed over the months leading up to the evaluation. Often called *value-line* LEDs, some lighting and energy-efficiency experts fear that these less expensive LED models may suffer from poor quality (premature failure, lack of omnidirectionality, limited durability, and questionable light quality) stemming from a rapid increase in manufacturing that may sacrifice quality control in order to meet customer demand.[7] While the new ENERGY STAR specification allowed some lower-cost models to qualify for the label,[8] numerous others that still fail to meet the ENERGY STAR specifications remain on store shelves. Their increasing availability and very low price will likely have impacts on the lighting market. The impacts could be positive, such as leading to greater consumer adoption of all LEDS (including ENERGY STAR models); they could be negative, if value-line LEDS prove to be poorly performing and turn consumers off to all LEDs (including ENERGY STAR models); or they could be a mixture of the two.

3. **DOE Rulemaking on EISA 2020 Implementation**: As explained above, the original EISA legislation called for a second wave of standard increases to go into effect in January 2020. As written, the next wave of standards would bar the manufacture, import, and sales of bulbs that did not meet the 45 lumens/watt backstop included in the original EISA 2007 legislation. Yet, the legislation also allowed the DOE to issue a rule by January 1, 2017 that could alter certain aspects of the rule.[9] In two rules dated December 29, 2016 and published January 18, 2017, the DOE expanded the definition of *general service lamp* to include many specialty bulbs that had previously been exempt from EISA. Although it remains to be seen whether EISA and these rules will be enacted or enforced by the new administration, as it now stands, on January 1, 2020, all general service lamps must meet a 45 lumens/watt standard and no longer be manufactured or imported into the United States.

4. **November 2016 Election:** In January 2017, the Republican party took control of both the Legislative and Executive branches of government. Members of the new administration have voiced skepticism about the role of human activity in climate change and are generally less supportive of energy-efficiency and renewable energy compared to fossil fuels.[10] A prior failed legislative attempt to overturn the lighting

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[7] CFLs suffered a dip in quality in the mid-2000s, which permanently led some consumers to reject them. These commentators fear a similar fate if value-line LEDs prove to be of low quality.

[8] The study defined *value-line* LEDs as those LEDs that did not qualify for the ENERGY STAR label under Specification 2.0.

[9] The DOE had also considered increasing the lumens per watt standard for CFLs and LEDs but ultimately dropped that consideration.

[1010] See summaries of cabinet member positions at http://www.nbcnews.com/feature/trump-cabinet; accessed March 2017.

efficiency standards of EISA nevertheless resulted in a budget rider that remains in effect that bars Congress from allocating funds towards its enforcement. As of March 2017, the new administration has not addressed the EISA legislation directly, but some commentators expect the law will not be enforced and may be overturned.

The true market impacts of these developments, as well as how Eversource and UI will respond to these developments, challenge all efforts at estimating prospective NTG ratios. For this reason, this study takes advantage of the collective knowledge of lighting program administrators and implementers outside of Connecticut and evaluators with experience in Connecticut and beyond to review retrospective NTG estimates for Connecticut for 2015, recent NTG estimates from other jurisdictions, and the most recent residential lighting market intelligence available to estimate prospective NTG for Connecticut through 2021.

1.2 Study Outcome and Objectives

The R1615 study outcomes included estimates of 2015 NTG ratios and predictions of 2016 to 2021 NTG ratios for LEDs. Where possible, results are reported separately for standard, reflector, and all other specialty LEDs—specialty bulbs are defined here as anything other than an A-line and reflectors LEDs, such as globe, 3-way, and candelabra bulbs).

The main study objectives included:

- Estimate 2015 NTG ratios overall and for standard and reflector LEDs (the most common specialty bulb) and compare these to 2013 estimates (when possible) and to the assumptions included in the 2016-2018 C&LM Plan and 2015 and 2016 PSDs;
- Examine studies in other jurisdictions and stay apprised of changes in the lighting market in response to federal standards and ENERGY STAR specifications as well as changes in the availability of various bulb types;
- Use the NTG estimates for 2013 and 2015, supplier and model-based predictions of future sales, and the information on NTG trends in other areas and on market changes to convene a panel of lighting experts to use a consensus-building approach to develop prospective (forward looking) NTG ratios standard and reflector LEDs for 2016 to 2018, and possibly through 2021.

2 Section 2 Methodology

The R1615 study involved in-depth interviews with manufacturers and high-level buyers (referred to as *suppliers*) and program and evaluation staff, sales data modeling, and demand elasticity modeling. The study also included a benchmarking task that examined LED market trends and NTG in other areas. A team of experts then engaged in a process of examining the results of the various Connecticut and external studies and lighting market trends and using them in a consensus approach to develop recommended standard and reflector LED NTG estimates. Table 3 summarizes the research tasks and the key research questions each address—some of which provided market information that informed the NTG consensus process. The following section describes these tasks; Appendix A provides additional details.

Table 3: Summary of Research Methods

Task	Key Research Questions
Supplier Interviews (n=16 lighting manufacturers and high-level buyers) (n=2 program managers/ evaluation staff)	• Based on supplier estimates of the program impact on sales, what was the NTG ratio for standard and reflector LEDs and what might those ratios be in 2016-2021)? • What will be the likely market and program impacts of the ENERGY STAR Specification? • What are their predictions for market penetration trends for standard and reflector LED products?
Demand Elasticity Modeling	• What is the relationship of price and promotion to sales (elasticity)? • What would LED sales be without the program's intervention (baseline sales); and • What is the program freeridership rate?
Sales Data Modeling	• What have been the trends in LED sales from 2009 to 2015 in states with programs and states without programs? • What is the NTG ratio for LEDs in 2015?
Benchmarking	• What have studies suggested are the recent and prospective LED NTG ratios in other jurisdictions?
Consensus NTG	• Considering the results of Task 2 – Task 4, what do persons knowledgeable about the CT, regional, and national lighting programs and market predict NTG to be in 2016 to 2020?

2.1 In-Depth Interviews – Methodology

As mentioned, the study included in-depth interviews with program and evaluation staff members (n=2) and lighting suppliers who participated in the program in 2015-2016 (n=16).[11] The supplier interviewees included the following:

- 15 lighting manufacturers who together accounted for 88% of the Connecticut 2015-2016 sales in the program tracking database
- One high-level lighting buyer who accounted for 3% of the 2015-2016 program sales[12]

The supplier interviews, which were completed from September through November 2016, covered the following primary topics:

- Program impacts to determine current (2015) and prospective (2016-2020) NTG ratios (R1615)
- The market impacts of ENERGY STAR Lamp 2.0 specification
- Market penetration trends for LED products

Most of the supplier interviews were fielded prior to the 2016 presidential election. Some interviewees indicated that their responses may change based upon the results of the election, largely assuming a less optimistic future for LEDs under the new administration. If asked today, it is likely that at least some suppliers would provide higher prospective NTG ratios and lower LED market shares than reflected in the results presented here.

Program staff interviews were conducted in November and December 2016 and touched on many of the same topics above (but were not asked NTG-related questions).

2.1.1 Retrospective NTG

To estimate retrospective NTG ratios, interviewers asked suppliers a series of questions about what their sales of standard and reflector LEDs would have been in the absence of the program. Generally, if a respondent said they would not have sold any of each type of LED in Connecticut without the program, the sales from this respondent were assigned a NTG ratio of 100%. If the respondent would have sold LEDs, they were asked a series of questions to estimate their anticipated sales in the absence of the program. If a respondent sold both types of LEDs, they answered each series of questions separately for the two types of bulbs. The following formula was used to calculate the retrospective NTG ratios for both bulb types:

$$NTG = \frac{(Supplier\ reported\ total\ sales - Supplier\ reported\ sales\ without\ program)}{Total\ program\ sales\ (actual)}$$

[11] A *high-level lighting buyer* refers to a purchaser of lighting products for a large chain retailer that participates in the Connecticut program. The data spanned the period of June 2015 through June 2016, which included a change in program cycles.

[12] In addition to this retail lighting buyer interview, we also completed a second "proxy" interview with a high-level retail buyer. In this case, the high-level retail buyer elected to have their primary lighting supplier do the interview in their stead. This other retail buyer accounted for 16% of 2015-2016 program sales.

Using the ratio of standard to reflector LED program sales, the study calculated an average weighted NTG ratio for LEDs overall. See the interview instrument in Appendix C.1 for further context.

Manufacturers were also asked the questions separately for each retail channel through which they offered program-supported bulbs, although to limit the survey's length, the study prioritized obtaining NTG estimates from retail channels with the greatest program sales volumes for manufacturers working through several channels.

The quantity of bulbs that each respondent sold through the program was used to weight the NTG ratios provided by individual respondents (within a given type of market actor) up to a retail channel level.

This method does have weaknesses stemming largely from three potential sources of bias, as explained below.

1. **The gaming or *don't kill the golden goose* bias**: This potential bias occurs when suppliers purposely exaggerate how much their lighting product sales would decrease in the absence of the program. Their motivations would be to ensure that they continue to receive program discounts/rebates.
2. **The *green retailer* bias**: This potential bias occurs when suppliers underestimate how much their sales would drop in the absence of the program. The reason for doing so may be an inflated confidence in their company's ability to market environmentally-friendly products. This bias might be considered a variation of the *social desirability bias*, a well-known concept in program evaluation literature.
3. **Lack of adequate market knowledge**: Another potential source of bias is the consideration that some suppliers simply lack the broader market knowledge to competently assess what would happen to product sales in the absence of the program. Lighting manufacturers are less prone to exhibit this bias because they must submit proposals to the Companies indicating how many of each product they think they can sell through each retail channel. The study's sample consisted largely of manufacturers, thereby minimizing the impacts of this potential source of bias.

The relative influence of these three sources of bias on the results and the degree to which they offset each other remain unknown.

2.1.2 Prospective NTG

A primary goal of the R1615 study was to develop prospective—that is, forward-looking—NTG ratios for LEDs. To develop prospective NTG ratios, the study asked suppliers to predict future standard and reflector LED market shares for 2017, 2019, and 2021 in Connecticut, first assuming that the Companies would continue offering LED rebates through 2021 and then assuming that the Companies would terminate program support at the end of 2016. Using the following formula, the responses yielded prospective NTG estimates (i.e., program attributable market share) for both bulb types for each of the three years:

$$NTG = \frac{(LED\ market\ share\ with\ program - LED\ market\ share\ without\ program)}{LED\ market\ share\ with\ program}$$

The prospective NTG method differs from the retrospective approach in the following ways:

- Suppliers predicted the program impacts based on where they believe the market would be moving, rather than reviewing past and current market conditions.
- Suppliers predicted the program impacts on LED sales in the Connecticut LED market in general and not just their own LED sales.
- Because they were predicting program impacts for the overall Connecticut LED market, the study did not ask them to differentiate among retail channels.

In most cases, the analysis weighted market share predictions based on respondents' 2015-2016 program sales for each bulb type.

2.2 Sales Data Modeling – Methodology

The sales data modeling quantified the relationship between lighting program intensity (e.g., residential lighting program spending per household) and LED lighting sales to estimate a program NTG ratio. It relied primarily on 2015 sales data prepared by the CREED LightTracker initiative, although it also leveraged other data sources.[13,14] The LightTracker sales data were primarily generated from two sources: point-of-of sale (POS) state sales data (representing a subset of retail channels, with the notable exceptions of HI, hardware, and some club stores) and National Consumer Panel (NCP) state sales data (representing a different group of retail channels). These two sources collectively represent bulb sales at the retailers that account for the majority of such sales across the United States.[15] In addition to the LightTracker data, the model inputs included a combination of program data from administrators across the nation collected by the evaluation team in coordination with the CREED Initiative, and household and demographic data collected through various publicly available websites. The model input data sources are listed here, and discussed in more detail below:

- National bulb sales
    - POS data (grocery, drug, dollar, discount, mass market, and selected club stores)
    - Panel data (HI, hardware, online, and selected club stores)
- US Census Bureau Import data (CFL imports)[16]
- ENERGY STAR® shipment data (imports and ENERGY STAR market share)
- North American Electrical Manufacturers Association (NEMA) shipment data
- American Community Survey (ACS) data (household characteristics and demographic data)
- Retailer square footage per state (based on the two primary retailer channel data sources)

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13 CREED serves as a consortium of program administrators, retailers, and manufacturers working together to collect the necessary data to better plan and evaluate energy efficiency programs. LightTracker is CREED's first initiative, focused on acquiring full-category lighting data, including incandescent, halogen, CFL, and LED bulb types, for all distribution channels in the entire United States. As a consortium, CREED speaks as one voice for program administrators nationwide as they request, collect, and report on the sales data needed by the energy efficiency community. (https://www.creedlighttracker.com)

14 The information contained herein is based in part on data reported by IRI through its Advantage service for as interpreted solely by LightTracker, Inc. Any opinions expressed herein reflect the judgement of LightTracker, Inc. and are subject to change. IRI disclaims liability of any kind arising from the use of this information.

15 For example, in Connecticut in 2015, 90% of LEDs and 70% of CFLs were obtained from HI, club, and mass merchandise stores. In Massachusetts in 2015, 79% of LEDs and 66% of CFLs came from HI, mass merchandise/discount, hardware, and club stores. Estimates of incandescent and halogen sales and all types of sales are not readily available, but surveys generally find HI and mass merchandise stores to be the most common sources of bulbs. See *Connecticut LED Lighting Study Report (R154)*. Final delivered to the Energy Efficiency Board January 2016. http://www.energizect.com/sites/default/files/R154%20-%20CT%20LED%20Lighting%20Study_Final%20Report_1.28.16.pdf. NMR. 2015. ***Results of the*** *Massachusetts On-site Lighting Inventory: 2014*. Delivered to the Massachusetts Program Administrators and Energy Efficiency Advisory Council Consultants March 2014. http://ma-eeac.org/wordpress/wp-content/uploads/Lighting-Market-Assessment-and-Saturation-Stagnation-Overall-Report.pdf.

16 The analysis summarized here focuses on LED-only modeling; however, the LightTracker Initiative included models with CFLs as reported for other program administrators. The report discusses the joint CFL/LED modeling effort in Appendix A.

- General population surveys, lighting saturation studies and other primary data collection made publicly available through evaluation reports

Although Appendix A.1 addresses the strengths and weaknesses of the LightTracker data in more detail, it is critical to understand that the contract between IRI (the third-party who provides LightTracker data) and the evaluation contractor limits the depth of analysis and reporting of the data. For example, the contract does not allow for the reporting of which retailers report sales or analysis of sales by lumen bins or other bulb features (even if the features were included in the original data set or identifiable based on information contained therein). Despite these shortcomings, the evaluation team believes that the ability to analyze market-level bulb sales data at the state and national level outweighs the contractual limitations placed on the analysis and reporting.[17]

Appendix A.1 also summarizes the steps taken to develop key variables in the model. Other variables (e.g., demographics, electricity price, etc.) reflect data as collected from third-party sources but required no manipulation for inclusion in the model.

2.2.1 Sales Data Model Specification

The primary goal of the model was to quantify the impact of state-level program activity on the sales of LED lighting. Appendix A.1.2 includes detailed discussion of the data sources for each variable and the modeling equation. Key aspects of the lighting dataset as analyzed include:

- 2015 sales volume and pricing for CFLs, LEDs, halogens, and incandescent bulbs for all channels combined, and broken out by the POS and non-POS channels
- Data reporting by state and bulb type
- Inclusion of all bulb styles and controllability (e.g., three-way and dimmable)

The analysis relies on a market lift approach. The approach first uses the model to predict the count of LED bulbs with and without the program (the counterfactual of no program activity is determined by setting the program variable to zero). This change in count represents the *lift*, or net increase in the number of LED bulbs resulting from program activity. The lift is then divided by the total number of program LEDs sold (i.e., the gross number of LED bulbs) to determine NTG:

$$NTG = \frac{(LED\ bulbs\ sold\ with\ program - LED\ bulbs\ sold\ with\ no\ program)}{LED\ program\ incented\ bulbs\ sold}$$

The study tested other factors that influence the sales of efficient lighting, including demographic, social, household, and retail channel variables to capture and control for the unique characteristics of each state that potentially affect the uptake of efficient lighting products, but none were significant predictors of LED purchases. In fact, the regression coefficients for the LED program intensity variables proved inconsistent across a number of

[17] Prior to the LightTracker Initiative, evaluator access to market-level bulbs sales at any level of analyses were sporadic. Most retailers agreed to provide program administrators and evaluators their sales of program-supported bulbs only.

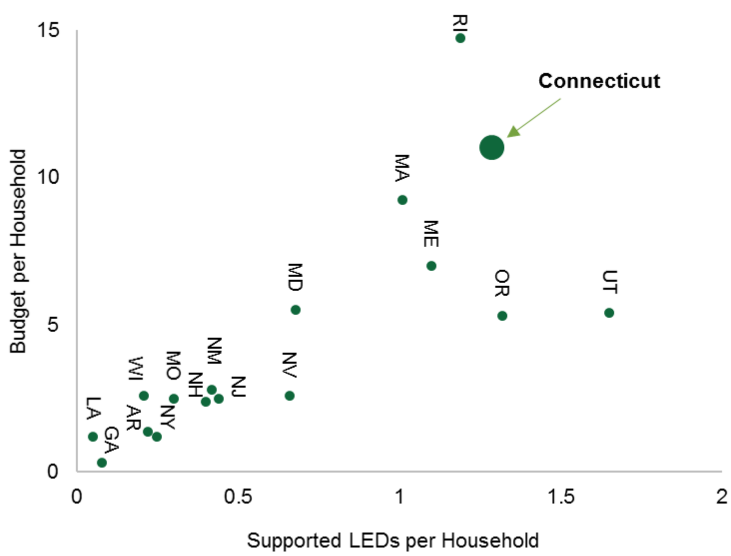
model specifications.[18] The robustness of the models suffered because only 17 states had sufficiently granular data to estimate a lamp-specific model. This was largely because LEDs were still gaining market share in 2015, and it was challenging to gain technology-specific program spending for a number of states. Additionally, the high cost of LED bulbs means more program dollars must be spent per LED bulb and that the resulting modeled impact will be smaller and more difficult to detect. In short, the sales data model presented in the section Net-to-Gross Estimates is the best LED sales data model that could be developed.

2.2.2 Review of Program Support and LED Sales

Appendix A.1.2 compares in detail the measures of program support and LED sales for the 17 states included in the model. The data showed variation across the states: Program spending on LEDs ranged a great deal; Connecticut exhibited the second highest spending at $10.97 per household (Figure 1), but the state also ranked highly in the number of LEDs it supported with those program dollars. Figure 2 shows the relationship between this ranking and the number of LEDs purchased per household according to the LightTracker dataset.

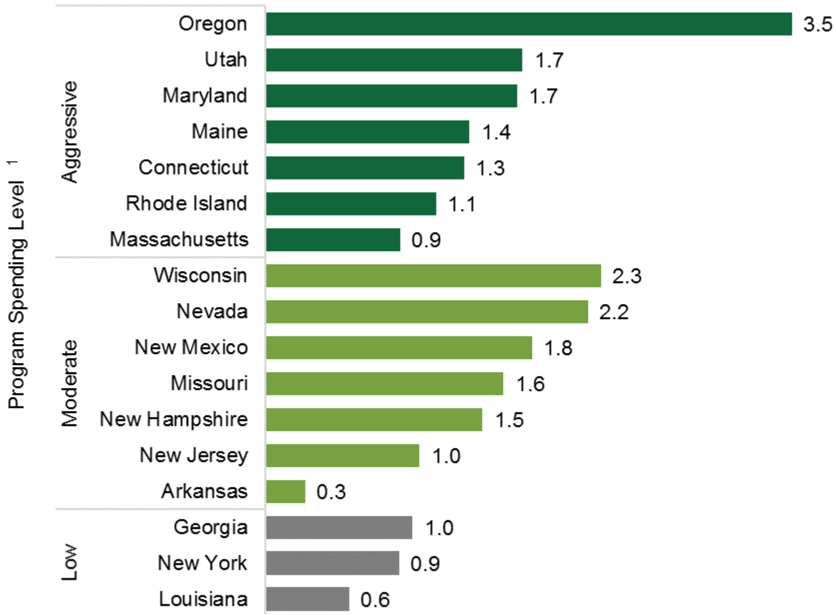
Figure 1: LED Program Spending and Bulbs Supported per Household in 2015 by State

(Based on literature review, n=17 states)



[18] As part of the CREED Initiative, Apex Analytics (Apex) developed a combined CFL and LED model for two other states using these same data, but the results are not yet public. Appendix A.1.2 provides the model which was robust and not overly sensitive to specification. The model was driven by CFLs, however, which provides little useful information for understanding LED NTG and predicting prospective NTG through 2018 and beyond. Therefore, the current study (R1615) did not use this joint CFL/LED model.

Figure 2: Average LEDs Purchased per Household in 2015 by State
(Based on LightTracker data, n=17 states)



[1] LightTracker classifies the intensity of program spending by the amount spent per household. States spending > $5 per household are classified as *Aggressive* spending, those spending > $1 and < $5 are *Moderate* spending, and those spending =< $1 are *Low* spending.

More generally, the level of program support was correlated to the number of bulbs supported per household. The states with the most aggressive program spending did not always exhibit the highest number of overall LED purchases. Connecticut (along with Rhode Island and Maine) was in the top tier of program spending but the middle of overall LED purchases within the model sample.

The study attempted to explain the unexpected findings, arriving at three plausible explanations:

- First, as mentioned above, the LightTracker data represent the best source of market-level sales data available, but the dataset is not perfect. The point-of-sale data that make up part of the overall dataset exclude HI, hardware, and some membership stores, some of the most common places at which consumers buy bulbs.[19] Except for the mass merchandise channel, retailers in the point-of-sale dataset tend to carry and sell a smaller volume of bulbs, and stocking leans towards inefficient bulb types, which could bias any effort to describe national sales from these channels only. In contrast to the point-of-sale data, the panel data that account for the remainder of the LightTracker dataset include all retail channels and retailers. However, a thorough review of the data suggests that households likely differ in how diligently they scan lighting purchases, which could also create bias (e.g., if they were more likely to scan memorable purchases). Each of these weaknesses may introduce bias, particularly leading to undercounts of purchases made in certain channels (exacerbated by the uneven distribution of retailers across the nation) or transactions—such as light bulb purchases—that may be less memorable (and therefore more prone not to being scanned). The model attempts to control for the channel-related bias through the inclusion of a variable for the square footage of retailers not in the POS data, but the evaluators did not find a satisfactory way to mitigate bias related to inconsistent scanning.

- Second, the modelling team did not have access to estimates of household-level socket saturation for each state, yet previous research has suggested that prior high levels of energy-efficient socket saturation reduce current energy-efficient bulb sales.[20,21] In short, the more long-lived bulbs a household already has installed, the fewer lighting purchases it must make. Unfortunately, the lack of saturation rates for most of the 17 states preclude us from testing this explanation directly.
- Third, and related to the second point, is the history of program activity.[22] Again, research has shown the importance that the duration of prior program activity has on energy-efficient bulb purchases. States with long-standing, aggressive programs succeeded in getting households to adopt these energy-efficient bulbs, and, again, because of longer measure lives, households need to purchase fewer bulbs now as a result. In short, other states are catching up to the level Connecticut and some other program states established in prior years.

2.3 DEMAND ELASTICITY MODELING – METHODOLOGY

Examining lighting products that incur price changes and promotion during the program period provides valuable information regarding the correlation between sales and prices.

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[19] For bulb sales by channel in Massachusetts, see NMR Group. 2016. *RLPNC 16-3 Lighting Decision Making*. http://ma-eeac.org/wordpress/wp-content/uploads/RLPNC-16-3-Lighting-Decision-Making-Memo.pdf. The forthcoming Massachusetts RLPNC 16-6 Shelf Stocking and Webscraping Study addresses bulb stocking practices and availability by retail channel.

20See NMR 2010. *Results of the Multistate CFL Modeling Effort*. at http://www.energizect.com/sites/default/files/FINAL%20CFL%20Modeling%20Report%20CT%20020210.pdf

[21] See NMR 2011. *Results of the Multistate CFL Modeling Effort (Y2)*. At file:///C:/Users/Chris/Downloads/2011-Multi-State-CFL-Modeling-Report.pdf

[22] See NMR 2011. *Results of the Multistate CFL Modeling Effort (Y2)*. At file:///C:/Users/Chris/Downloads/2011-Multi-State-CFL-Modeling-Report.pdf , section 4.

Demand elasticity modeling derives from the same economic principle driving program design: demand for efficient lighting is elastic and changes in price and merchandising generate changes in quantities sold (i.e., the upstream buydown approach). Demand elasticity modeling uses sales and merchandising information to achieve the following:

- Quantify the relationship of price and merchandising to sales
- Predict the likely sales level without the program intervention (i.e., baseline sales)
- Estimate freeridership by comparing predicted baseline savings with predicted program savings

Importantly, the demand elasticity approach relies only on program data; therefore, the resulting estimate is net-of-freeriders, which excludes spillover. Including spillover would produce a full NTG estimate and would be higher than net-of-freeriders. However, the data do not allow for this adjustment. Estimating freeridership using the demand elasticity model involved estimating price elasticities and coefficients for non-price effects (e.g., in-store promotions and merchandising).

Price elasticity is measured as a proportional change in demand relative to a proportional change in price. For example, if the price of a light bulb decreases by 10% and sales increase by 20%, the elasticity is equal to two. The upstream program approach assumes that decreasing prices for efficient lighting products will increase demand. Estimating price elasticities and having the price absent program incentives (and therefore the proportional discount) allows researchers to estimate demand for program bulbs absent the program incentives. To estimate a freeridership ratio, predicted program sales and sales likely to occur without program incentives and promotions are first multiplied by savings per-bulb. The freeridership ratio is then the relationship between the predicted savings without the program and the predicted savings with the program:

$$Freeridership\ Ratio = \frac{Predicted\ Savings\ without\ Program}{Predicted\ Savings\ with\ Program}$$

As the demand elasticity approach relies exclusively on program data, the model's robustness depended on data quality. Overall, the available data from the Connecticut Lighting Strategy achieved a sufficient quality to support the analysis. However, there were several necessary adjustments made to several key inputs in the model. The modifications to the following inputs are discussed in greater detail in Appendix A.2.1:

- **Seasonality**: The demand elasticity model included a seasonal trend provided by APT, the previous program implementer, to control for seasonal sales variations that result from seasonality (i.e., changes in daylight hours) rather than program factors. The seasonal trend represented the proportion of annual national sales expected to occur in a given month from a major national lighting manufacturer. Using data at a national aggregation level, including non-program products and areas without programs, limited the degree that resulting trends correlated with program activity.
- **Price Variation**: The modeling approached combined sales and prices for similar products (e.g., all 60-watt equivalent A-line bulbs) within the same store rather than observing price and sales variations for each individual model number. Aggregating

prices and sales captures 1) substitutions between comparable program products within each category and 2) variations in price across comparable products. The model only included sales with price variations as products with no variation in price do not contribute any information to the model. The greater the price variation levels across retailers and lamp styles, the more representative the elasticity estimates became when applied to sales of products that did not exhibit price variations.

- **Promotional Displays**: Program data contained a comprehensive list of all in-store promotional events, but the information on merchandising displays only represented a sample of locations. Due to the merchandising data's nature, the model could not predict sales for observations with missing merchandising data, and substituting merchandising coefficients would risk overstating program impact. However, not accounting for merchandising may overestimate freeridership to the extent that the price coefficients do not reflect all the merchandising impact. Ultimately, the study excluded display merchandising data from the model.

The demand elasticity model specification is described in detail in Appendix A.2.2. In short, the study organized bulb and pricing data as a panel, with a cross-section of program bulb quantities for each unique retail location, bulb type, and baseline wattage combination. These were modeled over time as a function of price, bulb characteristics (specialty, standard, reflector), and retail channel (e.g., club, HI, HTR, and mass market). Nesting elasticity estimates this way accounts for differences in retailer strategies and target demographics, as well as differences in demand given bulb characteristics.

Using *block bootstrap* standard errors, the distribution of freeridership predictions was normally distributed with a median value nearly identical to the estimated freeridership rate (52.8% compared to 52%) with precision of +/- 7% at the 90% confidence interval (Appendix A.2.3).

2.4 Benchmarking – Methodology

After reviewing numerous studies, the team identified 11 studies estimating retrospective and prospective NTG ratios for upstream lighting programs from 2013 to present to use for benchmarking R1615 results. Benchmarking the studies offered insights into the validity and reasonableness of the NTG ratio that the R1615 study estimated. Appendix A.3 lists the references.

2.5 Consensus Panel – Methodology[23]

The previous tasks yielded multiple estimates of and insights into NTG for 2015 and 2016 and predictions of NTG for 2017 through 2021. Each of the methods, however, has strengths and weaknesses, and only one approach had the ability to provide predictions for prospective NTG. Therefore, the study turned to a team of lighting experts and asked them to engage in

[23] The consensus-panel differed from a Delphi approach: panelists provided only one round of anonymous estimates and the *final* decisions were determined during a single meeting through dialogue as opposed to another round on anonymous submittals.

a consensus-building approach (i.e., consensus panel) to integrate the NTG estimates into finalized recommended values for LEDs for each year (i.e., retrospective for 2015 and 2016 and prospective for 2017 to 2020). As a first step in this process, the evaluators prepared a summary of the results from the current R1615 research tasks, results from the 2014/2015 R86 Connecticut NTG study, and recent LED NTG results from other jurisdictions, including the known strengths, weaknesses, and sources of potential bias of the various approaches and studies. The summary was distributed to the EEB Evaluation Consultants, the leads of the individual R1615 research efforts, and one program manager from a different service territory.[24] They provided their own assessments of which methods offered the strongest estimates of NTG. Then, to reach agreement on appropriate NTG values, the same individuals provided their own estimates of NTG based on the results of the various methods together with information on prior saturation trends, NTG estimates from other jurisdictions, their own expertise, and the most current information available on the implementation of the ENERGY STAR Lamp 2.0 specification. In February 2017, the group met to discuss the approaches and their estimates, ultimately reaching consensus on recommended values for 2015 through 2020.[25]

Consensus panels help limit the bias introduced by any single method or evaluation study author in recommending a NTG value. Instead, the reliance on multiple estimates and the collective wisdom of individuals familiar with the Retail Products program and programs regionally and nationally limits individual bias to successfully assess a rapidly changing market.

[24] An implementer from another jurisdiction was invited but declined participation.
[25] Members of the evaluation team successfully used this approach recently in Massachusetts, as documented in NMR, Cadmus, and DNV GL, 2015. ***Multistage Net-to-Gross Assessment Overall Report.*** Delivered to the PAs and EEAC Consultants in August. http://ma-eeac.org/wordpress/wp-content/uploads/Multistage-Lighting-Net-to-Gross-Assessment-Overall-Report.pdf.

3 Section 3 Net-to-Gross Estimates

The study examined NTG ratios through supplier interviews, sales data modeling, demand elasticity modeling, and benchmarking. A panel of lighting experts considered the results of these approaches and market intelligence to arrive at recommended NTG values retrospectively for 2015 and 2016 and prospectively for 2017 through 2020. Table 4 presents the results of the R1615 efforts.

Table 4: Estimated and Recommended LED NTG Estimates

Source	Retrospective[1]		Prospective				
	2015	2016	2017	2018	2019	2020	2021
% of CT Lighting Strategy 2015 Program Bulbs	100%	100%	-	-	-	-	-
2016 to 2018 PSD	82%	82%	-	-	-	-	-
In-depth supplier interviews	61%	61%	40%		38%		35%
Sales data modeling	70%	70%	-	-	-	-	-
Demand elasticity modeling[2]	61%	61%	-	-	-	-	-
Consensus panel / Recommended	**63%**	**57%**	**47%**	**40%**	**36%**	**33%**	**-**

[1] The in-depth interviews addressed 2015-2016 estimates together, while the sales data and demand elasticity modeling addressed only 2015. The consensus panel recommended separate estimates for 2015 and 2016.
[2] Because the model includes only program data, the estimate is net-of-freeriders, which excludes spillover.

Appendix A.4 describes the consensus panel's reasoning behind their recommendations. In short, four factors drove their decision making, as described in more detail below:

- **Steady declines.** After anonymously providing estimates, the consensus panel used the average of their estimated NTG ratios for the LED market overall which they initially provided for 2015 through 2016. They recommended 63% for 2015 and 57% for 2016.
- **Long-term uncertainty.** Panelists' average estimates for 2018 through 2020 continued the steady decline from 2017: 47% for 2017, 40% for 2018, 36% for 2019, and 33% for 2020. Through discussion, the panel decided that the market holds too much uncertainty to make concrete predictions and, as such, the estimates should be reevaluated in late 2017 or 2018—or by 2019 at the latest.
- **Bulb type**. The consensus panelists ultimately decided to combine standard and reflector bulbs into a single category of non-HTR LEDs due to the similarity in separate estimates and uncertainty regarding the adoption and implementation of the DOE rule that expands the general service lamp definition to include reflectors and many other specialty bulb types.
- **Distinction across markets.** One of the themes stretching across panelists' reports of the market was that incentives appear more pivotal for incenting HTR customers

to purchase LED bulbs. Therefore, they recommended that increasing NTG estimates for the HTR market by 20 percentage points across years would result in fair estimates.

3.1 Retrospective NTG Estimates: LEDs Overall

- ***The study tasks resulted in overall 2015 LED NTG ratios ranging from 61% to 70%. The results—coupled with additional market information—led the consensus panel to recommend an overall non-HTR LED NTG ratio (inclusive of standard (A-line), reflector, and other specialty types) of 63% for 2015 and 57% for 2016.***

Table 5 compares the retrospective LED NTG ratios across research activities by bulb type and shows the ratios that the consensus panel recommends.

Table 5: Estimated and Recommended Retrospective LED NTG Estimates[1]

Source		LED Bulb Type				HTR – All LED Styles
		All	Standard	Reflector	Specialty	
% of CT Lighting Strategy 2015 Program Bulbs		*100%*	*68%*	*23%*	*9%*	-
2016 to 2018 PSD		82%	-	-	-	-
In-depth supplier interviews		61%	63%	58%	-	100%
Sales data modeling		70%	-	-	-	-
Demand elasticity modeling[2]		61%	73%	62%	40%	-
Consensus panel / Recommended	**2015**	**63%**	**63%**	**63%**	**63%**	**83%**
	2016	**57%**	**57%**	**57%**	**57%**	**77%**

[1] The in-depth interviews addressed 2015-2016 estimates together, while the sales data and demand elasticity modeling addressed only 2015. The consensus panel recommended separate estimates for 2015 and 2016.
[2] Because the model includes only program data, the estimate is net-of-freeriders, which excludes spillover.

For the 2015-2016 period, suppliers estimated an overall LED NTG ratio of 61%, the sales data modeling resulted in an overall LED NTG ratio of 70%, and demand elasticity estimated net-of-freeriders of 61%. In comparison, the last supply-side-based LED NTG estimate for Connecticut's program (for the 2014 period) was 74% and the 2017 PSD uses a value of 82% (based on the recommendations of the R86 Lighting NTG study).

Suppliers attributed a decline in program attribution to increasing availability of LEDs, declining LED prices, and broader consumer acceptance of LED products. In the words of one supplier,

> *"The industry has been saying for over a year now, publicly, that the LED transition is happening. It's happening partially because of programs like the Massachusetts and*

Connecticut programs, [but also] partly because of non-ENERGY STAR high-quality, low-priced products from major manufacturers."

Literature over the past several years outside of Connecticut have estimated overall LED NTG ratios ranging from 73% to 100%, with a median value of 85% (n=9 studies). The most geographically comparable, recently conducted study relied on consensus panel to estimate retrospective NTG ratio of 95% for Massachusetts for 2014. The individual research efforts conducted there included supplier interviews, demand elasticity modeling, sales data modeling, and comparison area approaches, with empirical estimates ranging from 75% to 98%. The Massachusetts consensus panel predicted a prospective NTG ratio of 93% for 2016 for Massachusetts. Section 3.3 includes details and further benchmarking discussion.

3.1.1 Retrospective NTG Estimates by Bulb Type

- ***Suppliers and demand elasticity modeling attributed greater program impact on standard bulb sales compared to specialty and reflector sales. Yet the consensus panel believed that the estimates were adequately similar and the uncertainty great enough to assign standard, reflector, and specialty bulbs the same NTG.***

Supplier interviews and demand elasticity modeling both explored NTG by bulb type. The approaches arrived at the somewhat unexpected finding that NTG or net-of-freeriders estimates were higher for standard LEDs compared to reflector and specialty LEDs.

Suppliers estimated a standard LED NTG ratio of 63% and reflector LED NTG of 58%. Table 26 shows demand elasticity results overall and by bulb type. With greater elasticity, specialty (-2.20) and standard (-1.88) LEDs exhibited higher net-of-freeridership rates (62% and 73%, respectively) when compared with reflector LEDs (40%).

The consensus panelists reported the likely explanations for the lower NTG for reflector bulbs. One explanation ties directly to the characteristics of LEDs: reflectors are directional bulbs (i.e., the light only shines downward), are typically located in recessed cans installed in ceilings or in other difficult to access fixtures (making a long-life bulb appealing), and are frequently tied to dimmer switches. While standard LEDs do come in non-dimmable models and most strive to be omnidirectional, these features are not necessary for reflectors. Another explanation for lower elasticities for specialty products stems from the fact that there are few viable alternatives to using a specialty bulb in particular applications. For example, households are unlikely to install anything but a flame-style, small-screw base bulb in a candelabra designed for such bulbs. Likewise, panelists noted that reflector CFLs have not successfully penetrated the market, creating less market competition for energy-efficient reflector LEDs. The panelists concurred that the uncertainty in the estimates—and the fact that panelists' NTG estimates by bulb type varied by five percentage points or less (Appendix A.4.4)—was too great to justify assigning separate NTG ratios for standard, reflector, and specialty bulbs. Thus, they recommended the same retrospective and prospective estimates for non-HTR LEDs presented in Table 5 be applied to reflector and other specialty bulbs as well.

Table 6: LED Elasticities and Freeridership by Bulb Type
(Demand elasticity modeling results)

Bulb Type	Average Elasticity	Freeridership	Net-of-Freeridership
Reflector	-0.84	60%	40%
Specialty	-2.20	38%	62%
Standard	-1.88	27%	73%
Overall	**-1.61**	**39%**	**61%**

3.1.2 Retrospective NTG Estimates by Retail Channel

➢ ***Based on suppliers' estimates, the big box stores, with relatively low NTG ratios, drove the overall NTG ratios.***

The supplier interviews and demand elasticity analysis were able to provide NTG estimates for some retail channels. The contract covering the LightTracker data prevented the sales data approach from providing similarly detailed results.

The program discounted bulbs in six retail channels:

- HTR[26]
- Grocery
- Hardware
- HI, such as Lowe's
- Mass market retailers, such as Target
- Club, such as Costco

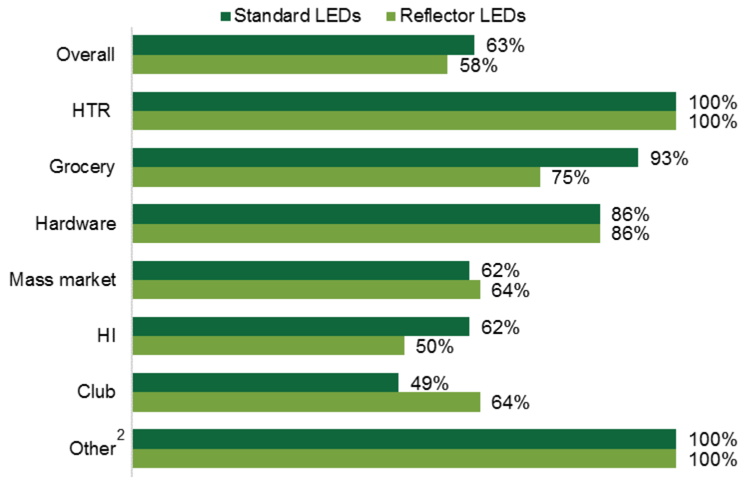
Suppliers' retail channel-level estimates resulted in higher NTG ratios in the HTR channels and lower NTG ratios in the big box stores, including HI, mass market, and club channels (Figure 3). Because big box stores composed over 90% of the program's 2015-2016 program sales for standard LEDs and LED reflectors, the NTG estimates for these channels largely determined the program-level NTG results. For example, HI retailers represented 68% of program sales and had NTG ratios of 62% for standard LEDs and 50% for specialty LEDs. Club retailers represented 18% of program sales and had NTG ratios of 49% and 64% respectively. Finally, mass market retailers, representing 6% of program sales had NTG ratios of 62% and 64%, respectively.

The consensus panel determined that HTR channels rely on program support more than other channels. Panelists, therefore, assigned higher NTG ratios for HTR channels, adding 20 percentage points to their recommended annual estimates.

[26] According to program staff, the program considers stores HTR based on two factors: 1) if the store is located in a low-income community with a large minority and/or elderly population and 2) if it is a discount store, such as Dollar Tree or Ocean State Job Lot. For the purpose of analysis, the study used the second criterion to classify a store as HTR.

Figure 3: LED Retrospective NTG Estimates by Retail Channel for 2015-2016

(Supplier interview results, n=16)[1]



[1] Sample sizes vary by retail channel.

[2] *Other* represents LED sales through special program-driven community or corporate events.

Table 7 shows the number of supplier interviewees who provided NTG estimates (i.e., sample sizes) for each retail channel and the percentage of total program sales through that channel which those interviewees cumulatively represented. Except for the hardware channel, the NTG estimators cumulatively accounted for the vast majority of program sales. Furthermore, the hardware channel accounted for only a very small percentage of 2015-2016 program LED sales (<1% for both standard and reflector LEDs).

Table 7: Retrospective LED NTG Estimates and Program Sales by Retail Channel and Bulb Type

(Supplier interviews results)

	Standard LEDs			Reflector LEDs		
Retail Channel	n	NTG	% of Program Sales[1]	n	NTG	% of Program Sales[1]
HTR	2	100%	99%	2	100%	99%
Grocery	2	93%	68%	1	75%	59%
Hardware	2	86%	27%	2	86%	27%
HI	7	62%	100%	9	50%	99%
Mass market	4	62%	100%	3	64%	100%
Club	3	49%	100%	4	64%	98%
Other	1	100%	100%	1	100%	100%
Overall	**16**	**63%**	**99%**	**16**	**58%**	**99%**

[1] Percentages of 2015-2016 program sales through the respective channel which estimators represented.

➢ ***Demand elasticity modeling showed particularly high net-of-freeridership among mass market retailers.***

When compared by retail channel, LEDs sold in mass market stores exhibited particularly high net-of-freeridership at 85%, which is counter to what the suppliers estimated. Additionally, mass market retailers produced the greatest estimated elasticity for LEDs (-2.72)—it was noticeably higher than that of LEDs overall (-1.61) (Table 8). Recall that greater elasticities mean greater price sensitivity. According to program data, however, mass market retailers accounted for only 5% of LED sales in 2015, yet club and HI stores accounted for 85% of LED sales (Table 20 in Appendix A.2.1). [27]

Table 8: LED Retrospective Net-of-Freeridership and Elasticities by Retail Channel

(Demand elasticity modeling results)

Retail Channel	Elasticity	Net-of-Freeridership
Club	-1.52	55%
HI	-1.68	63%
HTR and grocery[1]	-0.53	42%
Mass market	-2.72	85%
Overall	**-1.61**	**61%**

[1] HTR stores represented a limited percentage of sales in the model; a such, the analysis aggregated HTR and grocery.

➢ ***Comparable average markdowns across retail channels indicates that differences in elasticities were a primary driver of differences in freeridership.***

Table 9 shows average prices per LED by retail channel. Before and after applying incentives, grocery retailers exhibited the highest price per bulb.

Overall, LEDs average markdown (i.e., the incentive as a share of the original price) was similar across channels, ranging from 46% to 55%. With relatively comparable markdown levels, differences in elasticities between channels served as the primary driver of freeridership differences between retail channels.

[27] Mass market retailers may provide an opportunity to lower program freeridership with increased program focus. However, mass market retailers typically do not move the same volume as HI and club retailers. Additionally, future elasticities will likely be influenced by the prevalence of and competition from lower-priced, non-ENERGY STAR LEDs.

Table 9: Price per LED by Retail Channel

(Lighting program data – 2015)

Retail Channel	Average Values			
	Initial Price per Bulb	Rebate per Bulb	Final Price per Bulb	Markdown %
Club	$ 10.07	$ 4.66	$ 5.41	46%
HI	$ 9.84	$ 4.54	$ 5.30	46%
HTR and grocery[1]	$ 13.41	$ 7.09	$ 6.32	53%
Mass market	$ 8.67	$ 4.74	$ 3.92	55%
Overall	**$10.12**	**$4.79**	**$5.33**	**47%**

[1] Demand elasticity modeling required adequate sample sizes for statistical significance so it grouped HTR and grocery channels. HTR retailers alone had the lowest final price per bulb ($3.50). After removing HTR bulbs from the estimate, the average weighted final price per bulb was still $6.32, suggesting that grocery stores dominate this combined category.

3.2 Prospective NTG Estimates

- ***Suppliers predicted decreases in LED NTG from 2017 to 2021, dropping from 40% to 35%. The consensus panel also expected declines, recommending placeholder values that drop from 47% in 2017 to 33% in 2020. However, the panel also recommended reevaluating NTG in the near future to verify or alter these prospective values, citing the rapidly changing and uncertain lighting market.***

Only one of the primary-research tasks had the ability to measure prospective NTG ratios—supplier interviews. This was done by asking suppliers to estimate market share with and without the program in 2017 to 2020.[28] As shown in Table 10, suppliers predicted steadily decreasing prospective NTG ratios of 40% in 2017, 38% in 2019, and 35% in 2021. They estimated that standard LED NTG would be 39% in 2017 but hold steady through 2021 at 37%. Suppliers estimated lower NTG for reflector LEDs in 2017 through 2021, starting at 41% and declining to 33%.

The consensus panel considered the results of the supplier interviews and various market indicators and intelligence to estimate prospective NTG. The panel reached a consensus estimate of 47% for combined non-HTR LED NTG (standard [A-line], reflector, and other specialty bulbs) in 2017, and expected steady declines after that: 40% for 2018, 36% for 2019, and 33% for 2020. Due to market and legislative uncertainties they suggested that these values be reevaluated in 2017 or 2018 and no later than 2019. The panel recognized that reflector NTG may be slightly lower than standard NTG, but they predicted that the estimates were close enough (varying by five percentage points or less) and the uncertainty great enough to use the same estimate for all types of LEDs.

[28] Importantly, the prospective market share estimation method differs from the retrospective one, which was based on suppliers estimating the impact of the program on their organization's sales. Therefore, the two approaches are not directly comparable, and the study discusses only prospective estimates here.

Because they were asked about overall market share, suppliers did not address prospective NTG by retail channel. However, as noted, the consensus panel explained that other market information points to a stronger program impact on the HTR channel than other types of stores, so they suggested prospective LED NTG estimates 20 percentage points higher for the HTR market than for the market overall: 67% for 2017, 60% for 2018, 56% for 2019, and 53% for 2020.

Table 10: Prospective NTG Estimates by Year and Bulb Type

(Supplier interview results)

LED Bulb Type	n	Prospective		
		2017	2019	2021
Standard	13	39%	35%	37%
Reflector	13	41%	43%	33%
All	**13**	**40%**	**38%**	**35%**

These values are also considerably lower than the Massachusetts consensus panel estimates for overall LED NTG ratios of 85% for 2017 and 78% for 2018 (Section 3.3), although as noted earlier, the market has changed considerably since the panelists there developed their estimates, which likely limits their current applicability.

3.3 Benchmarking

Table 11 lists the literature used in the benchmarking effort. As mentioned previously, overall LED NTG ratios ranged from 73% to 100%, with a midpoint of 85% (n=9 studies). As mentioned previously, these values are higher than the overall net-of-freeridership and NTG ratios estimated for R1615: 61% from demand elasticity modeling, 70% from sales data modeling, and 61% from supplier interviews. Underscored by the consensus panel, the estimates from other states, however, were developed prior to the R1615 research, and given the rapidly changing market, it is not surprising that Connecticut values would differ from those of earlier studies. Some of the NTG values examined represented deemed or assumed NTG, while others did not clearly define the source of the estimate. The values for Efficiency Maine (77%), Xcel Colorado (91%), and Entergy Arkansas (80%) came from demand and price elasticity modeling. Many of these efforts included participant spillover and nonparticipant spillover in addition to freeridership, possibly providing further evidence that the R1615 demand elasticity modeling effort may underestimate the Connecticut program influence.

Supplier interviews also informed the Xcel Colorado and PG&E estimates. Connecticut suppliers' estimate for reflector LEDs (58%) was much higher than the only NTG ratio for reflectors found in literature: PG&E's 2013-2014 upstream lighting program evaluation conducted by DNV GL resulted in a NTG ratio of 27% for reflector LEDs. The reader should note that the two to three years that have passed since that evaluation and the geographical differences between California and Connecticut do not make the R1615 and the California studies perfectly comparable. The California estimates also stand out as being far lower than any others developed, which could reflect a more mature LED market in the state or variations in the estimation methods used there.

Table 11: Benchmarking Retrospective NTG Estimates

State	Entity/Company	Associated year	LED NTG	Research methods
Northeast				
MA	Statewide	2016[1]	93%	Prospective NTG prediction from consensus panel
MA	Statewide	2014	95%	Retrospective NTG estimate from consensus panel[3]
RI	Statewide	2012	92%	Assumption[4]
ME	Efficiency Maine	2013-2014	77%	Price elasticity
CT	Statewide	2014	82%	Demand elasticity, sales data modeling, supplier interviews
Central/Midwest				
CO	Xcel	2015	91%	Demand elasticity, store-intercepts, supplier interviews
Undisclosed (not yet public)		2015	85%	Literature review
IL	ComEd	2014-2015	73%	Store-intercepts
West				
CA	PG&E	2013-2014	40% / 27%[2]	Choice model and supplier interviews
	SCE		42% / 28%	
	SDG&E		35% / 28%	
South				
NM	SPS	2014	100%	Assumption[2]
TX	CPS Energy	2015	85%	Assumption[2]
AK	Entergy	2013	80%	Demand elasticity modeling

[1] Represents a prospective NTG prediction developed in 2015 based on research completed in 2014.
[2] Standard and reflector LEDs, respectively
[3] NTG estimates derived from individual studies ranged from 75% for supplier interviews to 98% from sales data modeling for 2013.
[3] Values derived from program savings assumptions (such as from a PSD)

One study published prospective NTG ratios, estimating as far forward as 2018 (Table 12). Drawing on results from a consensus panel held in Massachusetts in May of 2015, it resulted in LED NTG ratios of 85% for 2017 and 78% for 2018. These rates are considerably higher than those predicted by the supplier interviewees from R1615 which estimated 40% for 2017, although the Massachusetts estimates are dated given the rapid change in the market. The consensus panel concurred with this perspective.

Table 12: Benchmarking Prospective NTG Estimates

State/Region	Entity/Company	LED NTG		Research methods
		2017	2018	
CT	Statewide	40%	-	Supplier interviews
MA	Statewide	85%	78%	Consensus Panel

The consensus panel considered the strengths and weaknesses of each study to guide the selection of the most reliable NTG values to use for Connecticut's LEDs. Ultimately, the consensus panel determined that all studies were too dated or geographically distant to strongly factor into their considerations. The bullets below address additional strengths and weaknesses of the studies; these assertions come the authors of the literature and the expertise of the consensus panel:

- **Demand and price elasticity modeling.** Using inputs such as price, promotional activity, product placement, and sales variations within a specified program period, the elasticity modeling approaches offer statistically reliable results compared to activities like in-depth interviewing, literature reviews, or consensus panels. For both Connecticut studies, some retail channel data were missing which may have led to incomplete results that do not take into account the full picture. The Xcel Colorado demand elasticity modeling had a low measurement error, signaling its potential reliability; on top of that, it was weighted with two other research effort results (store intercepts and supplier interviews). The Xcel study included spillover in addition to freeridership.
- **Supplier interviews.** R1615, the 2014 Connecticut study, the Xcel Colorado, and California studies drew from supplier interviews. While suppliers offer context and a good understanding of the market, and can represent a large portion of sales in a single interview, they may be biased because of their inherent interest in program continuation because their companies leverage program incentives.
- **Store intercepts**. Store intercepts offer the opportunity to collect details on customers' true decision-making process; they also offer the opportunity to achieve large enough sample sizes to estimate NTG with statistically significant precision. The ComEd Illinois study, for example, had a sample size of 726. It includes spillover and nonparticipant spillover. The California study's choice modeling inputs included store intercept data.
- **Consensus panels and literature reviews.** Qualitative efforts drawing on the perspectives of industry experts and industry-wide data create the opportunity for sanity checks and assessments of the reasonableness of quantitative findings. The Massachusetts study used a consensus panel. The MidAmerican literature review was also perspective based; researchers used the average NTG values associated with programs which they perceived as comparable to the MidAmerican program and were geographically close to Illinois—they do not account for nationwide dynamics.
- **Program savings documents.** A few of the values from the benchmarking effort are assumed values that administrators have used in their program planning

documentation. It is unclear from where the Rhode Island, SPS New Mexico, and CPS Energy Texas NTG ratios came so these should be considered with caution.

4 Section 4 Market Trends and Predictions

The following section reports residential lighting sales trends and suppliers' predictions for upcoming sales trends that informed the consensus NTG process described above.

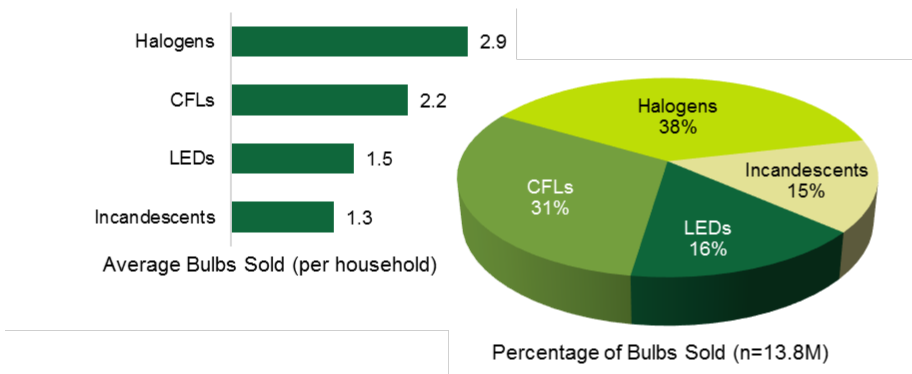
4.1 Recent Market Trends

- ***Aggregated sales data show that halogens and CFLs dominate the residential market as a whole in 2015, yet LED market share has been on the rise.***

Connecticut residents were most likely to have purchased halogen bulbs in 2015, with the average household having purchased 2.9 of them that year; in comparison, households purchased only 1.5 LEDs, on average (Figure 4). LightTracker panel sales data (adjusted by square footage of retail space) showed that across all residential bulb sales in 2015 in Connecticut, LEDs accounted for less than one-fifth purchases (16%), while halogens accounted for 38% of them.

Figure 4: Residential Lighting Sales in 2015 in Connecticut

(Based on LightTracker adjusted panel data)

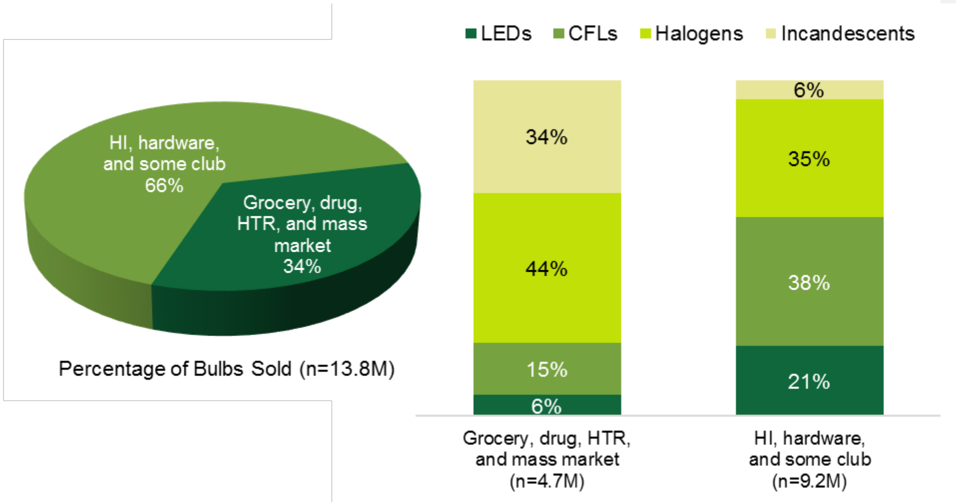


The adjusted panel data included two types of data for 2015—one projected from scanned UPCs of purchased products obtained from a voluntary consumer panel and one derived from POS data. The projected sales consumer panel data included HI, hardware, and some club retailers, while the POS data came from grocery, drug, HTR, and mass market retailers; the latter group accounted for about one-third of 2015 bulb sales in Connecticut (34%). As shown in Figure 5, LEDs (21%) and CFLs (38%) accounted for much larger shares of the HI, hardware, and club retailer group's sales in comparison to the grocery, drug, HTR, and mass market retailer group's sales (6% and 15%, respectively). The latter group had considerably larger shares of halogen and incandescent bulbs than the former group.

Despite that the grocery, drug, HTR, and mass market retailers represented the minority of 2015 sales in Connecticut, they were the only data available for looking back at actual trends across years. Therefore, the trends illustrated and discussed below may overestimate incandescent and halogen sales and underestimate CFL and LED sales.

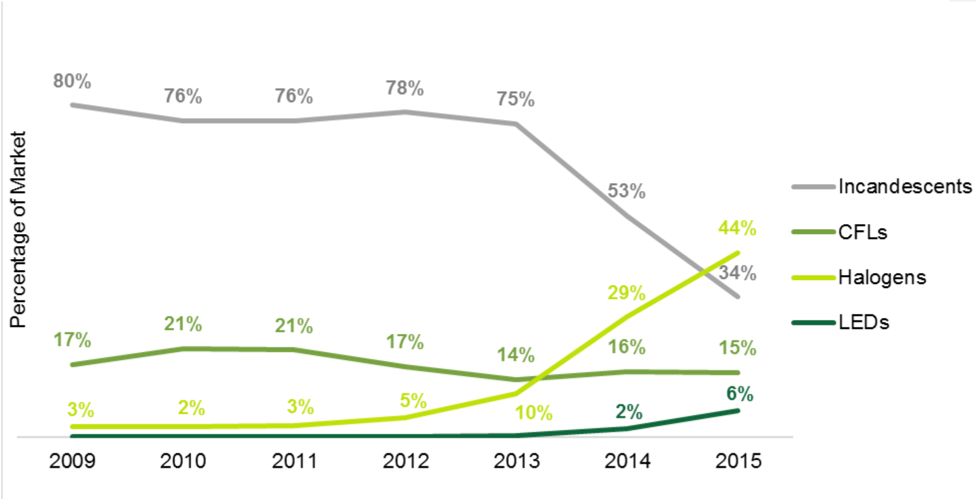
Figure 5: Residential Lighting Market Shares in 2015 in Connecticut by Retailer Group

(Based on LightTracker adjusted panel data)



Longitudinal POS data for the grocery, drug, HTR, and mass market retailers shows that incandescent bulbs decreased from representing four-fifths of the market in 2009 (80%) to only about one-third of the market in 2015 (34%). As shown in Figure 6, halogen bulbs diverged, comprising only 3% of those retailers' market in 2009 but growing to represent more than two-fifths of it in 2015 (44%). CFLs experienced little change over the seven-year period, beginning at 15%, peaking in 2010 and 2011 at 21%, and finishing at 17% of that market in 2015. LEDs represented less than 1% of that market until 2014 (2%) and then tripled in market share in one year (6% in 2015). As discussed in detail below, suppliers estimated that LEDs will continue to rapidly gain market share in the coming years, while shares of halogens, CFLs, and incandescent bulbs will decline.

Figure 6: Residential Lighting Sales Trends from 2009-2015 in Connecticut
(Based on subset of retailer LightTracker POS data)[1]



[1] Charts include sales from the grocery, drug, HTR, and mass market retailers only.

4.2 Market Share Predictions

To develop the prospective NTG estimates described in Section 3.2, suppliers provided their estimates of Connecticut LED market share estimates assuming, first, that the Lighting Strategy continued through 2021, and, second, that the program ended in 2016.

Most of the Connecticut interviewees, however, also served the Massachusetts program. To leverage resources, suppliers engaged in one interview covering related topics in both states. As part of the Massachusetts evaluation, suppliers were asked to predict market shares for **all** lighting technologies for 2017, 2019, and 2021, not only LEDs. As with the Connecticut-specific estimates, the suppliers first assumed that the Massachusetts program continued to provide LED discounts through 2021, and second assumed the program ended LED discounts in 2016. Due to the length of the interview, the study did not ask for Connecticut-specific estimates for all bulb types, and instead uses Massachusetts responses as a proxy for Connecticut market share predictions.

The Connecticut and Massachusetts market share estimates presented below differ. Importantly, this is most likely a result of methodological differences in data collection and not inherent differences in the lighting markets between the two neighboring states. The Connecticut-specific market share estimates obtained to calculate NTG ratios addressed LEDs only, and did not ask for estimates for other bulb technologies. In Massachusetts suppliers had to provide market share estimates for all technologies, and those estimates had to sum to 100%. It is likely that, in Massachusetts, suppliers adjusted their market share estimates until they arrived at values that summed to 100%. In Connecticut, suppliers likely gave the first response for LED market share since they did not have to compare them to other bulb types.

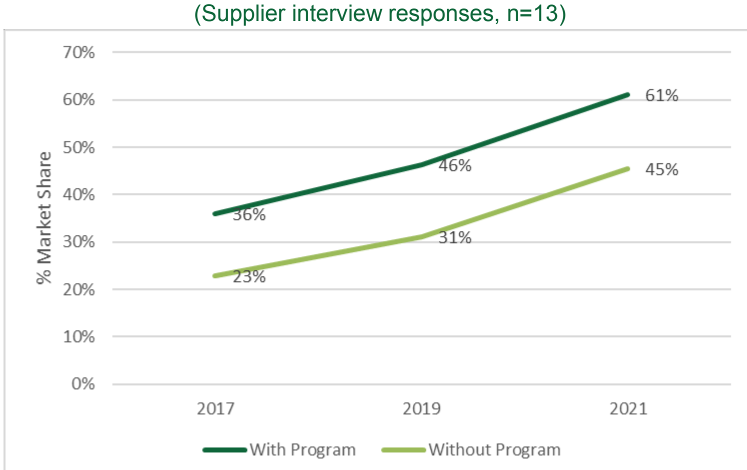
Finally, the study presents the unweighted market share estimates for both Connecticut and Massachusetts.[29] This reflects a decision made by the Massachusetts Program Administrators and Energy Efficiency Advisory Council consultants reflecting that state's evaluation needs. Showing the unweighted data for both states increases comparability in comparing Connecticut and Massachusetts and avoids any confusion that could arise from comparisons of this report and similar Massachusetts reports.[30]

- ***Suppliers expect that continued program activity boosts standard and reflector LED market shares by 13 to 16 percentage points, resulting in a 2021 predicted market share of 61% and 53% with the program. They expect the trajectory of market share will increase 41% in the with program scenario and 50% in the without program scenario.***

Connecticut suppliers predicted that standard market share with the program would be 36% in 2017, increasing to 46% in 2019 and 61% in 2021. Market shares without the program were predicted to be 23% in 2017, 31% in 2019, and 45% in 2021. Predicted market shares with the program were one-fourth to one-third higher than without the program. The expected trajectory was 41% between 2017 and 2021 in the scenario with program support and 50% in the scenario without program support.

Figure 7: Market Share Predictions for Standard Bulbs by Year in Connecticut

(Supplier interview responses, n=13)



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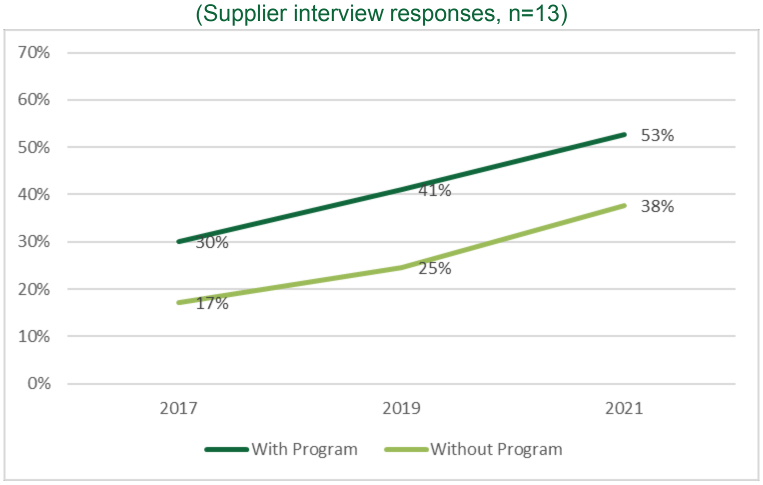
[29] The NTG ratios presented in Section 3.2 remain weighted by the proportion of sales associated with each supplier, the same weighting method used in prior Connecticut studies.

[30] That is, if this study presented one set of market share estimates for Massachusetts and the Massachusetts studies presented another set of estimates.

The Connecticut suppliers predicted slightly lower market shares for reflector LEDs. They predicted a reflector market share of 30% in 2017, 41% in 2019, and 53% in 2021. Predicted reflector market share without the program were between 13 and 16 percentage points lower: 17% in 2017, 25% in 2019, and 38% in 2021. Predicted market share with the program was 30% to 40% higher than without the program. The expected trajectory of growth was slightly higher than for standard LEDs at 43% between 2017 and 2021 in the scenario with program support and 55% in the scenario without program support.

Figure 8: Market Share Predictions for Reflector Bulbs by Year in Connecticut

(Supplier interview responses, n=13)



- ***Suppliers expected that program rebates will continue to be valuable because they reduce the first cost of LEDs, but the rapid adoption of LEDs independent of the program will decrease the influence of the program.***

When asked to explain their market share predictions, the most frequent explanation (46% of respondents) was that if the Connecticut program continued, its rebates would support a higher level of LED sales because first cost is the biggest barrier to LED sales. However, nearly two-fifths of the respondents (38%) also observed that LED sales were increasing at a rapid rate and cited this as a reason for not giving the program more attribution for LED sales in future years.

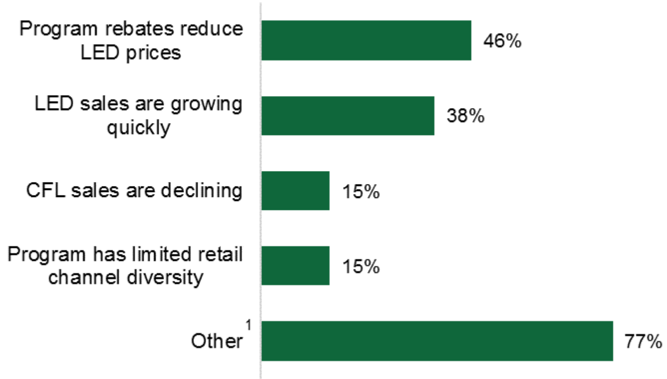
> *"Without the program, people [wouldn't] pay for LEDs"*
>
> -Supplier interviewee

It is important to recall that the suppliers made their predictions about the future of the LED market prior to the 2016 presidential election. Given that some of the suppliers noted that a Trump presidency would change their thoughts about the future of the residential lighting market, it is possible that, if asked today, they would attribute greater impact to the program for future LED sales. Section 4 offers further context for external market factors.

One interviewee described numerous dynamics that played into the estimates; these responses were unique from the other more common responses. Thus, the *Other* category in the figure is represented by a large percentage (77%). Among the interviewee's explanations, the interviewee pointed to various aspects of the LED industry changing, such as price reductions; lamp, socket, and fixture markets transforming; and advancements in technology.[31]

Figure 9: Explanations for Prospective NTG Estimates

(Supplier interview responses, n=13)



Note: Total response percentages exceed 100% because multiple responses were allowed.
[1] Includes reasons that were mentioned only once.

- ***According to the Massachusetts suppliers' predictions, program support in the next several years will remain vital to LEDs' steadily increasing dominance in the regional market.***

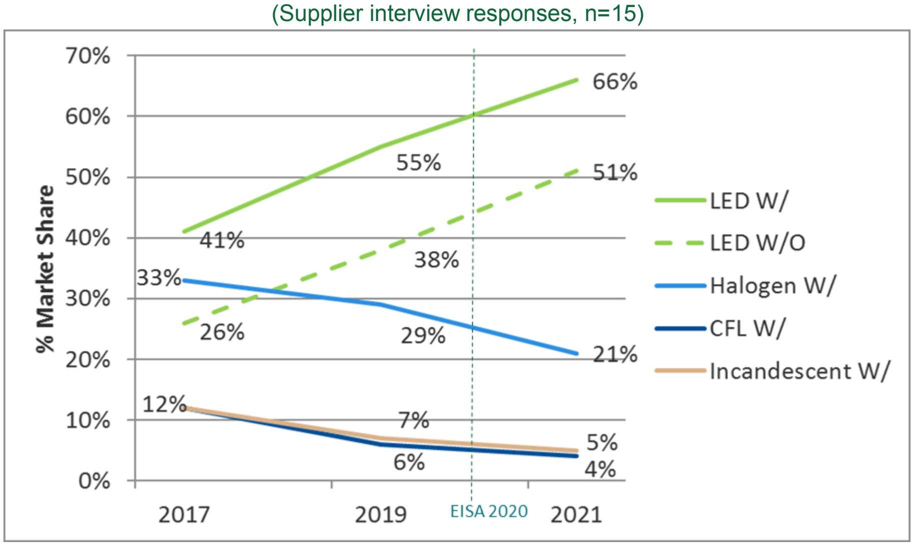
The 15 suppliers serving Massachusetts—most of whom also participated in the Connecticut program—provided predictions of market share for all bulb technologies in the presence and absence of the program from 2017 to 2021. The Massachusetts suppliers predicted that, should the Connecticut Lighting Strategy continue, LEDs would grow to represent one-half of the standard (55%) and reflector (49%) bulb markets by 2021 (Figure 10 and Figure 11).

[31] The interviewees responses in full included 1) the assumptions that halogens will go away in 2020 due to EISA; 2) the assertion that ENERGY STAR is a trusted brand with many consumers; 3) greater general availability of LEDs; 4) new housing will have different mixes of lighting sockets/fixtures than existing homes; 5) the LED fixture business is getting bigger; 6) the Connecticut program has lower rebates and smaller product allocations than the Massachusetts upstream lighting program; 7) A-lamps will continue to be a popular lamp type; 8) LED prices are coming down; 9) LED adoption in Connecticut is lower than it is in Massachusetts; 10) the simultaneous existence of both ENERGY STAR and non-ENERGY STAR LEDs will help LEDs stay competitive with halogens; and 11) the program helps improve LED technology.

Without the program, standard LEDs would not account for one-half of market share until 2021, and reflectors would only reach 47% market share by 2021. Suppliers predicted that the market share of all other bulb types would decline in the presence (shown) and absence (not shown) of the program. For standard bulbs, incandescent and CFL bulbs garner very small portions of the market share (less than one-fourth) in 2017 and decline from there. Halogens hang onto market share longer, falling from 33% in 2017 to 21% in 2021. Reflector trends vary slightly, driven largely by the expectation that incandescent reflectors would retain market share for a longer period of time—an assumption that the recent DOE rulemaking regarding the expanded definition of general service lamps brings into question.

Figure 10: Market Share Predictions for Standard Bulbs by Year in Massachusetts[1]

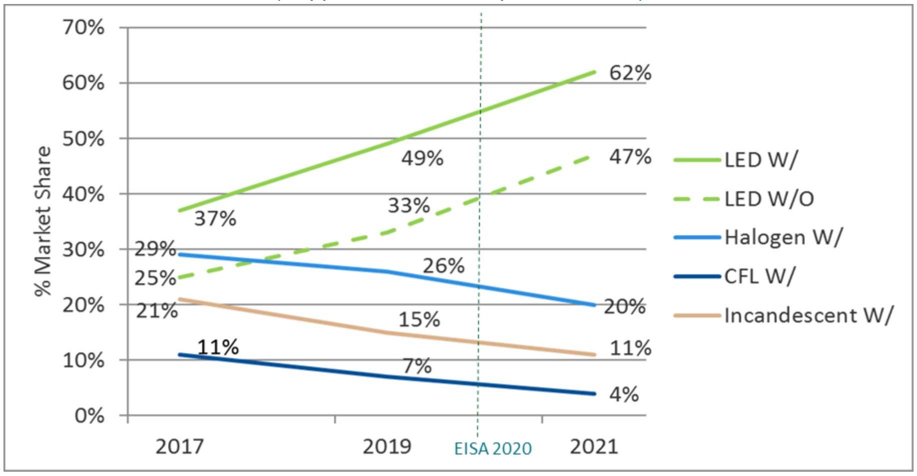
(Supplier interview responses, n=15)



[1] W/ = with the program; W/O = without the program. All other trend lines assume the program will still be providing incentives after 2016.

Figure 11: Market Share Predictions for Reflector Bulbs by Year in Massachusetts[1]

(Supplier interview responses, n=15)



[1] W/ = with the program; W/O = without the program. All other trend lines assume the program will still be providing incentives after 2016.

4.3 Market Impacts of ENERGY STAR 2.0

This section summarizes the interview responses of participating lighting market actors concerning the implementation of the new ENERGY STAR specification 2.0. The key implications of this new specification are that

1. Most CFLs will no longer be qualified for the ENERGY label (as of January 17, 2017, seven were), and
2. Some previously unqualified LEDs will qualify for the label. These newly qualified LEDs tend to have shorter measure lives (15,000 hours) and often lack dimmability and some other functions when compared to many LEDs previously qualified under ENERGY STAR 1.1 (25,000 hours for general service with most being dimmable).

Although it officially went into effect on January 2, 2017, the DOE allowed manufacturers to qualify and label bulbs under ENERGY STAR 2.0 in the summer of 2016. Programs across the nation—including the Connecticut Lighting Strategy—have started to offer newly qualified LEDs. The Companies have also accelerated the timeline for removing all program incentives from CFLs, and will cease to offer them in 2017 instead of 2018. The program and evaluation staff members explain that this decision rested on the fact that they only incent ENERGY STAR-qualified products because the more rigorous testing provides greater assurance of the quality of the product.[32] As part of its benchmarking efforts, this study has confirmed that nearly all program administrators still offering CFLs in 2016 will also remove them from their program offerings in 2017, citing the same reasons as the Companies in Connecticut.

Interviewers asked suppliers to reflect on 1) ENERGY STAR 2.0's impacts on the market as a whole; 2) its impacts on the LED market, specifically; and 3) its impacts on the halogen market, specifically. This sequential ordering of questions may make responses appear inconsistent in the following section. For example, when first asked about the ENERGY STAR 2.0's impact on the market generally, only three interviewees suggested that it would cause LED sales to increase; however, when asked what its impact would be on LEDs specifically, five other interviewees predicted that it would cause LED sales to increase.

4.3.1 General ENERGY STAR 2.0 Market Impacts

- ***Suppliers anticipated that ENERGY STAR 2.0 will cause CFL sales to decrease and stimulate LED sales to increase, with some suggesting LEDs and halogens will take the place of CFLs.***

As shown in Figure 12, when asked to project the impacts of ENERGY STAR 2.0 specification on the lighting market in Connecticut, suppliers were most likely to say that it will cause CFL sales to decrease (36%), LED sales to increase (21%), or would have no impact (21%). Some respondents predicted that both LEDs and halogens would take over parts of the CFL lost market share. A few lighting suppliers noted that all their products were already compliant with ENERGY STAR 2.0.

One respondent envisioned a scenario where the new specification would cause the ENERGY STAR share of total LED lamp sales to increase initially from current levels and then eventually decrease. The initial increase would be due to the new specification, including some value-line LED lines which were not formerly ENERGY STAR qualified.[33] However, the respondent feared that consumers would then shift to the even less expensive value-line LEDs that will still lack ENERGY STAR qualification. Assuming they are satisfied with the quality of these bulbs, it could lead to decreases in ENERGY STAR market share, even if overall LED market share increases.

Two lighting suppliers raised concerns about the quality of some of the new ENERGY STAR-qualifying LED products; one was concerned that inconsistent quality could lead to customer dissatisfaction.

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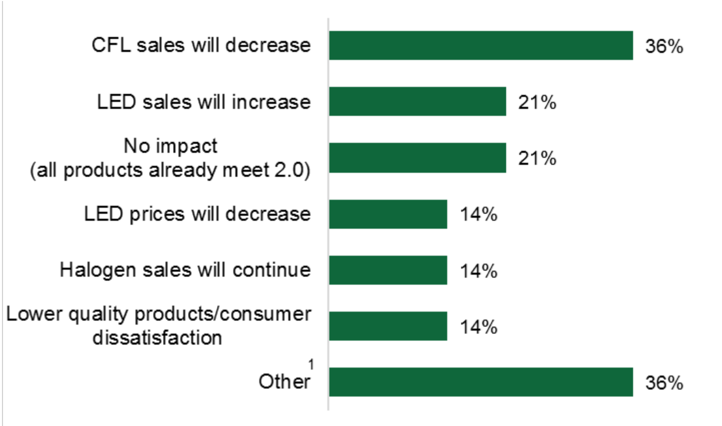
[32] As part of the preliminary work for Study R1616, the interviews addressed the invigorated HTR component of the Lighting Strategy. The decision not to offer CFLs will lead the program to shift from CFLs to LEDs in the stores targeted to reach customers considered HTR.

[33] The report addresses value-line LEDS that still will not qualify for ENERGY STAR 2.0 in Market Impacts of Non-ENERGY STAR LEDs.

Figure 12: Expected Impacts of ENERGY STAR 2.0 on Connecticut Lighting Market

(Supplier interview responses, n=14)



Note: Total response percentages exceed 100% because multiple responses were allowed.

[1] *Other* effects include all effects which only a single respondent mentioned. These include 1) the possibility that halogen market share will increase as it takes over CFL market share; 2) the prospect of an increase in the quality of LEDs due to the new specification; 3) a prediction of higher LED prices due to the new specification; 4) the need for larger program incentives to make the more expensive LEDs more competitive with other lamp technologies; and 5) the prospect (discussed above) that the new specification would cause the ENERGY STAR share of total LED lamp sales to initially increase from current levels and then eventually decrease.

4.3.2 ENERGY STAR 2.0 Impacts on LEDs and Halogens

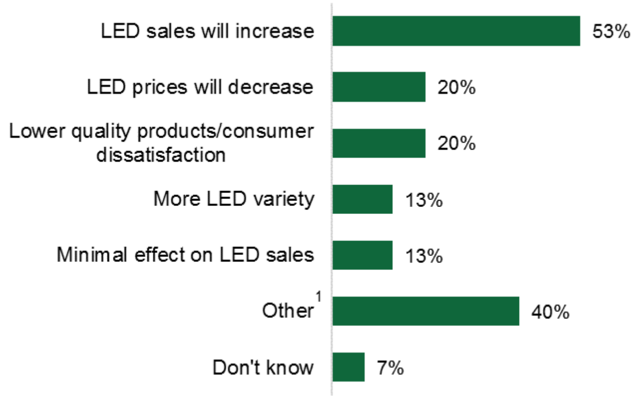
The interviewers also asked the lighting suppliers about the impacts of the ENERGY STAR 2.0 specification on LED bulbs in particular. Over one-half of respondents (53%) said that the new specification will lead to an increase in LED sales (Figure 13). Most suppliers cited lower prices as the main driver of these increased sales. They speculated that the new specification would allow the sale of less expensive LEDs that would be more cost competitive with other lighting technologies, particularly if program incentives were still available—especially for standard LEDs. One respondent also thought that LEDs would grab some of the market share that CFLs would be losing. Two respondents thought that higher LED costs could lead to a plateauing of LED market share as long as alternative lower-cost lamp technologies were still available

Three suppliers predicted that the new specification would lead to lower quality LEDs. One respondent opined that consumers do not care much about the shorter lifespan of some of these new ENERGY STAR-qualified bulbs, but that consumers may have issues with some LED A-lamps not being omnidirectional.

Two said that LED prices could increase not only for higher efficacy general purpose products, but also for newer LED technologies such as higher-wattage and three-way products.

Figure 13: Expected Impacts of ENERGY STAR 2.0 on LEDs

(Supplier interview responses, n=15)



Note: Total response percentages exceed 100% because multiple responses were allowed.

[1] *Other* effects include all effects which only a single respondent mentioned. These included 1) helping ENERGY STAR standard LEDs compete better with non-ENERGY STAR LEDs, 2) more variety in LEDs, 3) less variety in LEDs, 4) not much impact because all their products already meet the new ENERGY STAR specification, 5) the new specification will cause the ENERGY STAR share of total LED lamp sales to initially increase from current levels and then eventually decrease, and 6) the specification will result in customers only purchasing ENERGY STAR LEDs if program rebates are available.

Suppliers discussed their opinions about the impact of the new ENERGY STAR specification on halogens. They did not agree as to whether halogen sales would increase, decrease, or stay the same due to the new specification. Those who predicted that halogen sales would decline assumed that most halogens would be unable to meet the EISA 2020 efficacy standards, so manufacturers may reduce production. Likewise, the increasing popularity and decreasing cost of LEDs would also take away market share from halogens.

Interviewees who thought halogen sales would remain the same or possibly increase pointed to the decline in CFL market share as an opportunity for halogens. They noted that once CFLs disappear, halogens will be the lowest cost option for price-sensitive customers. One respondent also observed that there continues to be a segment of the lighting market that simply prefers incandescent and/or halogen technologies over CFLs and LEDs.

Some respondents noted that whether the Connecticut program continues to rebate LEDs will be the key factor as to whether halogen sales would increase or decrease. They theorized that if the program removed LED subsidies, many customers would switch back to halogens for first cost reasons.

4.3.3 ENERGY STAR 2.0 on CFLs

- ***Suppliers predicted that ENERGY STAR 2.0 will greatly curtail CFL sales and significantly decrease CFL market share.***

In response to ENERGY STAR 2.0, which means that most CFLs no longer qualify for the label, one manufacturer reported that his company briefly considered producing CFLs that could meet the new specification but eventually decided against it. Two manufacturers said that their companies planned to stop producing CFLs, and others noted that a major national mass market retailer announced it will stop selling CFLs in 2017. Some interviewees speculated that not only would CFL sales decline, but CFL diversity also would decrease. One respondent hypothesized that the majority of future CFLs sales will be limited to more popular higher-wattage models. Only one respondent explicitly thought that much of the lost CFL market share would go to halogens.

4.4 Market Impacts of CFL Phase-out

- ***Suppliers opined that the program's CFL phase-out would not intensify declining CFL sales, but they perceived that program support is vital in LEDs taking over that market share.***

According to program staff, at the start of 2012, only 1% of program incentive dollars went to LEDs, and in the 2012 to 2015 cycle 57% on average was devoted to LEDs. Currently, LEDs account for about 70% of program incentives. The Companies had anticipated continuing to sell at least some CFLs through 2018, but, as a result of ENERGY STAR Specification 2.0, the Lighting Strategy will shift to an all-LED program at some point in 2017.

Suppliers shared their perspectives on this programmatic shift: The consensus was that CFL sales were declining sharply anyway, and the removal of program support would not have much impact on this trend. One supplier predicted that some retailers would continue to sell CFLs, but these would be limited to 60W- and 75W-equivalent multi-packs, high-wattage CFLs, and 3-way products. The lighting suppliers predicted that LEDs would take over most of the lost CFL market share, with halogens also gaining some sales.

Respondents also emphasized that continued program support was necessary to ensure that LEDs—and not halogens--captured the lost CFL market share, especially in the 60W-, 75W-, and 100W-equivalent ranges. They claimed that if the program failed to make these LEDs price-competitive, many consumers would seek out halogens and lower cost incandescent and CFL bulbs still on the shelves. One supplier summarized,

"If the program stays, we will see LED market share go up, and we will see every other market share go down, at least a little bit. If the program goes, halogen market share is going to go up. LED market share will fill the void of CFLs and probably some of the incandescent market as it dies. But if Massachusetts or Connecticut—or any other program—pulled out today, the sale of LEDs would be reduced by significant margins. The sale of halogen-compliant products would be increased by significant margins."

A

Appendix A Methodology – Additional Details

The following appendix offers additional details on the methodology behind the research findings.

A.1 Sales Data Modeling

The following appendix section includes additional details on the methods for conducting the sales data modeling.

A.1.1 Sales Data Sources and Inputs

A.1.1.1 Lighting Sales

The LightTracker POS data set includes lighting sales data for grocery, drug, dollar, club, and mass market distribution channels. These data represent actual sales that are scanned at the cash register for participating retailers.

The NCP represents a panel of approximately 100,000 residential households across the nation that are provided a handheld scanner for their home and instructed to scan every purchase they make that has a bar code. For Connecticut, the NCP included approximately 680 households in 2015. The use of a scanner avoids potential *recall bias* that is prevalent in self-report methods that ask about lighting purchases, although some bias likely remains related to how often and for which products panelists remember to scan their purchases.

Although the dataset the LightTracker Initiative received from IRI included detailed records of lighting data purchases, the data required a considerable cleaning effort to ensure integrity and inclusion of all the necessary bulb attributes. For example, not all records had some of the more critical variables populated, including bulb type, style, wattage, or had clearly erroneous values (e.g., 60 watt CFLs).[34]

After thorough review and quality control of the dataset, LightTracker then re-classified, standardized, populated missing records, created additional variables, and performed general enhancements to the data, as described below.

To populate missing records, validate existing records, and include additional bulb attributes, the team created a proprietary Universal Product Code (UPC) database with approximately 20,000 bulbs from four sources:

- Manufacturer product databases provided to LightTracker;
- Product catalogs downloaded from manufacturer web sites via python-code based *web scraping*
- Product offerings downloaded from retailer web sites

[34] As mentioned earlier, the contract with the third-party data source precludes including many of these variables in the analysis, but the evaluators can use such data to identify errors and reclassify certain products (e.g., night lights).

- Automated lookups of online UPC databases, such as www.upcitemdb.com

LightTracker next merged the bulb database with the POS/Panel data, populating fields based on a hierarchy of data sources believed to be most reliable. Prioritization was typically based on the following order: manufacturer specifications, UPC lookups, original IRI-based database values. Web lookups also served to determine final assignments for a large number of bulbs.

In addition, LightTracker investigated the bulb assignment and the quantity of bulbs per package by examining the average price per unit and identifying outliers in terms of per bulb prices. This process helped identify misclassification of certain bulb types (e.g., bulbs that were flagged as low cost LEDs but were really LED nightlights, so needed to be considered as *other*), as well as bulb counts that sometimes represented box shipments (e.g., a package identified as having 36 bulbs was really a six-pack of CFLs that was shipped with six packages per box).

A.1.1.2 Program Activity

To research program activity, LightTracker utilized internal resources of evaluation teams working for CREED members (including NMR working for the EEB) and conducted a literature review of publicly available reports found on the internet or provided by program administrators or their evaluators,[35] and reached out to local utilities when reports were not available. Program activity data collected included:

- Total claimed CFL and LED upstream bulbs (broken out by bulb type) reported by each program
- Upstream CFL and LED incentives
- Total upstream program budget

It should be noted that, where available, LightTracker leveraged program expenditures as reported directly by administrators; otherwise they defaulted to ENERGY STAR reported expenditures as a proxy. Data from each program administrator were aggregated by state. Each state was assigned a modeling flag based on the source of and confidence in the data provided across all major program administrators, as outlined in Table 13. As an example, any state with no program activity (verified across members of each evaluator team) was assigned a *0*. A *1* was assigned if LightTracker had successfully collected all program activity data points from every program administrator (including any muni or coop activity) in a state. A *2* was assigned to any state that had some program administrator data captured but other program administrator data (usually overall program expenditures) derived from ENERGY STAR. A *3* was assigned to the remaining states where the sole data points were derived from ENERGY STAR. The modeling team was then able to iterate through the model using states with the most accurate data.

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[35] In particular, the approach relied on searches in the ENERGY STAR® Summary of Lighting Programs https://www.energystar.gov/ia/partners/downloads/FINAL_2015_ENERGY_STAR_Summary_of_Lighting_Programs.pdf website and also referenced the www.dsireusa.org website.

Table 13: Program State Classification based on Accuracy of Program Data for Sales Data Modeling

(Classifications made by LightTracker)

Source of Data in Model	Non-program State	LightTracker (solely)	LightTracker and ENERGY STAR	ENERGYSTAR (solely)
Model Flag[1]	0	1	2	3
States	Alabama Delaware Kansas Kentucky Mississippi Montana Nebraska North Dakota Tennessee Virginia	Arkansas[2] Connecticut[2] Georgia[2] Louisiana[2] Maine[2] Maryland[2] Massachusetts[2] Missouri[2] Nevada[2] New Hampshire[2] New Jersey[2] New Mexico[2] New York[2] Oregon[2] Rhode Island[2] Utah[2]	Arizona California Colorado Idaho Iowa Ohio Pennsylvania Texas Washington Wyoming	Florida Illinois Indiana Michigan Minnesota Oklahoma South Carolina South Dakota Vermont West Virginia

[1] The modeling flag is associated with the source and confidence in the data.
[2] States included in the sales data modeling.

For Connecticut program activity, the modeling team restricted the data to the 17 states with the most detailed level of program activity gathered (noted in Table 13), which ranged from very low levels of LED program activity to very high ones. This decision reflected two factors: 1) the desire to use the strongest data available on program activity, and 2) the fact that LED sales in 2015 remained small compared to other bulb types, limiting the model's ability to identify the impact of program activity on sales, which the researchers feared would result in Type II error (concluding that programs had no impact, when in fact they did)[36] simply because of low statistical power and incomplete data. The evaluators recognize the small sample size and limitation to states with programs as shortcomings of the resulting model.

[36] In statistical nomenclature, failing to reject the null hypothesis when in fact the alternative hypothesis is true.

For this reason, Table 14 shows the results of the Connecticut 2015 LED sales data model with non-program states included. Utilizing the non-program states adjusted r-squared to go negative and all of the predictors to no longer be significant.

Table 14: LED Sales Data Model with Program and Non-Program States

(n=27 states)

		Model Coefficient & P-Value
Independent Variables Row 1 = regression coefficient Row 2 = p-value of coefficient	Intercept	0.489
		0.844
	LED Program Spending per Household	0.056
		0.431
	Non-POS Retailers Sqft per Household	0.003
		0.980
	Political Index	0.030
		0.324
	Average Electricity Price	-0.268
		0.113
Model Adjusted R-squared		-.048

A.1.1.3 Presence and Absence of Retailers (Channel Variables)

LightTracker conducted secondary internet research in order to determine the number and the total square footage of store locations in each state for five primary energy efficient bulb retailers: Home Depot, Lowes, Walmart, Costco, and Menards (a combination HI, mass market store located in the Midwest).[37] These data were utilized as explanatory variables in the model since these retailers sell such a large quantity of light bulbs but their concentration varies in states across the nation.

A.1.2 Sales Data Model Specification

The primary goal of the model was to quantify the impact of state-level program activity on the sales of LED lighting. Key aspects of the lighting dataset as analyzed include:

- 2015 sales volume and pricing for CFLs, LEDs, halogens, and incandescent bulbs for all channels combined, and broken out by the POS and non-POS channels
- Data reporting by state and bulb type
- Inclusion of all bulb styles and controllability (e.g., three-way and dimmable)

The general form of the model is specified below, followed by a more detailed discussion of the data sources for each variable.

[37] This is a national model, and Menards is an important and expanding retailer in the Midwest. To exclude it would exclude a key retailer that could affect the results.

$$Total\ LED\ Sales\ per\ HH_i = \beta_0 + \beta_1 * LED\ Program\ Spending\ per\ HH + \beta_c * \sum_{1}^{c} Channel\ Variables + \beta_d * \sum_{1}^{d} Demographic\ Variables$$

Where:

Total LED Sales per HH$_i$ = Total LED sales in state i divided by the number of households in state i.

***LED Program Spending per HH$_i$* =** The number of 2015 retail lighting program dollars per household in state i. Equal to total retail lighting program expenditures in state i (LED incentive + non-incentive) divided by the number of households in state i.

Channel Variables:

Sqft NonPOS per HH$_i$ = The average non-POS retail square footage per household in state i. Equal to non-POS sqft divided by the number of households in state i.

Demographic Variables:

***Political Index$_i$* =** A state-level partisan voter index developed by Cook Political Report,[38] using presidential election voting results through 2014 as a state-level partisan proxy. A higher than 1.0 value represents greater Democratic influence and a value less than 1.0 indicates greater Republican influence.

***Average Electricity Cost$_I$* =** The State-level average residential retail rate of electricity, sourced directly from the Energy Information Agency (EIA)[39]

β_0 = The model intercept

β_1 = The primary coefficient of interest. This represents the marginal effect or program intensity, or the expected increase in the number of LED sales for $1 in additional program spending per household.

β_c and β_d = Array of regression coefficients for the channel variables and demographic variables

ϵ_i = Error term.

Clearly, there are other factors that influence the sales of efficient lighting, and the team considered a number of demographic, social, household, and retail channel variables to capture and control for the unique characteristics of each state that potentially affect the uptake of efficient lighting products. The study tested the following predictor variables, but each was an insignificant predictor of LED purchases:

[38] http://cookpolitical.com/house/pvi
[39] https://www.eia.gov/electricity/data/state/

- Square Feet of POS Retailers per Household
- Median Income
- Average Cost of Living
- Households Built before 1980
- Renter Pays Utilities
- Owner Occupied Household
- Percentage of Population with a College Degree

The modeling team also explored variance inflation factors (VIF), which serve as a test of multicollinearity. The VIF measures how much the variance of estimated regression coefficients are inflated as compared to when the predictor variables are not linearly related. The lower the VIF value (scale starts at zero) the smaller the correlations among predictor variables while a VIF over 10 is considered highly correlated. Table 15 shows that the modeled independent variables have a low level of collinearity and are appropriate to use in the same model.

Table 15: Sales Data Model Predictor Variables Inflation Factors

Predictor Variable	Variable Inflation Factors
Average Electricity	2.84
Political Index	2.40
LED Program Spending per household	1.60
Non-POS Retailers sq. ft. per household	1.24

Table 16 shows the preferred sales data modeling results, including regression coefficient and p-value for all included independent variables. All p-values listed were significant at the 95% confidence level.

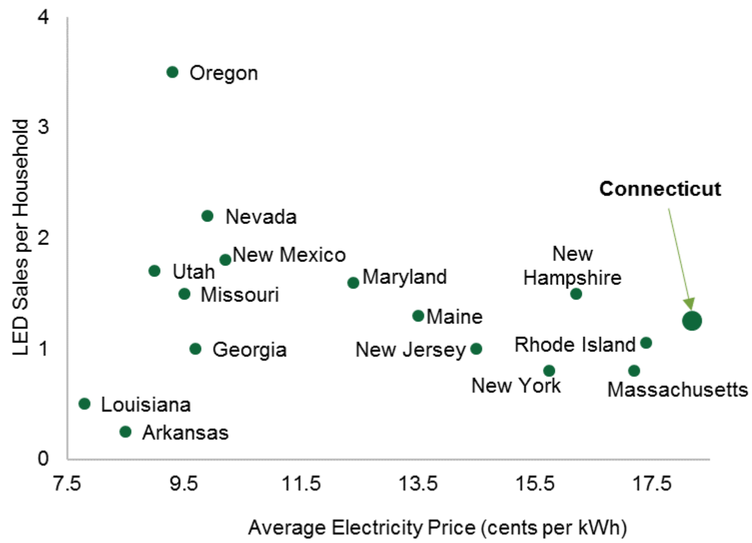
The model suggests that for each dollar increase in program spending per household, LED sales increased by 0.08 bulbs. The model also suggests that higher statewide square footage of non-reporting retailers and greater Democratic influence (versus Republican) were associated with more LED purchases in a state. Somewhat counterintuitively, the model also found that the average electricity price had a negative relationship with number of LED purchases (Figure 14). However, the states with the highest electricity prices also tended to have long standing programs and higher saturation rates, which, as discussed above, may reduce current bulb purchases.[40]

[40] Oregon presented as an outlier with LED per household sales of 3.7 and an average price of electricity of $0.88 kWh, the study performed a sensitivity analysis by removing Oregon from the model, and found that the model was not sensitive to Oregon's influence.

Table 16: Preferred Sales Data Model Summary Statistics
(n=17 states)

		Model Coefficient & P-Value
Independent Variables Row 1 = regression coefficient Row 2 = p-value of coefficient	Intercept	-6.30
		0.003
	LED Program Spending per Household	0.084
		0.035
	Non-POS Retailers sq. ft. per Household	0.560
		0.001
	Political Index	0.085
		0.001
	Average Electricity Price	-0.268
		0.000
Model Adjusted R-squared		0.64

Figure 14: Relationship between LED Sales and Average Electricity Price
(Based on sales data modeling, n=17 states)



The NTG inputs are shown in Table 17. Note that a NTG ratio based on 2013 data from the point-of-sale source only and using a different model specification yielded an estimate of 87%. Given the increased and widespread adoption of LEDs over the past two years, coupled with the addition of the panel data and the related data cleaning and altered model specification, the reduction in NTG from 87% to 70% seems to make intuitive sense to the evaluation team.

Table 17: LED NTG Sales Data Modeling Estimate Inputs

Formula	Calculation Term	Value
	Total Connecticut LEDs 2015	2,312,398
	LED Program $ per Household Actual	$10.97
	LED Program $ per Household Counterfactual	$0.00
A	LED Bulbs Counterfactual	77,485
B	LED Bulbs Modeled	1,469,263
C	LED Program Bulbs 2015	1,976,639
D = (B-A)	Net LED Bulbs Modeled	1,391,778
D ÷ C	LED NTGR Modeled	70.4%

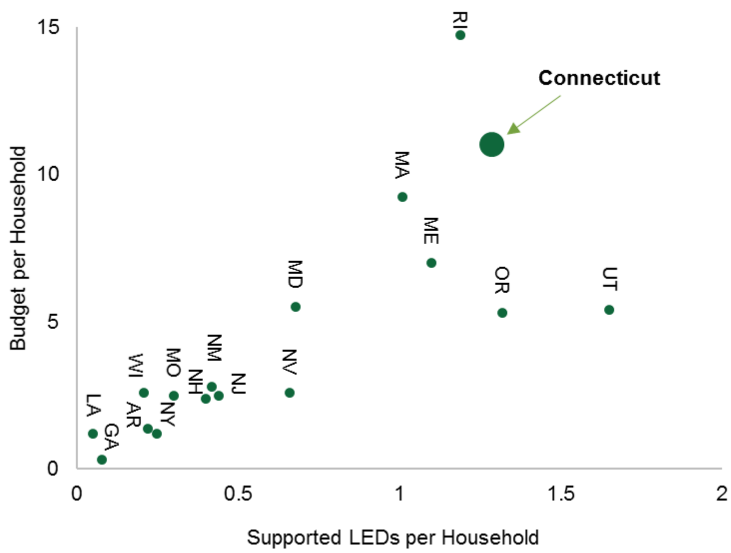
A.1.3 Review of Program Support and LED Sales

The following figures compare measures of program support and LED sales for the 17 states included in the model. The data show a great deal of variation across the states.

Figure 15 compares program spending and support by household. LED program spending (including administrative budget) ranged from a high of $15.83 per household in Rhode Island to a low of $0.26 in Georgia. Connecticut exhibited the second highest spending at $10.97 per household, but the state also ranked highly in the number of LEDs it supported with those program dollars. More generally, the level of program support was correlated to the number of bulbs supported per household.

Figure 15: LED Program Spending and Bulbs Supported per Household in 2015 by State

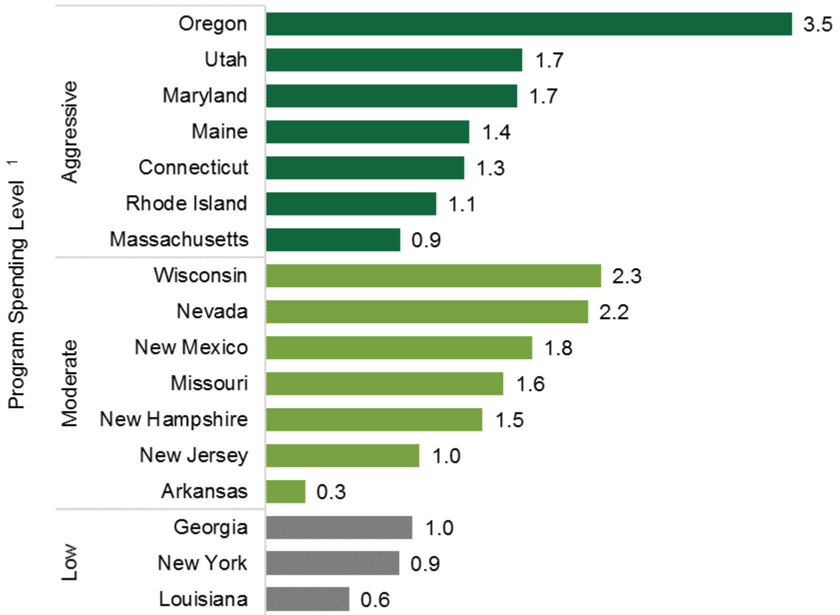
(Based on literature review, n=17 states)



Each state then received a ranking of the intensity of their program spending based on dollars spent per household. Figure 16 shows the relationship between this ranking and the number of LEDs purchased per household according to the LightTracker dataset. The states with the most aggressive program spending did not always exhibit the highest number of overall LED purchases. Connecticut (along with Rhode Island and Maine) was in the top tier of program spending but the middle of overall LED purchases within the model sample. Massachusetts actually exhibited relatively low sales in the LightTracker dataset.

Figure 16: Average LEDs Purchased per Household in 2015 by State

(Based on LightTracker data, n=17 states)



[1] LightTracker classifies the intensity of program spending by the amount spent per household. States spending > $5 per household are classified as *Aggressive* spending, those spending > $1 and < $5 are *Moderate* spending, and those spending =< $1 are *Low* spending.

Not yet public, Apex modeled total energy-efficient bulb market share to estimate a NTG ratio for a program in another state. R1615 and Apex's models both included the use of spending as the program variable, but the R1615 LED model excludes CFL incentives. Both studies included non-POS retailers, but R1615 used square footage non-POS per household while the Apex model used percentage of total retailer square footage that was non-POS. Both studies used the political index, but Apex's model also included predictors for median income, and a median income and political index interaction term. Table 18 provides the model specification. R1615 attempted to include these variables in its model; given R1615's smaller sample size, including more predictor variables restricted the degrees of freedom, causing it to behave erratically. In comparison to R1615's sales data modeling NTG ratio of 70%, Apex's model for the other state's program resulted in a combined CFL and LED NTG ratio of 61%.

Table 18: Market Share Model Summary Statistics for a CFL and LED Program
(Apex Analytics results, n=39 states)

		Model Coefficient & P-Value
Independent Variables Row 1 = regression coefficient Row 2 = p-value of coefficient	Intercept	-2.814
		0.015
	Program Spending per HH	0.024
		0.001
	Percent Sqft NonPOS	0.598
		0.057
	Political Index	0.032
		0.010
	Median Income	0.0000494
		0.020
	Political Index*Median Income	-5.43E-07
		0.011
Model R-squared		0.64

A.2 Demand Elasticity Modeling

The following appendix section includes additional details on the methods for conducting the demand elasticity modeling.

A.2.1 Modifications to Inputs

As the demand elasticity approach relies exclusively on program data, the model's robustness depended on data quality. Overall, the available data from the Connecticut Lighting Strategy achieved a sufficient quality to support the analysis. However, there were several necessary adjustments, as discussed below in regard to several key input categories:

- Seasonality
- Price Variation
- Promotional Displays

A.2.1.1 Seasonality

Conducting accurate economic analysis critically depends on separating data variations that result from seasonality from those that result from relevant external factors. For example, suppose umbrella prices fell at the beginning of the rainy season. One might erroneously conclude that the price reductions drove sales, when in actuality, the increase in precipitation likely had more to do with it. Skewed estimations result from an analysis that does not account for the natural seasonality of umbrella sales.

The current lighting demand elasticity model included a seasonal trend, provided by APT, the previous program implementer. The seasonal trend represented the proportion of annual national sales expected to occur in a given month from a major national lighting manufacturer. Using data at a national aggregation level, including non-program products and areas without programs, limited the degree that resulting trends correlated with program activity.

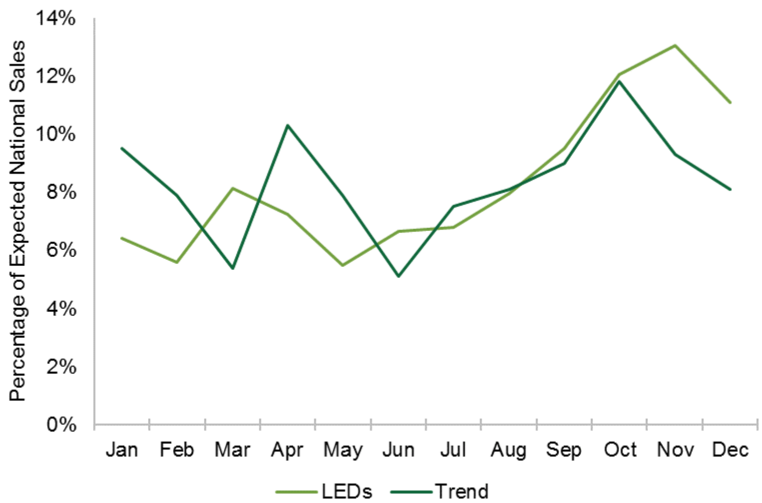
For example, sales fall during July (presumably due to longer daylight hours); so if program activity increases sales in July, analysis underestimates the program's impact if it does not control for seasonal variations. Alternatively, sales tend to rise in October; not controlling for seasonality likely overestimates program activity impacts during that month.

The sales data included in the model also fit this pattern, with peak sales in October and November 2015. Therefore, the model included the seasonal trend to control for seasonal sales variations.

LED sales followed the trend in the second half of 2015, excluding November and December. In the last two months of the year, as shown in Figure 17, LED sales were considerably higher than what we would expect given the trend. Additionally, incentive levels for LEDs decreased after March but the retailer price absent incentives also decreased, which more than offset the decreased incentives leading to lower LED prices throughout the remainder of 2015.

Figure 17: Percent of 2015 LED Sales by Month and Seasonal Trend

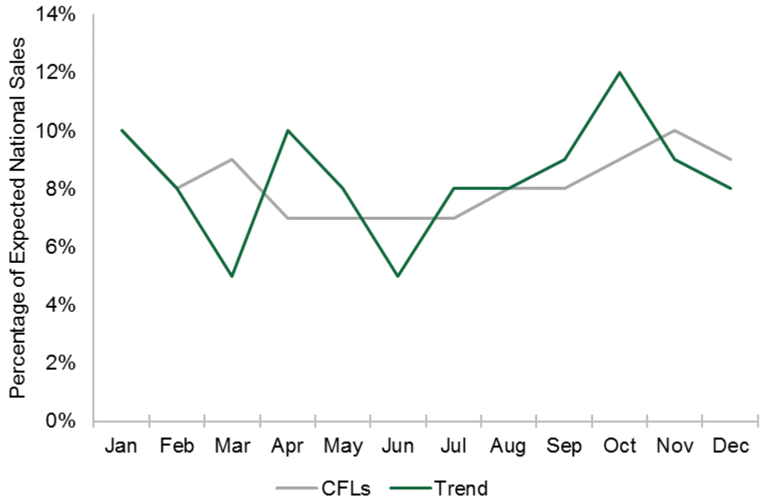
(2015 program data and APT seasonal trend data)



Incentive levels also changed for CFLs after March of 2015. Decreased incentive levels and correspondingly increased average bulb prices for CFLs did not appear to correspond with the sales drop other than April, the month immediately following the decrease in incentives. As shown in Figure 18, CFL sales increased in the fall, coinciding with the peak of the seasonal trend.

Figure 18: 2015 CFL Sales by Month and Seasonal Trend

(2015 program data and APT seasonal trend data)[1]



[1] Because prices and program activity changes over time, there are deviations between the seasonal trend and program CFL sales. For example, starting in April incentive levels dropped and sales decreased whereas the trend indicates an expected increase in sales. And in October the trend peaks but program CFL sales did increase as much as expected because incentives were lower after March. However, the general pattern holds with a dip in the summer months and an increase in sales going into fall.

Prices and incentives by month and technology are shown in Table 19.

Table 19: 2015 Prices per Bulb by Month and Technology
(2015 program data)[1]

Technology	Month	Initial Price Per Bulb	Rebate Per Bulb	Final Price Per Bulb
CFL	Jan	$3.72	$0.87	$2.85
	Feb	$3.55	$0.87	$2.68
	Mar	$3.62	$0.86	$2.76
	Apr	$2.78	$0.77	$2.01
	May	$3.34	$0.79	$2.55
	Jun	$3.40	$0.79	$2.61
	Jul	$3.39	$0.79	$2.61
	Aug	$3.41	$0.78	$2.63
	Sep	$3.42	$0.78	$2.63
	Oct	$3.42	$0.78	$2.64
	Nov	$3.46	$0.78	$2.67
	Dec	$3.48	$0.78	$2.69
LED	Jan	$16.49	$6.68	$9.81
	Feb	$16.18	$6.59	$9.58
	Mar	$16.49	$6.59	$9.90
	Apr	$13.83	$5.58	$8.26
	May	$14.56	$5.72	$8.84
	Jun	$14.53	$5.66	$8.87
	Jul	$14.51	$5.65	$8.87
	Aug	$14.58	$5.65	$8.93
	Sep	$14.45	$5.56	$8.88
	Oct	$14.13	$5.49	$8.64
	Nov	$14.09	$5.43	$8.66
	Dec	$13.94	$5.38	$8.56

[1] Prices and incentives in the table are not sale-weighted as they are in the model. These prices reflect the options the consumer faces on the shelf rather than reflecting the ultimate decision of the consumer.

Because price trends differed between CFL and LED bulbs, analysis interacted the seasonal trend with the retail channel and with bulb technology to control for changes in sales not related to price changes at a greater level of granularity.

A.2.1.2 Price Variation

Overall, a substantial number of products exhibited price variation. Additionally, most retailers offered multiple products that exhibited price variations.

Model sales and prices combined across all comparable products within each unique retailer's store location. The average price for each bulb type within each store reflects the monthly sales-weighted, per-bulb price across all comparable products. Monthly sales equaled the sum of all sales within each store across the same group of comparable products (e.g., prices and monthly sales for all 60-watt, incandescent-equivalent, general purpose LED bulbs at a single Home Depot store).

Combining sales and prices this way (rather than observing price and sales changes for each individual model number) presented an advantage: capturing any substitutions between comparable products (e.g., a decrease in the average price per-bulb when adding a three-pack of an existing bulb to the program).

Similarly, suppose an updated version of a bulb (with a different model number) replaced an original bulb model. The first model's sales likely drop because the retailer sells off back stock, even as the second model's sales increase. Aggregating prices and sales captures variations across both products rather than controlling for the sales impacts of factors unrelated to price (i.e., products phased out and replaced).

The demand elasticity model only included sales with price variations as products with no variation in price do not contribute any information to the model. The greater the price variation levels across retailers and lamp styles, the more representative the elasticity estimates became when applied to sales of products that did not exhibit price variations.

Overall the model included products that represented 79% of LED sales and 80% of CFL sales, though the representativeness varied by retail channel. As shown in Table 20, prices varied for more than 90% of both CFL and LED sales at HI stores, which accounted for 52% of all program sales. Mass market retailers also showed significant variation in prices with products representing over 90% of sales exhibiting changes in price. Club store prices varied less, with 44% of LED sales and 36% of CFL sales exhibiting price variations. Prices varied for over 60% of sales at HTR retailers for both CFLs and LEDs.

Table 20: Sales Represented in Demand Elasticity Model by Channel and Technology

(Based on demand elasticity modeling and 2015 program data)

Retail Channel	Technology	Percent of Sales in Model	Percent of Total Program Sales (2015)
Club	CFL	36%	8%
	LED	44%	17%
HI	CFL	96%	19%
	LED	96%	33%
HTR	CFL	63%	4%
	LED	69%	6%
Mass market	CFL	92%	11%
	LED	94%	3%

Additionally, significant variations occurred for most bulb types, as shown in Table 21.

Table 21. Sales Represented in Demand Elasticity Model by Type and Technology

(Based on demand elasticity modeling and 2015 program data)

Technology	Bulb Type	Percent of Sales in Model	Percent of Total Program Sales (2015)
LED	Reflector	92%	13%
	Specialty	26%	5%
	Standard	81%	40%
CFL	Reflector	0%	1%
	Specialty	16%	0%
	Standard	82%	41%

The model included sales representing more than 80% of standard, general service bulbs sales (both CFLs and LEDs) and 92% of reflector LED sales. Together, these accounted for 94% of total sales. The model included fewer specialty bulbs (e.g., globe, candelabra): 16% of CFLs and 26% of LEDs. These accounted for only 5% of total program sales. The model did not include CFL reflector sales as none exhibited price variations; reflector CFLs accounted for less than 1% of total program sales.

Overall, the model included 79% of total bulb sales in 2015 that exhibited price variations; 21% did not exhibited price variations.

A.2.1.3 Promotional Displays

Program data included records of in-store promotional events and product displays. Program implementer field staff collected these data when visiting stores to ensure compliance with retailer contractual agreements. Field staff verified prices, product placements, and shelf signs that indicated products were included as part of the program. They also collected data that tracked whether retailers displayed program bulbs in prominent promotional displays (e.g., clip strips, end caps, pallet displays).

While these data contained a comprehensive list of all in-store promotional events, the information on merchandising displays only represented a sample of locations that program implementer field representatives visited within a given week.

Due to the merchandising data's nature, the demand elasticity model could not predict sales for observations with missing merchandising data. Consequently, the team considered two separate models:

- Model 1 - included all observations with varying prices but did not control for merchandising
- Model 2 - controlling for price, but only using observations with merchandising data[41]

Although two models would have allowed for combining the estimated price coefficients from the first model and the estimated merchandising coefficients from the second model to predict sales and estimate freeridership, prices correlated with merchandising in the second model. This means that the first model's price coefficients reflected some merchandising impacts (as the model did not control for merchandising). Adding merchandising coefficients to the first-model's estimates would double-count some of the merchandising's effect, thus biasing predicted sales and overstating the program impact.

Ultimately, the study utilized the first model, which included in-store promotion data but excluded display merchandising data. Not accounting for merchandising may overestimate freeridership to the extent that the price coefficients do not reflect all of the impact of merchandising.

A.2.2 Demand Elasticity Model Specification

The demand elasticity model organized bulb and pricing data as a panel, with a cross-section of program bulb quantities for each unique retail location, bulb type, and baseline wattage combination. These were modeled over time as a function of price and retail channel (e.g., club, do-it-yourself, HTR, and mass market). This study also involved testing a variety of specifications to ascertain price impacts—the main instrument affected by the program—on the demand for bulbs. The model adopted the following basic equation (for cross-section i, in month t):

Equation 1

$$\begin{aligned} ln(Qit) = {} & \sum(\beta_{\pi} * ID_{\pi,i}) + \sum(\beta_{\theta 1}[ln(P_{it}) * (Retail\ Channel_{\theta,i})]) \\ & + \sum(\beta_{\theta 2}[ln(P_{it}) * (Technology_{\theta,i})]) + \sum(\beta_{\theta 3}[ln(P_{it}) * (Bulb\ Type_{\theta,i})]) \\ & + \sum(\beta_{\theta 4}[Display * (Retail\ Channel_{\theta,i})]) + \beta_{\theta 5} * Promo \\ & + \sum(\beta_{\theta 6}[Trend * (Retail\ Channel_{\theta,i})]) + \varepsilon_{it} \end{aligned}$$

Where:

- ln = Natural log
- Q = Quantity of bulbs sold during month t
- P = Retail price per bulb in month t
- Retail Channel = Retailer category (HI, mass market, HTR, club)

[41] Model 2 has more than 450,000 fewer sales than Model 1 due to excluding those that do not have merchandising data.

- Technology = CFL or LED
- Bulb Type = Product category (standard, reflector, specialty)
- ID = Dummy variable equaling 1 for each unique retail location, bulb type, and base watt; 0 otherwise
- Seasonal Trend = Quantitative trend representing the impact of secular trends not related to the program
- Display = Dummy variable equaling 1 if a product was featured in an off-shelf display in time period t
- Promo = Dummy variable equaling 1 if an in-store promotion event took place in time period t
- ε_{it} = Cross-sectional random-error term in time period t

The model specification assumed a negative binomial distribution. This served as the best fit of the plausible distributions (e.g., log normal, poisson, negative binomial, or gamma). The negative binomial distribution's long right tail coincides with a small proportion of products accounting for a disproportionate share of sales.[42]

The study tested numerous model scenarios to identify the model with the best parsimony and explanatory power using the following criteria:

- Model coefficient p-values (keeping values less than <0.1)[43]
- Explanatory variable cross-correlation (minimizing where possible)
- Model AIC (minimizing between models)[44]
- Utilizing the heteroskedastic consistent covariance matrix and clustered standard errors to account for heteroskedasticity
- Minimizing multicollinearity
- Optimizing model fit

The study preferred model specifications with elasticity estimates nested by technology, retail channel, and bulb type (general purpose, specialty, and reflector). This accounts for differences in retailer strategies and target demographics, as well as differences in demand given bulb characteristics. Ultimately, models were ranked by lowest AICs and lowest differences between monthly actuals and monthly predictions. The model with the lowest rank with the most intuitive specification and parameter estimates was chosen.

The model's fit can be examined by comparing model-predicted sales with actual sales. As shown in Figure 1, the model-predicted sales very closely matched actual sales without persistent bias in a single direction (over- or under-predicting for each month). This indicated that the model fit the data well.

---

[42] Figure 3 in the appendix presents a histogram of monthly bulb sales across all products and demonstrates the degree to which the observations are skewed.

[43] Where a qualitative variable had many states (such as bulb types), variables were not omitted if one state was not significant, but rather considered the joint significance of all states.

[44] Akaike information criterion (AIC) is a measure of relative quality used compare and assess model fit, as nonlinear models do not define the R-square statistic. AIC also offers a desirable property in that it penalizes overly complex models, similarly to the adjusted R-square.

As Figure 19 shows, the two largest discrepancies between predicted and actual sales occurred at the end of 2015. Overall, the predictions fit actual sales well, though the model over-predicted sales by 1.6% in aggregate.

Figure 19. Predicted and Actual Sales by Month in 2015
(Based on demand elasticity modeling and 2015 program data)

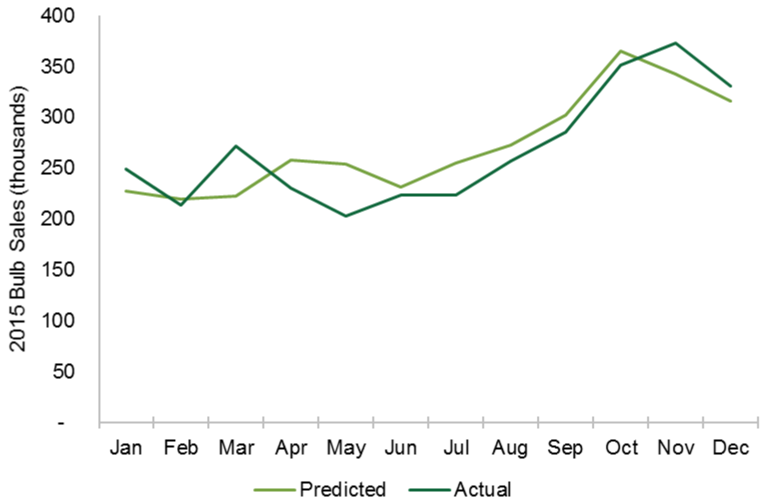


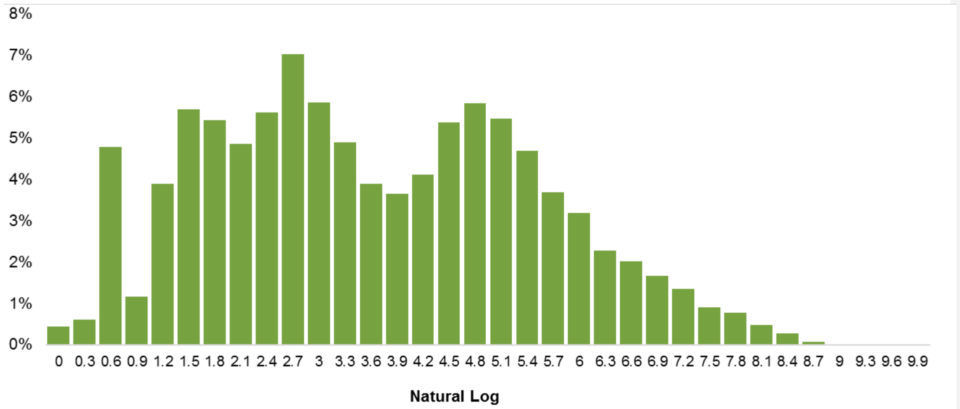
Table 22. Final Demand Elasticity Model Parameters

Parm	Level1	Level2	Level3	Estimate	Stderr	Lower CL	Upper CL	Z	ProbZ
Intercept				0.00	0.00	0.00	0.00	0.00	0.00
LnPe*Chan*Type*Techn	Club	Reflector	LED	-1.11	0.23	-1.56	-0.65	-4.77	0.00
	Club	Standard	CFL	-0.75	0.45	-1.63	0.14	-1.65	0.10
	Club	Standard	LED	-2.53	1.07	-4.64	-0.43	-2.36	0.02
	DIY	Reflector	LED	-0.58	0.09	-0.74	-0.41	-6.77	0.00
	DIY	Specialty	CFL	-2.71	0.84	-4.34	-1.07	-3.24	0.00
	DIY	Specialty	LED	-2.88	0.12	-3.11	-2.66	24.91	0.00
	DIY	Standard	CFL	-0.75	0.10	-0.93	-0.56	-7.81	0.00
	DIY	Standard	LED	-1.89	0.09	-2.06	-1.72	21.62	0.00
	HTR	Reflector	LED	-0.42	0.09	-0.59	-0.24	-4.68	0.00
	HTR	Specialty	LED	-0.77	0.19	-1.14	-0.40	-4.08	0.00
	HTR	Standard	CFL	-1.64	0.13	-1.90	-1.38	12.41	0.00
	HTR	Standard	LED	-0.54	0.15	-0.82	-0.25	-3.68	0.00
	Mass	Reflector	LED	-1.84	0.15	-2.13	-1.55	12.35	0.00
	Mass	Specialty	CFL	-1.85	0.63	-3.07	-0.62	-2.95	0.00
	Mass	Specialty	LED	1.07	0.41	0.26	1.88	2.60	0.01
	Mass	Standard	CFL	-0.54	0.14	-0.82	-0.26	-3.73	0.00
	Mass	Standard	LED	-3.11	0.15	-3.41	-2.81	20.33	0.00
Promos				0.03	0.00	0.02	0.04	7.19	0.00
trend*Channe*Technol	Club	CFL		1.03	2.55	-3.98	6.03	0.40	0.69
	Club	LED		2.14	1.10	-0.02	4.29	1.94	0.05
	DIY	CFL		3.41	0.42	2.59	4.23	8.12	0.00
	DIY	LED		4.19	0.47	3.27	5.11	8.91	0.00
	HTR	CFL		5.01	0.52	4.00	6.03	9.65	0.00
	HTR	LED		5.22	0.99	3.27	7.17	5.24	0.00
	Mass	CFL		2.58	0.48	1.64	3.52	5.40	0.00
	Mass	LED		8.68	0.88	6.96	10.39	9.91	0.00

Table 23. Comparative Demand Elasticity Model Fit Statistics by Distribution

Assumed Error Distribution	AIC	BIC
Negative Binomial	151,528	164,393
Poisson	644,400	657,257
Log-Normal	229,597	242,463
Gamma	151,901	164,766

Figure 20: Natural Log of Monthly Bulb Sales Histogram
(From demand elasticity modeling)



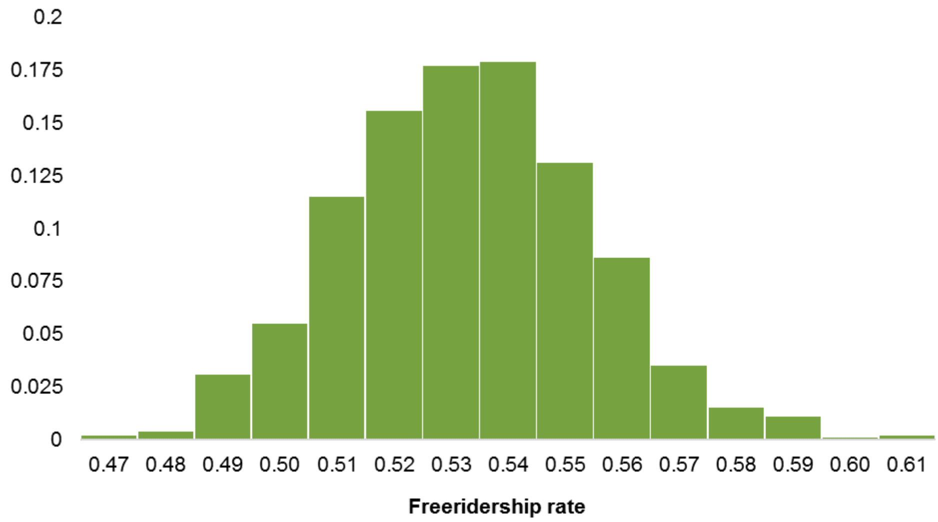
A.2.3 Demand Elasticity Model Precision

Upon developing the final model specification, the study calculated precision using *block bootstrap* standard errors to determine the sensitivity of the net-to-gross ratios. To develop bootstrap standard errors, analysts drew 1,000 new samples (with replacements drawn at the cross-section level) from the original data, estimating coefficients with each sample, predicting sales and saving with and without program incentives, and calculating a new freeridership ratio. Using this method, the 5th and 95th percentiles in these freeridership ratios represented the lower and upper bounds of the 90% confidence interval, as shown in Table 24. The distribution of freeridership predictions was normally distributed with a median value 52.8%, which is very similar to the program freeridership estimate of 52% presented in Table 25. Figure 21 shows the distribution of freeridership predictions from the bootstrap analysis.

Table 24: Demand Elasticity Modeling Freeridership Estimate Confidence Interval

Program Freeridership	5% Lower Bound Confidence Interval	95% Upper Bound Confidence Interval	Relative Precision at 90% Confidence
52%	49%	56%	± 7%

Figure 21: Demand Elasticity Modeling Bootstrap Freeridership Estimate Histogram



A.3 Benchmarking

The benchmarking analysis draws on the following references:

Cadmus Group. *Evaluation of Xcel Energy's Home Lighting and Recycling Program*. January 13, 2016. http://www.xcelenergy.com/staticfiles/xe/PDF/Regulatory/CO-DSM/CO-Regulatory-DSM-Home-Lighting-and-Recycling-Evaluation.pdf

Cadmus Group. *Arkansas Energy Efficiency Program Portfolio Annual Report*. Docket No. 07-085-TF: 2013 Program Year. April 1, 2014. http://www.apscservices.info/(X(1)S(g3lbwwyyzpugkz45efpyjmqi))/EEInfo/EEReports/Entergy%202013.pdf

DNV GL. *Impact Evaluation of 2013-14: Upstream and residential downstream lighting programs*. California Public Utilities Commission. April 1, 2016. http://www.energydataweb.com/cpucFiles/pdaDocs/1488/2013-2014%20California%20Upstream%20and%20Residential%20Lighting%20Impact%20Evaluation%20Report%20FINAL.pdf.

Frontier Associates. *Evaluation, Measurement, and Verification of CPS Energy's FY 2015 DSM Programs*. June 11, 2015. https://www.sanantonio.gov/Portals/0/Files/Sustainability/STEP/CPS-FY2015.pdf.

National Grid. *Rhode Island Technical Reference Manual for estimating savings from energy efficiency measures: 2016 Program Year*. 2015. https://www9.nationalgridus.com/non_html/eer/ri/PY2016%20RI%20TRM.pdf.

Navigant, Itron, Opinion Dynamics. *Residential ENERGY STAR Lighting PY7 Evaluation Report*. February 13, 2016. http://ilsagfiles.org/SAG_files/Evaluation_Documents/ComEd/ComEd_EPY7_Evaluation_Reports/ComEd_Residential_Lighting_PY7_Evaluation_Report_2016-02-13_Final.pdf

Navigant Consulting, NMR, Tetra Tech, DNV GL. *Multistage Lighting Net-to-Gross Assessment: Overall report*. August 2015. http://ma-eeac.org/wordpress/wp-content/uploads/Multistage-Lighting-Net-to-Gross-Assessment-Overall-Report.pdf.

NMR, Cadmus, DNV GL. *R86: Connecticut Residential LED Market Assessment and Lighting Net-to-Gross Overall Report*. June 2015. http://www.energizect.com/sites/default/files/CT%20Residental%20LED%20Lighting%20Market%20Assessment%20and%20Lighting%20NTG%20%28R86%29_Final%20Report_06.19.15.pdf.

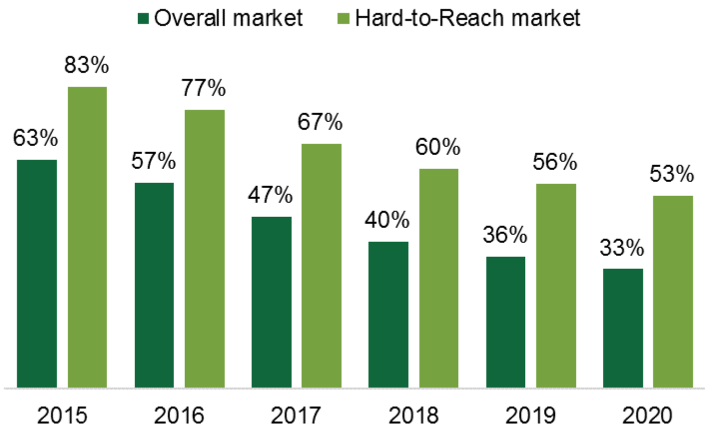
NMR. *Efficiency Maine Retail Lighting Program: Overall evaluation report*. April 16, 2015. http://www.efficiencymaine.com/docs/Efficiency-Maine-Retail-Lighting-Program-Evaluation-Report-2015.pdf.

Southwestern Public Service Company. *2014 Energy Efficiency and Load Management Plan*. Case No 13-_-UT. August 28, 2013. http://www.swenergy.org/Data/Sites/1/media/documents/news/news/file/SPS_2014_DSM_plan.pdf.

A.4 CONSENSUS PANEL

This appendix details the consensus panel's decisions, including the steps undertaken and the reasoning behind the recommended values. Figure 22 illustrates the consensus panel's recommended LED NTG estimates.

Figure 22: LED NTG Retrospective and Prospective Estimates by Market
(Consensus panel results, n=6)



A.4.1 Retrospective and Near-Term

When making their estimates, panelists highly valued the R1615 results in comparison to the benchmarking studies. When asked to rate the importance of the three primary activities completed for this evaluation on a scale of one to five, where one equals *not at all important* and five equals *extremely important*, they rated all three R1615 primary-research tasks the highest. They rated demand elasticity modeling (4.2) and supplier interviews (4.4) notably higher than the sales data modeling (3.0) with the explanation that the sales data modeling held some methodological weaknesses, such as the inability to control for prior saturation, low sample size, and unstable specifications (Section 2.2). As such, panelists' retrospective estimate for 2015 (63%) was nearly identical to the net-of-freeridership estimate from the demand elasticity modeling and the NTG estimate from supplier interviews, which were both 61%. They rated the benchmarking studies 2.67 or lower, on average, citing differences in geography and datedness (Section 3.3).

A.4.2 Long-term

Panelists' average LED NTG estimates for 2018 through 2020 assumed a steady decline, from 44% in 2018 to 33% in 2020, or almost one-half of their initial NTG estimate of 63% for 2015. In fact, one panelist estimated that NTG would slide to 10% in 2020.

Both their written responses and discussion during the panel demonstrated that panelists held a great deal of uncertainty about the LED market in the long-term. They considered program support to be vital to driving LED sales historically and at present. While they forecasted that the future LED market should be able to grow independent of program support, they could not reach consensus on *when* that would occur.

Panelists also reflected on market variables (explored in greater detail in Section 4). They reported the following as driving LED adoption: the influx of value-line LEDs (defined in

Section 1.1) yielding decreased prices, and the imminent disappearance of CFLs and rollout of ENERGY STAR 2.0 reducing energy-efficient lighting options. One panelist called LEDs a *market juggernaut*, estimating that LED prices are declining roughly 20% to 30% each year, but most agreed that changes in federal administration and the resulting uncertainty around the implementation and enforcement of EISA 2020 add additional layers of confusion.

The uncertainty in the market led panelists to encourage the EEB to reevaluate the recommended NTG estimates next year (late 2017 and 2018) or by 2019 at the latest.

A.4.3 Retail Channel

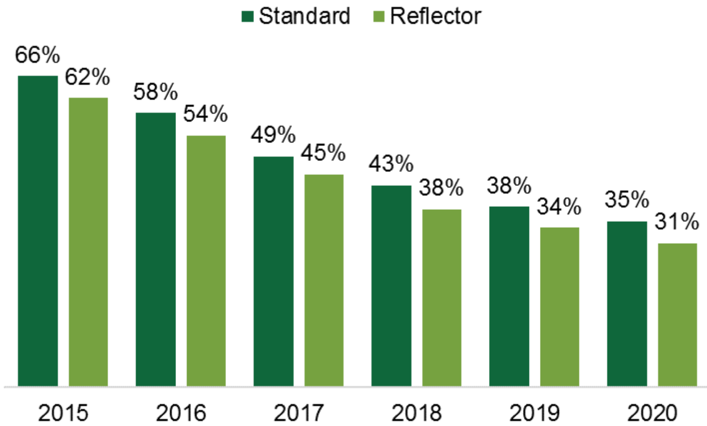
The panel discussion heavily considered HTR market dynamics where prices typically dictate adoption, current penetration is low, and distribution costs are high. Panelists forecasted that many HTR stores would not carry LEDs in absence of the program. Supplier interview results underscored this distinction, where, for example, standard bulb retrospective NTG was 63% for the program overall but was 100% for HTR retailers. To acknowledge this particularity, the panel determined that an increase of 20 percentage points for the HTR market's LED NTG across years would result in fair estimates, starting with 83% in 2015 and ending at 53% in 2020 (Figure 22).

A.4.4 Bulb Type

Panelists also provided separate estimates for standard and reflector bulbs. Reflector LED NTG estimates from the panelists (as well as demand elasticity modeling and supplier interviews) were consistently lower than those of standard LEDs, but they did not differ by more than five percentage points for any year. The consensus panelists ultimately decided to combine standard and reflector bulbs into a single category of non-HTR LEDs due to the similarity in separate estimates and uncertainty regarding the adoption and implementation of the DOE rule that expands the general service lamp definition to include reflectors and many other specialty bulb types.

Prior to making this decision, the discussion around reflectors focused on the nature of the separate estimates and the current and future reflector market. While one panelist was unaware of evidence supporting differences between standard and reflector LED NTG, others justified the difference in their estimates. Another panelist concluded that because LED reflectors were introduced before standard LEDs they have had more time to penetrate the market; another added that, as a result, they are currently at price parity with halogens for same light output. Additionally, one observed that customers perceived halogen reflectors as poor quality; another added that reflectors are natural applications for LEDs due to directional light output making them an easier market penetrator. Figure 23 illustrates the consensus panel estimates by bulb type.

Figure 23: LED NTG Retrospective Estimates by Bulb Type
(Consensus panel results, n=6)



B Appendix B Additional Results

B.1 Net-to-Gross Estimates by Technology

The demand elasticity modeling analysis estimated freeridership for CFLs in addition to LEDs to estimate an overall program freeridership ratio for 2015. As reported, the overall freeridership for LEDs alone was 39%, and the ratio for CFLs was 67%, resulting in an overall program freeridership ratio of 52% (Table 25). The resulting net-of-freeridership or, in this case NTG ratio, for LEDs (61%) was therefore higher than that of CFLs (33%).

Though freeridership was lower for LEDs, they accounted for a greater share of sales (58%) than CFLs (42%). However, they accounted for fewer savings that were modeled (53%) and therefore contributed less to overall program freeridership.[45]

Table 25: Net-of-freeridership, Sales, and Savings by Technology

(Based on demand elasticity modeling)

Techno-logy	Modeling Results		2015 Program Data Associated with Modeling			
	Free-ridership	Net-of-Free-ridership[1]	Total Bulb Sales	% of Sales	Total Savings (MWh)	% of Savings
LED	39%	61%	1,605,989	58%	44,022	53%
CFL	67%	33%	1,150,981	42%	38,655	47%
Overall	**52%**	**48%**	**2,756,970**		**82,676**	

[1] Given that the model does not include spillover, the NTG is equal to 1 minus freeridership (i.e., net-of-freeridership).

Table 26 shows average elasticity estimates and freeridership estimated through demand elasticity modeling by bulb type and technology.

- Specialty (38%) and standard (27%) LEDs were associated with the lowest freeridership rates; they also had high elasticity (-2.20 and -1.88, respectively).
- Like specialty LEDs, specialty CFLs (-2.64) proved highly elastic; however, they had high freeridership (71%). Meanwhile, standard CFLs also had high freeridership (67%), yet they (-0.76) proved the least elastic—they accounted for the largest share of sales in 2015 for a single bulb type (41%).
- Reflector LEDs also had high freeridership (60%) with low elasticity (-0.84).

[46] Section 4 explores changing market shares across bulb types and the program and market transitions to LEDs away from other bulb types, including CFLs.

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While specialty bulbs produced lower observed elasticity, they also sell at lower rates than standard and reflector bulbs, producing more noise in the data for demand elasticity modeling. However, specialty bulbs typically do not account for a large share of program sales and had the lowest proportion of sales included in the model due to little price variation. As prices for LEDs decreased through 2015 and program incentives continued to shift to LEDs,[46] the average final prices of standard CFLs increased relative to LEDs. However, demand for standard CFLs remained relatively stable, suggesting somewhat inelastic demand—Appendix A.2 provides more details on these program trends. The inelastic demand could result from inertia in the market. Utility-sponsored programs have promoted CFLs for many years, and some consumers—absent dramatic changes in price—may be more likely to buy bulbs with which they have the greatest familiarity.

Table 26: Elasticities by Technology and Bulb Type

(Based on demand elasticity modeling)

Technology	Bulb Type	Average Elasticity	Freeridership
LED	Reflector	-0.84	60%
LED	Specialty	-2.20	38%
LED	Standard	-1.88	27%
CFL	Specialty	-2.64	71%
CFL	Standard	-0.76	67%

[46] Section 4 explores changing market shares across bulb types and the program and market transitions to LEDs away from other bulb types, including CFLs.

C Appendix C Interview Instruments

This appendix includes the instruments used for the supplier interviews and program staff interviews.

C.1 Supplier Interviews

Contact Protocol

1. Call potential interviewees to ascertain most appropriate interviewee. Obtain email address(es) of appropriate interviewees. If company refuses interview, determine reasons for refusal and if it's logistical in nature, try to find workaround.
2. Send email interview invitation to appropriate interviewee. This invitation will include:
   a. Explanation of purpose and scope of interview.
   b. Explanation of time frame within which the interview will need to be completed.
   c. Explanation of expected duration of interview and flexibility to complete interview over multiple sessions.
   d. Instructions to propose a convenient interview time.
   e. Contact information for interviewers.
   f. Assurances of confidentiality.
3. Once an interview time has been arranged, the interviewee will be emailed, a couple days in advance of the interview, a summary of the interview topics and a table summarizing their shipments of discounted lighting products through the Connecticut ENERGY STAR Lighting Program disaggregated by lighting product categories and retail channels (for lighting manufacturers). The email will contain additional assurances of confidentiality.
4. At the beginning of the interview, collect information on interviewee's position and overall responsibilities, and experience with the program

C.1.1 Section 1: Program Participation Confirmation and Reasons for Participation

The Nature of Program Participation

1-1. Eversource, United Illuminating, and the Connecticut Energy Efficiency Board jointly participate in an ENERGY STAR Lighting Program. According to our records, your company has supplied/purchased lighting products that have received upstream incentives from the Connecticut ENERGY STAR Lighting Program during the past 12 months. This program has for many years offered upstream buydown or markdown discounts for CFL and LED products that are sold through various Connecticut retailers. Are you familiar with your company's participation in this program?

[IF UNAWARE, FIND SOMEONE WITH THE COMPANY WHO IS AWARE. IF THEY RECOGNIZE THIS PROGRAM BY A DIFFERENT NAME, EXPLAIN THAT FOR THE SAKE OF SIMPLICITY YOU'LL HENCEFORTH REFER TO THE PROGRAM AS "THE CONNECTICUT ENERGY STAR LIGHTING PROGRAM."]

a) Besides getting these financial incentives, are there any other aspects of the Connecticut ENERGY STAR Lighting Program in the past 12 months that your company has actively taken part in? [IF NOT MENTIONED, PROBE FOR:

- THEIR INVOLVEMENT IN POINT-OF-SALE PROMOTIONS (SIGNAGE, DISPLAYS, PROGRAM COLLATERAL, PRODUCT PLACEMENT) FOR THE CT PROGRAM
- THEIR INVOLVEMENT WITH ANY EXTERNAL MARKETING OF THE CT ENERGY-EFFICIENT LIGHTING REBATES
- THEIR INVOLVEMENT WITH ANY CUSTOMER EDUCATION EFFORTS IN CT CONCERNING LIGHTING PURCHASES]

b) [IF YES TO 1-1a.] What other aspects of this program has your company been involved in?

1-2. **[Previously Interviewed Only]** Has your company's participation or involvement in the Connecticut ENERGY STAR Lighting Program changed since you were last interviewed?

a) If so, how has it changed?

1-3. **[Not Previously-Interviewed Only]** About what year did your company first get involved with the Connecticut ENERGY STAR Lighting Program?

1-4. **[Not Previously-Interviewed Only]** What was your primary reason for getting involved with the Connecticut ENERGY STAR Lighting Program?

1) Retail partners wanted to participate

2) Rebates/discounts were attractive

3) Wanted prices to be competitive with other suppliers

4) Program branding/association helped product sales

4) Other reasons____________________[PLEASE SPECIFY]

1-5. **[Not Previously-Interviewed Only]** Did you have any other reasons for getting involved with the Connecticut ENERGY STAR Lighting Program?

a) [IF YES] What were these?

C.1.2 Section 2: Verifying Program Sales

2-1. Earlier I emailed you a table that shows the types of CFL and LED bulbs that our records show you sold through the Connecticut Lighting Program in the past 12 months. Does the table I sent to you seem correct in terms of the types and volume of CFLs and LED products you sold through the Connecticut ENERGY STAR Lighting Program?

a) [IF NO] [Record any corrections to the table]

2-2. Why did you choose to sell these particular products and packages through the Connecticut ENERGY STAR Lighting Program?

2-3. During the past 12 months, were there any ENERGY STAR lighting products which you sold in Connecticut without selling them through the program?

a) [IF YES] Which ENERGY STAR lighting products were these?

b) [IF YES] Why didn't you sell these ENERGY STAR lighting products through the program?

C.1.3 Section 3: Lighting Market Trends

[READ] *Now I would like to get your perspective on some forthcoming changes in the lighting market.*

EISA 2020

3-1. The Energy Independence and Security Act of 2007, otherwise known as "EISA" has established new lumens/watts standards for general service lighting. Are you aware that in 2020 the next phase of these EISA regulations will go into effect? [IF NECESSARY: A GENERAL SERVICE LAMP IS ONE WITH A MEDIUM SCREW BASE INTENDED FOR GENERAL SERVICE APPLICATIONS WITH LIGHT IN THE 310-2,600 LUMEN RANGE].

3-2. [IF AWARE OF EISA 2020, ELSE SKIP TO Q3-4] What do you expect will be the impacts of these 2020 EISA regulations on the Connecticut lighting market? [PROBE FOR WHEN EACH IMPACT MENTIONED EXPECTED (e.g. YEAR)]

[IF NOT ALREADY MENTIONED, PROBE FOR:]

3-2a. **Impact on LEDs - sales volume and lamp variety sold**

[PROBE FOR WHEN IMPACT EXPECTED (e.g. YEAR)]

[PROBE FOR ANY DIFFERENCES IN IMPACTS ON ENERGY STAR LEDs VS. NON-ENERGY STAR LEDs]

3-2b. **Impact on CFLs - sales volume and lamp variety sold**

[PROBE FOR WHEN IMPACT EXPECTED (e.g. YEAR)]

3-2c. **Impact on halogens – sales volume and lamp variety sold**

[PROBE FOR WHEN IMPACT EXPECTED (e.g. YEAR)]

[IF NOT ALREADY MENTIONED, ASK ABOUT THE IMPACT ON NON-COVERED HALOGEN PRODUCTS, PARTICULARLY REFLECTORS]

3-3. How do you expect these 2020 EISA regulations will impact your own company's lighting sales?

Table 27: Impacts of 2020 EISA Regulations

Topics	**Interviewee Responses**	
3-2 General impacts of regulations		
	Impacts on Sales Levels	**Impacts on Variety of Lamps Sold**
3-2a. Impacts on LEDs		
3-2b. Impacts on CFLs		
3-2c. Impacts on halogens		
3-3 How regulations will impact their own lighting sales		

ENERGY STAR Lamp 2.0 Specification

3-4. Are you aware that in 2017 a new ENERGY STAR specification – 2.0 – is scheduled to go into effect which will adjust measure life and efficacy requirements?

[IF UNAWARE, SKIP TO NEXT SECTION 'LIKELIHOOD OF PHASE 2 EISA SCENARIOS']

3-5. [IF AWARE OF ENERGY STAR 2.0] What do you expect will be the impacts of these new ENERGY STAR specifications on the Connecticut lighting market? [PROBE FOR TIMING OF CHANGE (e.g. YEAR) FOR EACH IMPACT MENTIONED]

[IF NOT ALREADY MENTIONED, PROBE FOR:]

3-5a. **Impact on LEDs on both sales volume and lamp variety sold**

[PROBE FOR WHEN IMPACT EXPECTED (e.g. YEAR)]

[PROBE FOR ANY DIFFERENCES IN IMPACTS ON ENERGY STAR LEDs VS. NON-ENERGY STAR LEDs]

3-5b. **Impact on CFLs on sales volume only**

[PROBE FOR WHEN IMPACT EXPECTED (e.g. YEAR)]

3-5c. **Impact on halogens on both sales volume and lamp variety sold**

[PROBE FOR WHEN IMPACT EXPECTED (e.g. YEAR)]

[IF NOT ALREADY MENTIONED, ASK ABOUT THE IMPACT ON NON-COVERED HALOGEN PRODUCTS, PARTICULARLY REFLECTORS]

3-6. How do you expect these new ENERGY STAR specifications will impact your own company's lighting sales?

Table 28: Impacts of Energy Star 2.0 Specifications

Topics	Interviewee Responses	
3-5 General impacts of new ES specs		
	Impacts on Sales Levels	**Impacts on Variety of Lamps Sold**
3-5a. Impacts on LEDs		
3-5b. Impacts on CFLs		
3-5c. Impacts on halogens		
3-6 How new ES specs will impact their own lighting sales		

[PROCEED ONLY IF RESPONDENT ANSWERED YES TO Q 3-1 (I.E. AWARE OF EISA 2020), ELSE SKIP TO Q3-17]

Likelihood of Phase 2 EISA Scenarios

[READ] I next want to draw on your market experience to predict the lighting regulations in effect in the year 2020.

As you likely know, the specifics of Phase 2 EISA are somewhat complicated given additional legislation and the recent DOE proposed rulemaking covering CFLs and LEDs. There are two main issues we would like you to consider for the scenarios in this section.

First, the original EISA 2007 legislation included a backstop standard of 45 lumens per watt for general service incandescent, halogen, CFL, and LED lamps set to go into effect January 1, 2020. <u>This backstop applies to the manufacture, import, and sales of all general service lamps</u>.

Second, on February 12, 2016, the DOE issued a proposed rulemaking that included a new efficiency standard for general service CFLs and LEDs **ONLY**. The DOE has proposed a higher lumens/watt standard for medium-screw based CFL and LED lamps of 85-100 lumens per watt depending on lumen output. This standard is to be effective in January 1, 2020 and would apply to manufacture and import of lamps but would allow all existing non-compliant lamps to sell through. The final ruling on this issue is due on or before December 31, 2016.

For these next questions, I will ask you to estimate the likelihood of each of a number of scenarios in terms of percentage. The total of your estimates should add up to 100%. We have defined three scenarios and will give you the opportunity to define a fourth if you think it is worth considering. First, let me read the three defined scenarios:

Scenario 1: EISA 2007 backstop is strictly enforced with a "hard-stop." In this scenario the EISA 2007 backstop is strictly enforced as of 2020 and lamps that do not meet the specifications may no longer be sold, manufactured or imported into the US after the effective date of the regulation. In this scenario, the proposed CFL/LED federal standard is not implemented.

Scenario 2: In this scenario both the EISA 2007 backstop and the proposed CFL/LED standard are implemented as of 2020. As in scenario 1, the EISA 2007 backstop is strictly enforced. In addition, the proposed CFL/LED federal standard with "sell-through" is implemented. In this scenario, CFL and LED lamps that do not meet the proposed CFL/LED federal standard cannot be manufactured or imported into the US. However, manufacturers and retailers would continue to "sell through" the existing stock of all non-compliant lamps, regardless of technology, until it is depleted.

Scenario 3: The EISA 2007 backstop is repealed and the proposed CFL/LED standard is not implemented. In this scenario, the manufacture and sale of all currently allowed lamp types continues. It is the scenario where the market operates without additional regulations other than those already in place.

Scenario 4: This is a scenario you define if you think that the three scenarios mentioned do not fully represent the likely options.

Before we continue, would you like me to restate the three defined scenarios?

[IF YES, DO SO. IF NO, PROCEED]

3-7. So, considering the three defined scenarios, is there another scenario that you think should be considered?

3-8. [IF ANOTHER SCENARIO] "What is that other scenario?" AND RECORD BELOW, IF NO, PROCEED]

Scenario 4: OTHER (SPECIFY)

____
____
____

3-9. In terms of percentage, what probability would you assign to Scenario 1 - EISA 2007 backstop is strictly enforced with a "hard-stop" and the proposed 2020 LED/CFL standards are not enacted?

3-10. What probability would you assign to Scenario 2 – both the EISA 2007 backstop and the proposed CFL/LED standard are implemented and manufacturers and retailers would continue to “sell through” all existing non-compliant lamps?

3-11. What probability would you assign to Scenario 3 –The EISA 2007 backstop is repealed and the proposed CFL/LED standard is not implemented?

3-12. [IF APPROPRIATE] And finally, what probability would you assign to the alternative you suggested?

[COMPLETE TABLE BELOW. MUST SUM TO 100%. IF NOT, ASK RESPONDENT TO REVISE PERCENTAGES UNTIL SUMS TO 100%.]

Table 29: Probability of Different EISA2 Scenarios

Scenario	%
1 – Strictly enforced	
2 – Sell through	
3 – Repealed	
4 – Other	
SUM	100%

3-13. Why do you think Scenario [IDENTIFY SCENARIO WITH HIGHEST PROBABILITY IN TABLE ABOVE] is the most likely scenario?

3-14. Do you think any future events—whether political, economic or other types of events—might cause you to change your probabilities?

3-15. [IF YES] How so? Anything else?

3-16. Which future event(s) do you think has the greatest impact on changing your probabilities?

3-17. [IF THEY INDICATED IN RESPONSE TO QUESTION 3-4 THAT THEY WERE AWARE OF THE NEW ENERGY STAR SPECS] Are you aware that the Connecticut ENERGY STAR lighting program may substantially reduce or even eliminate CFL discounts in 2017

3-18. How do you think the withdrawal of program support for CFLs would impact the Connecticut lighting market?

Non-ENERGY STAR LEDs

3-19. Recently the lighting market has experienced a growth in non-ENERGY STAR LEDs that do not qualify according to the new specification, ENERGY STAR Lighting 2.0, which was approved in 2016. These are these less expensive LED models which may lack some features (such as dimmability), have shorter measure lives, use slightly more energy, and may not be as bright when compared to ENERGY STAR-qualified LEDs. Are you familiar with these non-ENERGY STAR LED lamps?

[IF UNFAMILIAR WITH NON-ENERGY LEDS, SKIP TO Q3-20]

3-20. What do you expect will be the impacts of these non-ENERGY STAR LEDs on the overall Connecticut lighting market?

3-21. What do you expect will be the impacts of these non-ENERGY STAR LEDs on sales of LEDs in the Connecticut lighting market?

3-22. What do you expect will be the impacts of these non-ENERGY STAR LEDs on sales of ENERGY STAR LEDs in the Connecticut lighting market?

3-23. What do you expect will be the impacts of these non-ENERGY STAR LEDs on your own company's lighting sales?

Lingering Incandescents

3-24. Are you aware of any continuing availability of traditional incandescent bulbs?

a) [IF YES] What wattages of bulbs are you seeing? Any specific styles/types of bulbs? [Probe whether EISA-exempt bulbs or non-EISA exempt]

b) [IF YES] In what retail channels are these being sold?

c) Why are stores still selling these incandescents?

C.1.4 Section 4: Program Attribution in the past 12 months

Whether They Would Have Sold Any LED Lighting Products without the Program

[READ] *My next set of questions covers your sales of LED lamps in the past 12 months.*

3-25. [MANUFACTURERS ONLY] The Connecticut ENERGY STAR Lighting Program in the past 12 months paid average buydown or markdown discounts of $3.74 to $4.24 per LED A-lamp bulb and $5.49 to $5.62 per LED reflector bulb. Are there any retailers or retailer categories that you worked with through the Connecticut lighting program in the past 12 months that you think would not have been selling any LED products in Connecticut if these discounts had not been available?

a) [IF YES] Which retailers or retailer categories?

b) [IF YES] Why do you say this?

[IF RESPONDENT INDICATED THEY WOULD NOT HAVE SOLD ANY LEDS WITHOUT PROGRAM REBATE, SKIP TO C.1.5 5**]**

3-26. [RETAIL BUYER ONLY] The Connecticut ENERGY STAR Lighting Program in the past 12 months paid average buydown or markdown discounts of $3.74 to $4.24 per LED A-lamp bulb and $5.49 to $5.62 per LED reflector bulb. Do you think you would have sold any LED products in Connecticut if these discounts had not been available?

a) [IF NO] Why do you say this?

[IF RESPONDENT INDICATED THEY WOULD NOT HAVE SOLD ANY LEDS WITHOUT PROGRAM REBATE, SKIP TO C.1.5 5]

Retrospective Net-to-Gross – LED A Lamps

3-27. [MANUFACTURERS ONLY]
[INSTRUCTIONS TO SURVEYOR:

- FIRST ASK THE MANUFACTURER THE FREE RIDERSHIP QUESTION SEQUENCE FOR THE RETAILER CATEGORY THROUGH WHICH THEY SOLD THE MOST LEDS THROUGH THE PROGRAM (SEE TRACKING DATA MATRIX). EXCLUDE ANY RETAILER CATEGORIES THAT THEY IDENTIFIED IN QUESTION 3-25 AS NOT SELLING ANY LED BULBS AT ALL WITHOUT THE BUYDOWNS.
- REPEAT THE FREE RIDERSHIP BATTERY FOR ALL RETAIL CHANNELS WHICH ACCOUNTED FOR AT LEAST 20% OF THE SUPPLIER'S PROGRAM SALES]

The Connecticut ENERGY STAR Lighting Program in the past 12 months paid average buydown or markdown discounts of $3.74 to $4.24 per LED A-lamp bulb. If these program buydown/ markdown discounts and program promotional materials had not been available in the past 12 months, do you think your sales of these types of bulbs through [RETAILER CATEGORY] stores in Connecticut would have been about the same, lower, or higher?

b) [IF THE SAME OR HIGHER] Why do you say this? [RECORD RESPONSE AND THEN SKIP TO NEXT SECTION]

c) [IF LOWER] By what percentage do you estimate your sales of LED A lamps would be lower in the past 12 months if these program buydowns/ markdowns and program promotional materials had not been available? [RECORD % DECREASE]

i. I want to make sure I understand you correctly. You estimate that your sales would have been [PERCENTAGE FROM QUESTION above] % lower without the program support. So if you actually sold 100 LED bulbs in a given week, you think you'd have sold only about [100 – (PERCENTAGE FROM QUESTION 3-13b * 100)] in that period if the buydowns/markdowns hadn't been available? [IF RESPONSE IS ≠ YES, THEN CLARIFY ESTIMATED SALES DECREASE]

[REPEAT QUESTION BATTERIES FOR ALL RETAIL CHANNELS WITH SIGNIFICANT PROGRAM SALES]

3-28. [RETAIL LIGHTING BUYERS ONLY] The Connecticut ENERGY STAR Lighting Program in the past 12 months paid average buydown or markdown discounts of $3.74 to $4.24 per LED A-lamp. If these program buydown/ markdown discounts and program promotional materials had not been available in the past 12 months, do you think your sales of these types of bulbs in Connecticut would have been about the same, lower, or higher?

a. [IF THE SAME OR HIGHER] Why do you say this? [RECORD RESPONSE AND THEN SKIP TO NEXT SECTION]

b. [IF LOWER] By what percentage do you estimate your Connecticut sales of Energy Star LED A lamps would be lower in the past 12 months if these program buydowns/ markdowns and program promotional materials had not been available? [RECORD % DECREASE]

i. I want to make sure I understand you correctly. You estimate that your sales would have been [PERCENTAGE FROM QUESTION 3-24b.] % lower without the program support. So if you actually sold 100 LED bulbs in a given week, you think you'd have sold only about [100 – (PERCENTAGE FROM QUESTION 3-24b.) * 100)] in that period if the buydowns/markdowns hadn't been available? [IF RESPONSE IS ≠ YES, THEN CLARIFY ESTIMATED SALES DECREASE]

Retrospective Net-to-Gross – LED Reflectors

3-29. [MANUFACTURER ONLY]
[IF RESPONSE TO QUESTION 3-25 WAS THAT THEY WOULD NOT HAVE SOLD ANY LEDS WITHOUT PROGRAM REBATE, SKIP TO C.1.5 5]

[INSTRUCTIONS TO SURVEYOR:

- FIRST ASK THE MANUFACTURER THE FREE RIDERSHIP QUESTION SEQUENCE FOR THE RETAILER CATEGORY THROUGH WHICH THEY

SOLD THE MOST LEDS THROUGH THE PROGRAM (SEE TRACKING DATA MATRIX). EXCLUDE ANY RETAILER CATEGORIES THAT THEY IDENTIFIED IN QUESTION 3-25 AS NOT SELLING ANY LED BULBS AT ALL WITHOUT THE BUYDOWNS.

- REPEAT THE FREE RIDERSHIP BATTERY FOR ALL RETAIL CHANNELS WHICH ACCOUNTED FOR AT LEAST 20% OF THE SUPPLIER'S PROGRAM SALES]

The Connecticut ENERGY STAR Lighting Program in the past 12 months paid average buydown or markdown discounts of $5.49 to $5.62 per LED reflector bulb. If these program buydown/ markdown discounts and program promotional materials had not been available in the past 12 months, do you think your sales of these types of bulbs through [RETAILER CATEGORY] stores in Connecticut would have been about the same, lower, or higher?

a. [IF THE SAME OR HIGHER] Why do you say this? [RECORD RESPONSE AND THEN THANK AND TERMINATE]

b. [IF LOWER] By what percentage do you estimate your sales of LED reflectors would be lower in the past 12 months if these program buydowns/ markdowns and program promotional materials had not been available? [RECORD % DECREASE]

   i. I want to make sure I understand you correctly. You estimate that your sales would have been [PERCENTAGE FROM QUESTION 3-16b.] % lower without the program support. So if you actually sold 100 LED bulbs in a given week, you think you'd have sold only about [100 – (PERCENTAGE FROM QUESTION 3-16b * 100)] in that period if the buydowns/markdowns hadn't been available? [IF RESPONSE IS ≠ YES, THEN CLARIFY ESTIMATED SALES DECREASE]

[REPEAT QUESTION BATTERIES FOR ALL RETAIL CHANNELS WITH SIGNIFICANT PROGRAM SALES]

3-30. [RETAIL LIGHTING BUYERS ONLY]

[IF RESPONSE TO QUESTION 3-26 WAS THAT THEY WOULD NOT HAVE SOLD ANY LEDS WITHOUT PROGRAM REBATE, SKIP TO C.1.5 5]

The Connecticut ENERGY STAR Lighting Program in the past 12 months paid average buydown or markdown discounts of $5.49 to $5.62 per LED reflector. If these program buydown/ markdown discounts and program promotional materials had not been available in the past 12 months, do you think your sales of these types of bulbs in Connecticut would have been about the same, lower, or higher?

a. [IF THE SAME OR HIGHER] Why do you say this? [RECORD RESPONSE AND THEN THANK AND TERMINATE]

b. [IF LOWER] By what percentage do you estimate your Connecticut sales of Energy Star LED reflectors would be lower in the past 12 months if these program buydowns/ markdowns and program promotional materials had not been available? [RECORD % DECREASE]

   i. I want to make sure I understand you correctly. You estimate that your sales would have been [PERCENTAGE FROM QUESTION 3-30b)] % lower without the program support. So if you actually sold 100 LED bulbs in a given week, you think you'd have sold only about [100 – (PERCENTAGE FROM QUESTION 3-30b) * 100)] in that period if the buydowns/markdowns hadn't been available? [IF RESPONSE IS ≠ YES, THEN CLARIFY ESTIMATED SALES DECREASE]

C.1.5 Section 5: Program Attribution - Prospective

Prospective NTG -- LEDS

[READ] My final set of questions will cover what you think will be the likely future market penetration of LEDs in Connecticut both with and without the Connecticut ENERGY STAR lighting program.

We are going to explore two different scenarios.

In the first scenario the Connecticut Energy Star lighting program continues to offer upstream discounts for LEDs through 2020.

In the second scenario this program is discontinued after 2016.

And just to be clear we're talking about the retail lighting market and not sales through lighting distributors.

Prospective NTG – LED A-LAMPS

3-31. First, let's start by assuming that the Connecticut ENERGY STAR lighting program will continue to provide LED discounts through 2021. Please provide your best estimate of what you think the market shares of these LED A-lamps will be at year-end 2017, 2019 and 2021 with the Connecticut program continuing through 2020. Your predictions should include all LED A-lamps, including both ENERGY STAR and non-ENERGY STAR LED A-lamps.

Table 30: Market Shares for LED A- Lamps if Connecticut Program Continues to Provide LED Discounts Through 2021

Bulb Type	2015 CREED data (reference point)	2017 CT Retail Market Shares	2019 CT Retail Market Shares	2021 CT Retail Market Shares
LED A—Lamps	16%	%	%	%

3-32. Next let's assume that the Connecticut ENERGY STAR lighting program is discontinued after 2016. Again, please provide your best estimate of what you think the market shares of these LED A-lamps will be at year-end 2017, 2019 and 2021 with the Connecticut program ending in 2016. Your predictions should include all LED A-lamps, including both ENERGY STAR and non-ENERGY STAR LED A-lamps.

Table 31: Market Shares for LED A-Lamps if Connecticut Program is Discontinued After 2016

Bulb Type	2015 CREED data (reference point)	2016 CT Retail Market Shares	2019 CT Retail Market Shares	2021 CT Retail Market Shares
LED A-Lamps	16%	%	%	%

3-33. What assumptions are you making when predicting this Connecticut market share trend for LED A-lamps both with and without the program?

Prospective NTG – LED Reflectors

Next please provide your best estimate of what you think the market shares of these LED reflectors will be at year-end 2017, 2019 and 2021 with the Connecticut program continuing through 2021. Your predictions should include both ENERGY STAR and non-ENERGY STAR LED reflectors.

Table 32: Market Shares for LED Reflectors if Connecticut Program Continues to Provide LED Discounts Through 2021

Bulb Type	2017 CT Retail Market Shares	2019 CT Retail Market Shares	2021 CT Retail Market Shares
LED Reflectors	%	%	%

3-34. Next let's assume that the Connecticut ENERGY STAR lighting program is discontinued after 2016.
Please provide your best estimate of what you think the market shares of these LED reflectors will be at year-end 2017, 2019 and 2021 with the Connecticut program ending in 2016. Your predictions should include both ENERGY STAR and non-ENERGY STAR LED reflectors.

Table 33: Market Shares for LED Reflectors if Connecticut Program is Discontinued After 2016

Bulb Type	2017 CT Retail Market Shares	2019 CT Retail Market Shares	2021 CT Retail Market Shares
LED Reflectors	%	%	%

3-35. What assumptions are you making when predicting this Connecticut market share trend for LED reflectors both with and without the program?

That's all the questions I had for you today. Thanks again for taking the time

C.2 Program Staff Interviews

Appendix content

Hello, may I speak to [______]? My name is ______, and I'm calling from NMR Group, an independent research firm, on behalf of the sponsors of the Energize Connecticut Residential Retail Products Program. We are conducting interviews with [COMPANY] program staff members most familiar with the Lighting Strategy of this Program. The purpose of my call is to ask you some questions about the design and delivery of the lighting program and also to get your perspectives on the current nature and future direction of the Connecticut lighting market.
Is now a good time to speak with you?
Is this a good time for us to speak with you? (IF NOT, SET UP CALL BACK APPOINTMENT).
May I record this conversation?

C.2.1 Responsibilities, Organization

Let's start with a little information about you.

1. What is your position or job title?
2. What are your current responsibilities as manager for Lighting Strategy components of the Residential Retail Products Program? [ALLOW THEM TO RESPOND FIRST IN AN OPEN-ENDED FASHION, AND THEN PROBE FOR THEIR ROLES IN THE FOLLOWING KEY PROGRAM ACTIVITIES]
    a. Program planning? Program design? Management?
    b. Marketing the program to end users (e.g., point-of-sales marketing collateral, signage)
    c. Working with the program implementation contractors
    d. Tracking program activity/program tracking data

C.2.2 Program Design, Program Offerings, Hard to Reach

First, I'd like to talk about the program design and the lighting products your program supports.

3. Currently, what types of products does the program support? [PROBE: standard and specialty CFLs (including reflectors), standard and specialty LEDs (including reflectors), fixtures (including downlight kits), lighting controls.]
4. How has the product mix changed since the 2012 to 2015 program cycle? How has the product mix changed since the start of the 2016-2018 program cycle? Why has it changed? [PROBE FOR ENERGY STAR 2.0 AND EISA2 IF NOT MENTIONED; PROBE ON CFLS NO LONGER BEING QUALIFIED AND SOME VALUE-LINE BECOMING QUALIFIED.]
5. How are the types of products sold by program partners determined? [PROBE: Do the Companies determine it? The implementers? The partners?]

6. How are the volumes of products they sell determined? [PROBE: Do the Companies determine it? The implementers? The partners?]
7. Can partners change what they are doing after the MOU has been signed for the cycle?
    a. [IF YES] What kinds of changes can they make?
    b. What can't they change?
    c. What is the process for making these changes?
8. How is it determined which retail channels the lighting suppliers are selling program-discounted lighting product through?

[IF NOT ADDRESSED EARLIER] The 2016 to 2018 plan discussed increasing the promotion of CFLs in retail channels expected to serve "hard-to-reach" customers. I have a few questions about this component of the lighting strategy.

9. Which customers does the program considers to be "hard-to-reach"?
10. Can you tell me about the process of deciding in which stores to sell HTR bulbs?
11. [IF NOT ADDRESSED IN Q10] Do you base HTR sales on store location? Store type? Both? Are there any retailers for which some of the store locations are HTR but others are not?
12. [IF BASED ON STORE TYPE AND NOT ADDRESSED IN Q10 OR Q11] Why target these stores?
13. As you know, as of right now, no CFLs will quality for ENERGY STAR 2.0 but some lower cost LEDs will become qualified. Have you changed your HTR strategy given the new specification?
    a. If so, how? [PROBE: Are you changing the stores you are targeting for HTR? Are you shifting to LEDs in general? Only to lower-cost LEDs that meet Spec 2.0 but not 1.1?]

C.2.3 Program Marketing and Outreach

Now let's talk about your program's marketing and outreach efforts.

14. What types of marketing and outreach is currently being done to promote this program?
15. Who develops these marketing/outreach strategies?
16. Who implements these marketing/outreach activities?
17. Are there any marketing/outreach activities designed to target customers who are in hard-to-reach (HTR) lighting market sectors such as low-income customers, or customers for whom English is not their first language?
    a. [If YES] What are these HTR marketing/outreach activities?
18. Which program marketing and outreach activities do you believe have been the most effective? Why do you say this?
19. Which program marketing and outreach activities do you believe have been less effective? Why do you say this?

20. Does your program work directly with lighting suppliers and retailers on content and timing of their own promotional campaigns?

    b. [IF YES] What is the nature of your collaboration

C.2.4 Future of Lighting Market

I'd like to talk more about the future of the lighting market. We are asking manufacturers and suppliers the next question in Connecticut and other states, and we'd like to get your input on these questions as well.

As you likely know, the specifics of Phase 2 EISA are somewhat complicated given additional legislation and the recent DOE proposed rulemaking covering CFLs and LEDs. There are two main issues we would like you to consider for the scenarios in this section.

First, the original EISA 2007 legislation included a backstop standard of 45 lumens per watt for general service incandescent, halogen, CFL, and LED lamps set to go into effect January 1, 2020. This backstop applies to the manufacture, import, and sales of all general service lamps.

Second, on February 12, 2016, the DOE issued a proposed rulemaking that included a new efficiency standard for general service CFLs and LEDs **ONLY**. The DOE has proposed a higher lumens/watt standard for medium-screw based CFL and LED lamps of 85-100 lumens per watt depending on lumen output. This standard is to be effective in January 1, 2020 and would apply to manufacture and import of lamps but would allow all existing non-compliant lamps to sell through. The final ruling on this issue is due on or before December 31, 2016.

For these next questions, I will ask you to estimate the likelihood of each of a number of scenarios in terms of percentage. The total of your estimates should add up to 100%. We have defined three scenarios and will give you the opportunity to define a fourth if you think it is worth considering. First, let me read the three defined scenarios:

> **Scenario 1**: EISA 2007 backstop is strictly enforced with a "hard-stop." In this scenario the EISA 2007 backstop is strictly enforced as of 2020 and lamps that do not meet the specifications may no longer be sold, manufactured or imported into the US after the effective date of the regulation. In this scenario, the proposed CFL/LED federal standard is not implemented.
>
> **Scenario 2**: In this scenario both the EISA 2007 backstop and the proposed CFL/LED standard are implemented as of 2020. As in scenario 1, the EISA 2007 backstop is strictly enforced. In addition, the proposed CFL/LED federal standard with "sell-through" is implemented. In this scenario, CFL and LED lamps that do not meet the proposed CFL/LED federal standard cannot be manufactured or imported into the US. However, manufacturers and retailers would continue to "sell through" the existing stock of all non-compliant lamps, regardless of technology, until it is depleted.
>
> **Scenario 3**: The EISA 2007 backstop is repealed and the proposed CFL/LED standard is not implemented. In this scenario, the manufacture and sale of all

currently allowed lamp types continues. It is the scenario where the market operates without additional regulations other than those already in place.

Scenario 4: This is a scenario you define if you think that the three scenarios mentioned do not fully represent the likely options.

Before we continue, would you like me to restate the three defined scenarios?

[IF YES, DO SO. IF NO, PROCEED]

21. Considering the three defined scenarios, is there another scenario that you think should be considered?
22. [IF ANOTHER SCENARIO] "What is that other scenario?" RECORD, IF NO, PROCEED]
23. In terms of percentage, what probability would you assign to Scenario 1 - EISA 2007 backstop is strictly enforced with a "hard-stop" and the proposed 2020 LED/CFL standards are not enacted?
24. What probability would you assign to Scenario 2 – both the EISA 2007 backstop and the proposed CFL/LED standard are implemented and manufacturers and retailers would continue to "sell through" all existing non-compliant lamps?
25. What probability would you assign to Scenario 3 –The EISA 2007 backstop is repealed and the proposed CFL/LED standard is not implemented?
26. [IF APPROPRIATE] And finally, what probability would you assign to the alternative you suggested?

[COMPLETE TABLE BELOW. MUST SUM TO 100%. IF NOT, ASK RESPONDENT TO REVISE PERCENTAGES UNTIL SUMS TO 100%.]

Table 34: Probability of Different EISA2 Scenarios

Scenario	%
1 – Strictly enforced	
2 – Sell through	
3 – Repealed	
4 – Other	
SUM	100%

27. Why do you think Scenario [IDENTIFY SCENARIO WITH HIGHEST PROBABILITY IN TABLE ABOVE] is the most likely scenario?
28. Do you think any future events—whether political, economic or other types of events—might cause you to change your probabilities? [IF YES] How so?

The last set of questions I have for you is about a subset of LEDs that do not qualify under ENERGY STAR Version 1.1 and still won't qualify under Version 2.0. These LED bulbs often lack certain efficacy (lumens per watt) and lifetime requirements that keep them qualifying for ENERGY STAR models. Some people call these “value-line” LEDs.

29. Are you familiar with these types of LEDs?

[IF YES CONTINUE; IF NO, GO TO CONCLUSION]

30. What do you think are the strengths of value-line LEDs? What about weaknesses? [Probe: I’m thinking not only about engineering characteristics but also about such things as price, availability, etc.]
31. What impact will value-line LEDs have on the residential lighting market in general? On energy-efficient lighting programs such as Connecticut Lighting Strategy of the Retail Products Program?

C.2.5 Conclusion

32. What would you say are the biggest strengths of the Lighting Strategy?
33. What are its biggest weaknesses?
34. What are the most important opportunities for the Lighting Strategy?
35. What are the threats to the program?
36. Is there anything we did not discuss that you feel is important to understanding the Connecticut Lighting Strategy?

Thank you so much for your time. That is all the questions I have for you.