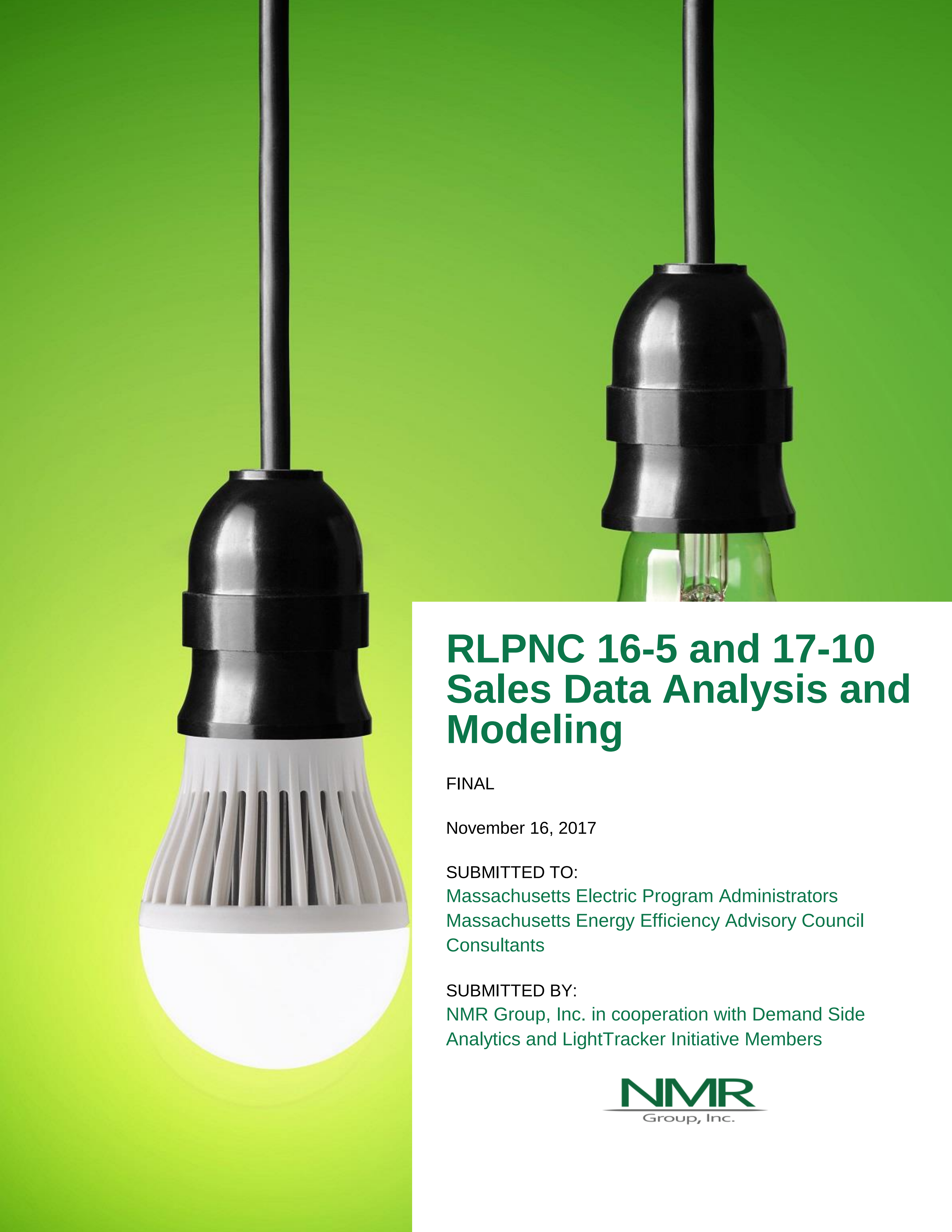

RLPNC 16-5 and 17-10 Sales Data Analysis and Modeling

FINAL

November 16, 2017

SUBMITTED TO:
Massachusetts Electric Program Administrators
Massachusetts Energy Efficiency Advisory Council Consultants

SUBMITTED BY:
NMR Group, Inc. in cooperation with Demand Side Analytics and LightTracker Initiative Members

Abstract

This report describes the results of two studies that analyzed sales data from a dataset compiled by the Consortium for Residential Energy Efficiency Data (CREED). One study describes market share of screw-base light bulbs, and the other estimates net-to-gross ratios (NTGR) for light emitting diodes (LEDs). The studies show that energy-efficient lighting programs in Massachusetts and beyond have had a profound impact on the market. Compared to non-program states, Massachusetts and other program states have higher market shares of LEDs and compact fluorescent lamps (CFLs). In addition, the data suggest that greater adoption of energy-efficient bulbs (in terms of socket saturation and sales) leads to lower bulb sales overall due to the longer measure life of CFLs and LEDs.

As expected, the market shares for LEDs and halogens have increased since 2009, whereas market share for incandescents and CFLs are decreasing. When examining market share by lumen ranges, we observe that inefficient lamps dominate the lowest and highest lumen ranges. Many of these bulbs are currently exempt from federal lighting standard increases, and some will remain exempt in 2020. This offers an opportunity for targeted program opportunities.

Statistical modeling results confirm the importance of program spending for boosting LED sales. Other factors also influence LED sales: program age, income, concentration of certain retail stores, and political leanings. The significance of program age suggests that a portion of efficient lighting sales are due to permanent changes in the market resulting from ongoing program activity. When we estimated NTGRs for LEDs, we compared predicted LED sales with actual 2016 Massachusetts program spending and assuming zero spending in the state. We treated program age two ways: one assuming the program never existed, and the other assuming the program existing until 2015 but not in 2016. The NTGR for the first approach is 55% and for the second approach is 39%.

The study results will primarily be used to inform the development of market adoption models and the LED NTG consensus process. Therefore, we refrain from making recommendations.

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ES Executive Summary

This report describes recent screw-base light bulb sales, market share, and shipments in Massachusetts, New York, program and non-program states (defined below), and the entire United States. It also presents retrospective net-to-gross ratios (NTGRs) for light emitting diodes (LEDs), which were developed through a multistate effort. The findings derive from a database of light bulb sales data compiled by the LightTracker Initiative of the Consortium for Residential Energy Efficiency Data (CREED), and shipment data reported by the Association of Electrical Equipment and Medical Imaging Manufacturers (NEMA).[1,2,3] CREED is a consortium of program administrators, retailers, and manufacturers working together to collect the necessary data to better plan and evaluate energy efficiency programs. LightTracker, CREED's first initiative, focuses on acquiring full-category lighting data, including screw-base 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 by requesting, collecting, and reporting the sales data needed by the energy efficiency community.[4]

NMR Group, Inc. (NMR) analyzed the sales and shipment data to describe market trends and worked with LightTracker analysts (the team) to develop the retrospective LED NTGRs for 2016. These two studies will provide information for the RLPNC 17-11 LED NTG Consensus study and the 17-6 Annual Report and Planning Market Adoption Model study; therefore, NMR refrains from drawing overall conclusions or recommendations based on these two sales data efforts.

Table 1**Error! Reference source not found.** summarizes the topics explored in the study and their relevant data sources. LightTracker provided NMR with two different datasets: full-category lighting data covering all channels and point-of-sale (POS) data for a subset of channels that cover approximately 40% of the market in Massachusetts and the nation. For most topics, the study compares Massachusetts to the nation, New York State, states with lighting programs, and states without lighting programs. The New York State data covers the entire state, including Long Island, which has programs through Public Service Enterprise Group (PSEG). This contrasts to other RLPNC studies in which NMR limits data collection to Upstate New York and Westchester County, which lack programs. Thus, for the purposes of this report, New York is a program state.

The NEMA market share review only includes national data, while the bulb price analysis only compares Massachusetts to the nation and the non-program states. For the NTGR modeling task, the team explored the impact of state-level program activity on weighted LED sales across the nation while controlling for additional factors that may influence LED sales. We used the model

[1] The information contained herein is based in part on data reported by IRI through its Advantage service 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.

[2] Data presented include LightTracker calculations based in part on data reported by Nielsen through its Strategic Planner and Homescan Services for the lighting category for the 52-week period ending approximately on December 31, 2016, for the available state level markets and Expanded All Outlets Combined (xAOC) and Total Market Channels. Copyright © 2016, Nielsen.

[3] NEMA "Lamp Indices." Accessed on August 15, 2017, at http://www.nema.org/Intelligence/Pages/Lamp-Indices.aspx

[4] See (https://www.creedlighttracker.com).

results, the LED sales data, and the program-tracking databases to calculate NTGRs for Massachusetts program LED sales in 2016.

Table 1: Study Topics and Data Sources

Topic	Years Analyzed	Areas Examined[1]	Data Source[2]
Market share (sales)	2009 to 2016	MA, NY, US, program states, non-program states	LightTracker full category, POS
Market share (shipments)	2011 to 2017	Entire US only	NEMA
LED ENERGY STAR qualification	2016	MA, NY, US, program states, non-program states	LightTracker POS
Bulb sales	2016	MA, NY, US, program states, non-program states	LightTracker full category
Bulb Price Analysis	2016	MA, US, non-program states	LightTracker POS[3]
NTGR Modeling	2016	38 states with adequate data, including MA	LightTracker full category

[1] New York represents the entire state, including New York City, Long Island, and the Downstate region. This differs from other RLPNC studies that focus on Upstate New York and Westchester County. Long Island actually has program activity, making New York a program state.

[2] Full category LightTracker data includes sales information for all retail channels and represents 100% of the lighting market. Point-of-sale (POS) data include mass merchandise, dollar, discount, grocery, drug, and some membership stores, representing 40% of lighting sales in Massachusetts and 38% nationally.

[3] Pricing data for bulb types by technology was available for the full category dataset, but not for detailed breakdowns. See Section 2.3 for more details.

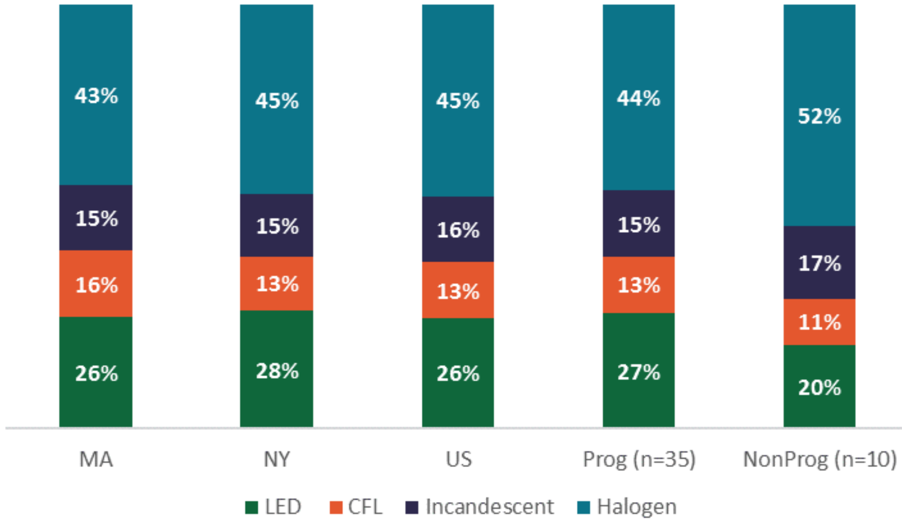
FINDINGS

This section highlights the key findings from the study. The descriptive data analysis compares Massachusetts, New York, the entire nation, program states, and non-program states. The NTGR modeling analysis draws on all available states in the LightTracker dataset.

Market Share and Bulb Sales

Of the areas considered in this analysis, Massachusetts had the highest combined market share of energy-efficient bulbs in 2016 (42%). As Figure 1 shows, energy-efficient bulb market share in non-program states lagged behind all other areas (MA, NY, US, and program states). Halogens make up the difference in market share in non-program states.

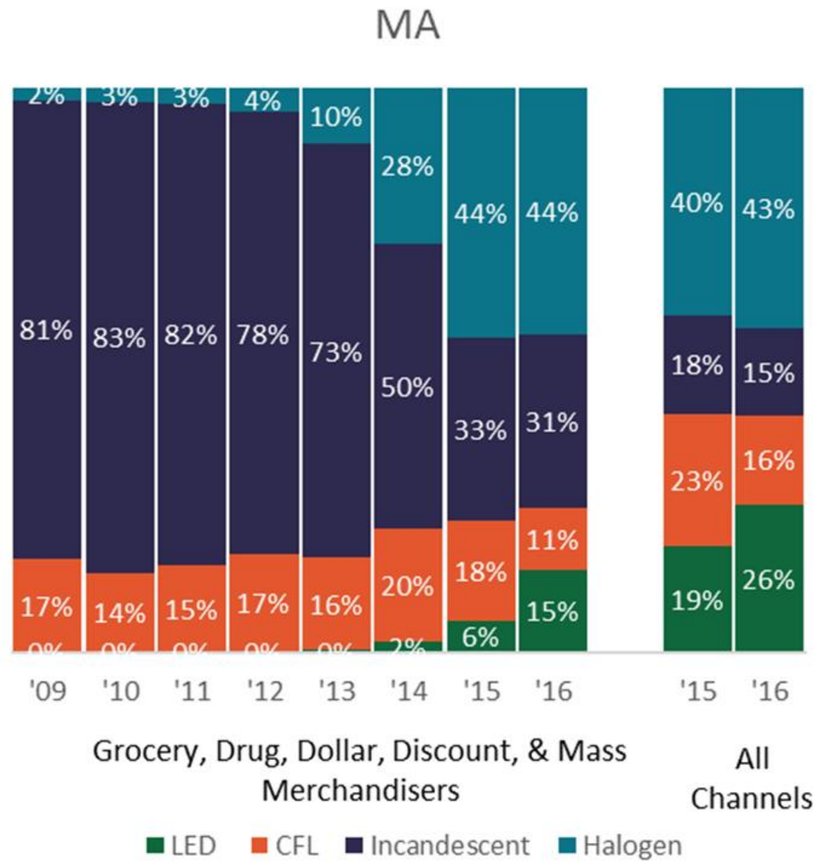
Figure 1: 2016 Market Share in Massachusetts and Comparison Areas[1]



[1] All retail channels

In the US, market shares for LEDs and halogens are increasing, whereas market shares for incandescents and CFLs are contracting. The market shares of bulbs in Massachusetts and all other areas considered, as well as the NEMA shipment share data, follow the same trend (Figure 2).

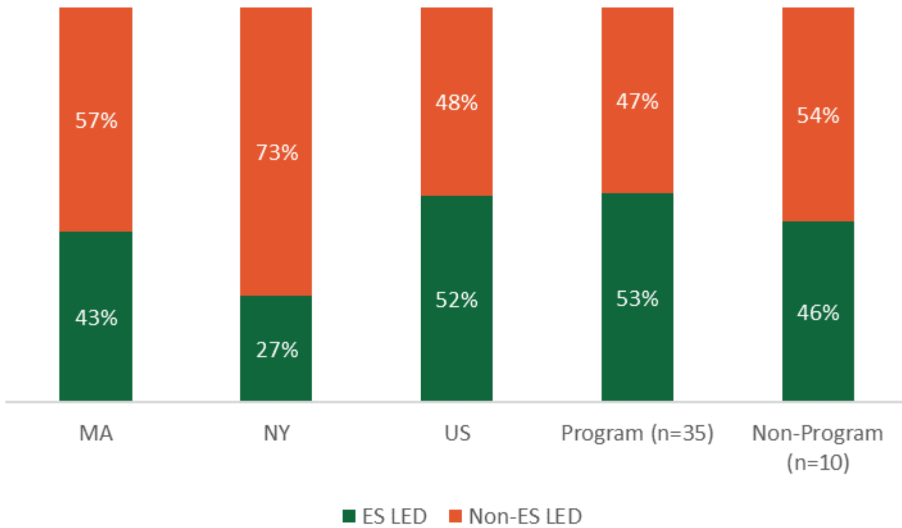
Figure 2: MA Market Share by Bulb Technology Type 2009-2016[1]



[1] Includes grocery, drug, dollar, discount, and merchandise stores, and represents approximately 40% of the Massachusetts market.

The proportion of confirmed ENERGY STAR qualified bulbs sold in Massachusetts is higher than New York but lower than the US, program, and non-program states. The LightTracker team used a variety of data sources to determine whether the LEDs in the dataset had ever qualified for the ENERGY STAR label (See Section 2.1.2 for more details). Among the LEDs for which LightTracker could verify status, 43% were ENERGY STAR qualified in Massachusetts in 2016 (by any prior or current specification) (Figure 3). This is higher than in New York (a finding that confirms similar results in other RLPNC studies) but lower than in the US (52%), program states (53%), and non-program states (46%). The data do not allow for an assessment of why Massachusetts has relatively low percentages of qualified ENERGY STAR LED sales based on the LightTracker dataset, but the fact that the analysis is based only on some retail channels could provide partial explanation. The excluded channels tend to carry a large percentage of ENERGY STAR products in Massachusetts.

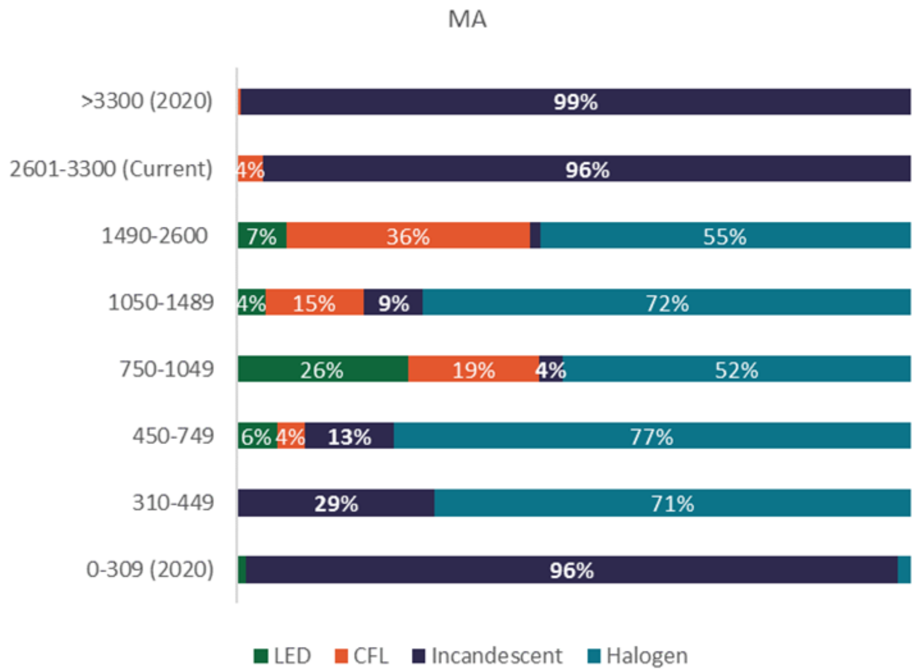
Figure 3: LED ENERGY STAR Status by Area[1]



[1] Includes grocery, drug, dollar, discount, and merchandise stores, and represents approximately 40% of the Massachusetts market, 38% of the US, 33% of New York, 38% of program states, and 41% of non-program states.

Incandescent and halogen bulbs account for nearly all A-line bulb sales in current and future EISA (2020) exempt lumen bins. Low- and high-lumen bulbs that are currently EISA exempt and will remain so in 2020 compose about nine percent of the Massachusetts lighting market (another one percent are currently exempt but will cease to be in 2020). However, market share by bulb-type varies considerably by lumen range. The market shares of the lowest and highest lumen ranges are almost entirely made up of incandescents. This suggests that there are current and future program opportunities for low and high lumen bulbs (Figure 4). Section 2.1.4 and Appendix C provide additional analysis by lumen bins.

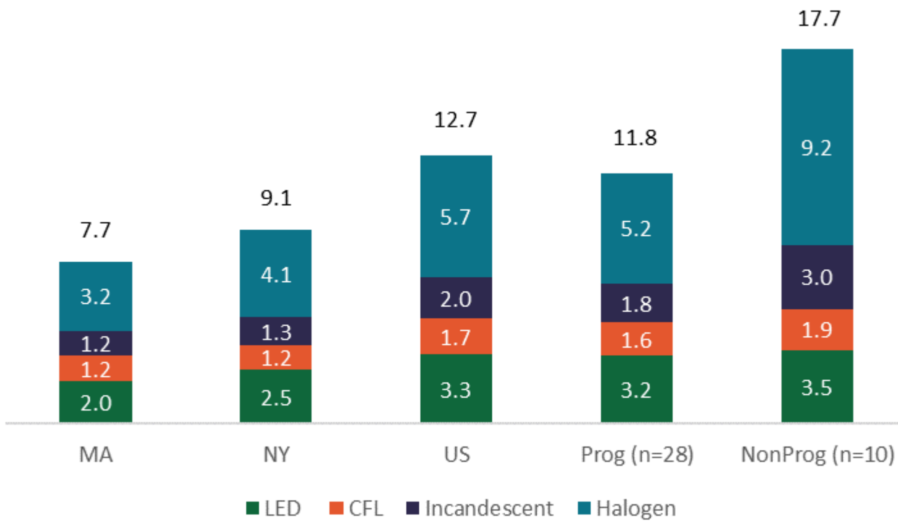
Figure 4: A-line Bulb Market Share by Lumen Bins and Bulb Type[1,2,3]



[1] Includes grocery, drug, dollar, discount, and merchandise stores, and represents approximately 40% of the Massachusetts market.
[2] Columns sum to 100%, but data labels of 2% or less have been hidden for aesthetic purposes.
[3] *Current* refers to bulbs that are currently exempt from EISA but will cease to be in 2020. *2020* refers to bulbs that are currently exempt from EISA and will remain exempt in 2020.

Socket saturation and market share of energy-efficient bulbs (LEDs and CFLs) likely influence bulb sales per household across the US. As Figure 5 shows, Massachusetts has the lowest sales per household when compared to the other study areas considered in the descriptive analysis. As explored in-depth in Section1.1, bulb sales tend to correlate with energy-efficient socket saturation and energy-efficient bulb market share. A greater concentration of CFLs and LEDs reduces the frequency of bulb sales due to the longer lifespans of efficient bulbs.

Figure 5: Bulb Sales per Household Across Areas[1]

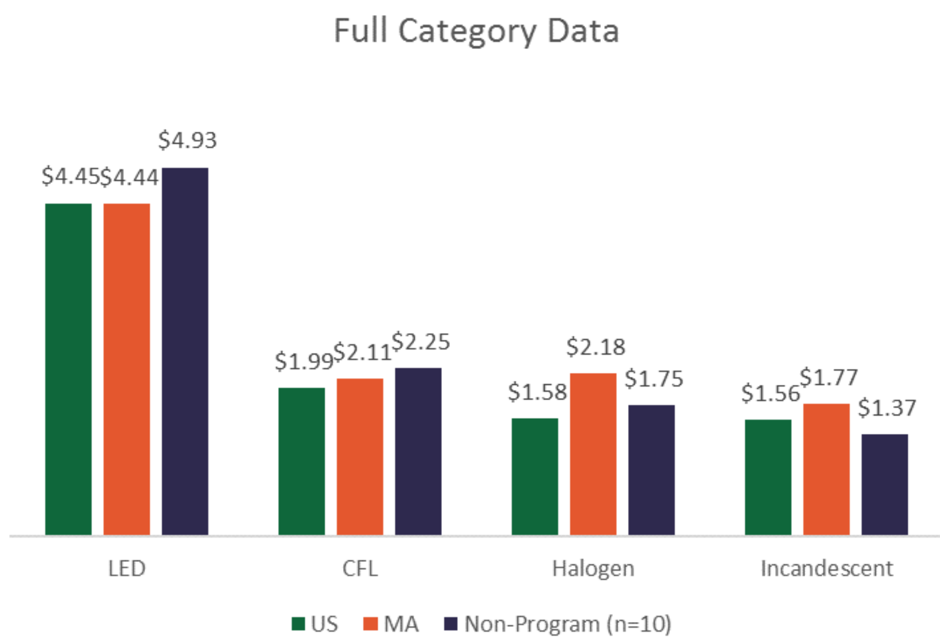


[1] All retail channels

Bulb Price Analysis

LED and CFL prices—which include program incentives—generally remained higher than incandescent and halogen prices in 2016. LED prices are double those of other bulb types, but CFLs are nearly price competitive with halogens and incandescents (Figure 6). Because they reflect the shelf price, the estimates include program discounts for LEDs and CFLs.

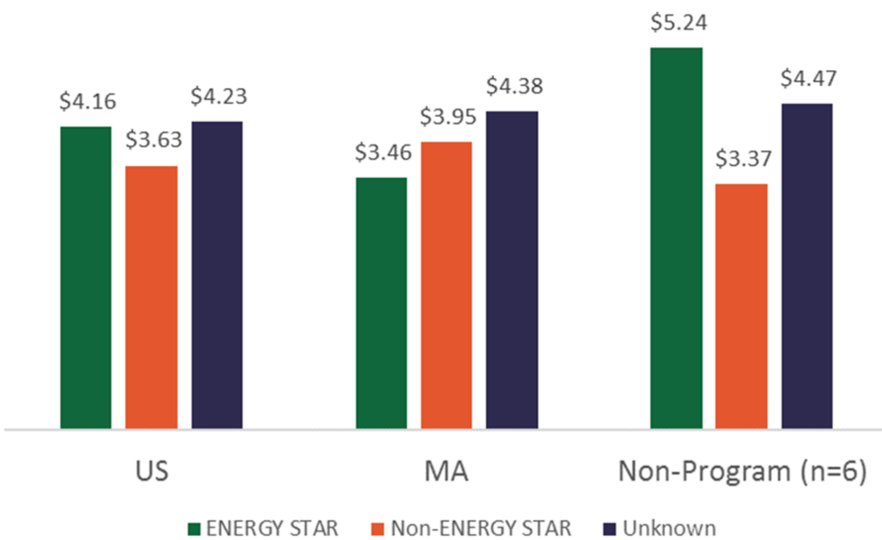
Figure 6: Average Shelf Price per Bulb by Bulb Type [1,2]



[1] All retail channels
[2] Does not include *private label* bulbs sold at specific retailers, so the prices reported here are likely somewhat higher than actual prices.

ENERGY STAR LEDs cost more than non-ENERGY STAR models in non-program states and across the nation. However, this was not the case in Massachusetts. Program price supports in Massachusetts helped to make ENERGY STAR models the least expensive LED option, as shown in Figure 7.

Figure 7: Average Shelf Price per LED by ENERGY STAR Qualification[1,2,3]

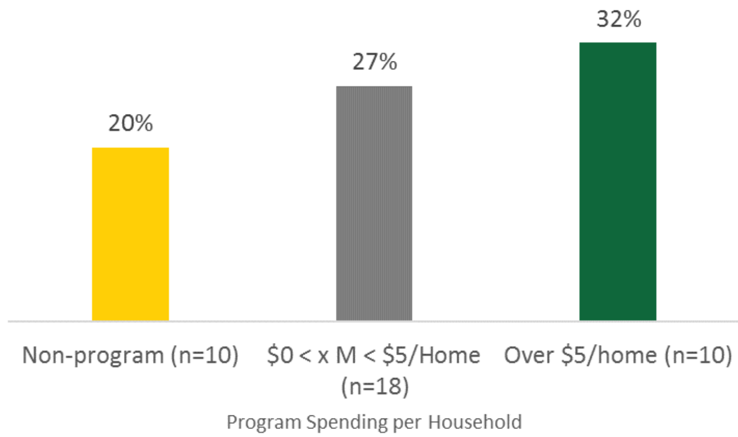


[1] Includes grocery, drug, dollar, discount, and merchandise stores, and represents approximately 40% of the Massachusetts market, 38% of the US, and 41% of non-program states.
[2] Does not include *private label* bulbs sold (aka store brands), so the prices reported here are likely somewhat higher than actual prices.
[3] The non-program sample size of six (compared to ten for most other analyses) reflects a lack of sufficient pricing data for a subset of POS states.

Net-to-Gross Modeling

LED shares increase as program spending increases. In states like Massachusetts that have aggressive program activity (spending over $5 per household in upstream lighting programs), LEDs consist of 32% of total 2016 bulb sales. In comparison, LEDs make up 20% of total bulb sales in non-program states (Figure 8).

Figure 8: Program Spending and LED Market Share (2016)



Statistical modeling results confirm the importance of program spending for boosting LED sales; program age, income, concentration of certain retail stores, and political leanings also influence LED sales. The significance of program age suggests that a portion of efficient lighting sales are due to changes in the market as a result of ongoing program activity (Table 2). Massachusetts has one of the oldest programs in the nation but a moderate LED market share compared to other program states. Massachusetts' continued aggressive support of CFLs through most of 2016 may have contributed to its lower LED market share, as some households bought CFLs rather than LEDs.

Table 2: Model Summary Statistics (n=38 States)

Independent Variable	Model Coefficient	*p*-value of Coefficient
Intercept	-0.908	0.013
Program Spending per Household (Sqrt)	0.029	0.001
Political Index	0.010	0.005
Median Income	<0.001	0.007
Political Index * Median Income	<-0.001	0.006
Non-POS sqft per HH	0.011	0.187
Program Age	0.002	0.068
Model Adjusted R^2		**0.677**

The NTGRs suggested by the recommended model are 55% when assuming the Massachusetts program never existed (i.e., there was no program activity in 2016 or any years prior), and 39% when assuming the program existed through 2015 but not in 2016. The team modeled and compared the counterfactual scenario (which can only be modeled, as it never actually happened) with a *modeled* LED market share, rather than the actual LED market share, to allow for a more comparable calculation (Table 3).

Table 3: Model Summary Statistics (n=38 States)

Calculation Term	Counterfactual: No Massachusetts Programs Ever	Counterfactual: No Massachusetts Program in 2016
Total Massachusetts Bulbs 2016 (A)	19,460,804	19,460,804
Program $ per HH Actual (B)	$11.31	$11.31
Program $ per HH Counterfactual (C)	$0.00	$0.00
Program Age Actual (D)	18	18
Program Age Counterfactual (E)	0	17
LED Market Share Counterfactual (F)	17.5%	21.7%
LED Market Share Modeled (G)	31.8%	31.8%
LED Qty Modeled (H=A*G)	6,188,536	6,188,536
LED Qty Counterfactual (I= A*F)	3,405,641	4,222,994
Net LEDs Modeled (J=H-I)	2,782,895	1,965,541
Program LED Bulbs 2016 (K)	5,096,082	5,096,082
NTGR Modeled (L=J/K)	55%	39%

RECOMMENDATIONS

This study refrains from making any specific recommendations, as the market data and NTGR estimates calculated from this study will inform the 17-6 Market Adoption Model Study and the 17-11 LED Net-to-Gross Consensus study.

1

Section 1 Introduction

This report describes recent light bulb sales and market share in Massachusetts, New York, program and non-program states (defined below), and the entire United States. It also presents retrospective net-to-gross ratios (NTGRs) for light emitting diodes (LEDs).[5] Both sets of findings are derived from a database of light bulb sales compiled by the LightTracker Initiative of the Consortium for Residential Energy Efficiency Data.[6,7,8] The study also presents updated shipment data from the Association of Electrical Equipment and Medical Imaging Manufacturers (NEMA).[9]

The electric Program Administrators (PAs) and Energy Efficiency Advisory Council (EEAC) Consultants commissioned the study. NMR Group, Inc. (NMR) analyzed the sales and shipment data and worked with other LightTracker analysts (especially Demand Side Analytics) to develop models used to estimate LED NTGRs for 2016. The results of these two studies will be considered together with results from numerous other lighting evaluations currently underway to inform the RLPNC 17-11 LED NTG Consensus study and the 17-6 Annual Report and Planning Market Adoption Model study. As such, the current report refrains from drawing overarching conclusions or making recommendations.

1.1 Study Objectives and Research Questions

The objectives of the amended RLPNC 16-5 Sales Data Analysis Study and of the RLPNC 17-10 Sales Data LED NTG Modeling Study, include the following:

- Examine current market share, bulb sales, and bulb shipments in Massachusetts, New York, states with and without upstream lighting programs, and the entire nation.
- Explore trends in bulb market share from 2009 to 2016 and quarterly bulb shipment share from 2011 to first quarter 2017.
- Compare average prices of LEDs to other bulb types in the bulb price analysis.

[5] Note that the model was part of a multistate effort and included the input and support of other consulting firms.

[6] 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, CREED's first initiative, is 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).

[7] The information contained herein is based in part on data reported by IRI through its Advantage service, 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.

[8] Data presented include LightTracker calculations based in part on data reported by Nielsen through its Strategic Planner and Homescan Services for the lighting category for the 52-week period ending approximately on December 31, 2016, for the available state level markets and Expanded All Outlets Combined (xAOC) and Total Market Channels. Copyright © 2016, Nielsen.

[9] NEMA "Lamp Indices." Accessed on February 22, 2017, at http://www.nema.org/Intelligence/Pages/Lamp-Indices.aspx

- Assess market share in very low (<310) and very high lumen bins (>3,300), which roughly coincide with ranges that will remain exempt when Phase 2 of the Energy Independence and Security Act (EISA) goes into effect in 2020.

This analysis includes the entire state of New York, which differs from other RLPNC studies that rely on the state as a comparison area. Massachusetts uses Upstate New York and Westchester County as a comparison area in many lighting studies because the New York State Energy Research and Development Authority (NYSERDA) stopped offering incentives on efficient lighting in 2014. However, the sales data are reported at the state-level, which includes Downstate as well as Long Island, where Public Service Enterprise Group (PSEG) has lighting programs. New York is accordingly considered a program area in this study. When interpreting the findings from New York—and drawing comparisons to other studies—one should keep the different geographic areas and the program status in mind.

The studies collectively addressed the following research questions:

- What are the short- and long-term trends in light bulb shipments, sales, and market share in Massachusetts?
- How do these trends in Massachusetts compare with New York, program and non-program states, and the nation?
- What is the bulb price of LEDs in Massachusetts compared to other bulb types?
- Does the current LED share of bulbs in very high and very low lumen bins suggest any future program opportunities?
- What do the data suggest regarding current program impact and program impact relative to national or comparative markets?
- What was the relationship between program intensity and LED sales in Massachusetts, other states, and the nation in 2016?
- What factors other than program intensity contribute to LED sales?

1.2 Data Sources

NMR and the LightTracker analysis team leveraged a variety of data sources to perform the analyses described in this report. These include the following main sources:

- Light bulb sales compiled by CREED as part of the LightTracker Initiative
- Longitudinal sales data (2009 to 2016) and shipment data (2011 to 2017)
- Program activity
- Retail Channel Variables
- State-Level Household and Demographic Characteristics

The sections below provide more detail on each of these data sources.

1.2.1 2016 Lighting Sales

CREED generated the sales data from two sources: point-of-sale (POS) state sales data (representing grocery, drug, dollar, discount, mass merchandiser, and selected club stores) and National Consumer Panel (NCP) state sales data (representing home improvement, hardware, online, and selected club stores). Raw datasets were purchased from third-party vendors, and the LightTracker team cleaned, processed, and calibrated the data for analysis, which resulted in a dataset that represents all retail channels serving the residential lighting market. The LightTracker POS dataset represents actual sales that are scanned at the cash register for participating retailers. NMR additionally reviews NEMA shipment data, available on the organization's website, to assess market share. Table 4 summarizes the sources.

Table 4: Study Topics and Data Sources

Topic	Years Analyzed	Areas Examined[1]	Data Source[2]	Market Coverage
Market share (sales)	2009 to 2016	MA, NY, US, program states (n=28), non-program states (n=10)	LightTracker full category for sales by bulb type, POS for sales overtime, by bulb shape, and by lumen bins	100% for 2016, 40% for MA[2]
Market share (shipments)	2011 to 2017	Entire US only	NEMA	100% for reporting manufacturers
LED ENERGY STAR qualification	2016	MA, NY, US, program states (n=28), non-program states (n=10	LightTracker POS	40% for MA[2]
Bulb sales	2016	MA, NY, US, program states (n=28), non-program states (n=10	LightTracker full category	100%
Bulb Price Analysis	2016	MA, US, non-program states (n=6)	LightTracker POS[3]	40% for MA[2]
NTGR Modeling	2016	38 states with adequate data, including MA	LightTracker full category	100%

[1] New York represents the entire state, including New York City, Long Island, and the Downstate region. This differs from other RLPNC studies that focus on Upstate New York and Westchester County. Long Island actually has program activity, making New York a program state.

[2] Full category LightTracker data includes sales information for all retail channels and represents 100% of the lighting market. Point-of-sale (POS) data include mass merchandise, dollar, discount, grocery, drug, and some membership stores, representing 40% of lighting sales in Massachusetts and 38% nationally.

[3] Pricing data for bulb types by technology was available for the full category dataset, but not for detailed breakdowns. See Section 2.3 for more details.

The NCP represents a panel of approximately 100,000 residential households that are provided a handheld scanner for their home and instructed to scan in every purchase they make that has a bar code. For Massachusetts, the NCP included approximately 1,326 households in 2016. The use of a scanner avoids potential "recall bias," which is prevalent in self-report methods that ask about lighting purchases.

Both the POS and the NCP datasets provide national level estimates of bulb sales. They also provide state-level data for individual states with sufficient sales and/or panel participation.

Though the dataset the team received included detailed records of lighting data purchases, the data required a considerable effort to ensure data integrity and inclusion of all the necessary bulb attributes. For example, some records did not have critical variables populated, such as bulb type, style, or wattage. In addition, some records had clearly erroneous values (e.g., 60 watt LEDs). After thorough review and quality control of the dataset, the team then re-classified and standardized the data. The team also populated missing records, created additional variables, and performed general enhancements to the data. To populate missing records, validate existing records, and include additional bulb attributes, the team created a proprietary Universal Product Code (UPC) database with approximately 30,000 bulbs from the following five sources:

- Manufacturer product databases provided to LightTracker
- Product catalogs downloaded from manufacturer web sites via web scraping
- Product offerings downloaded from retailer web sites
- Automated lookups of online UPC databases, such as www.upcitemdb.com
- ENERGY STAR databases available online at https://www.energystar.gov/productfinder/product/certified-light-bulbs

The team also compared its estimates against additional sources, such as the Department of Commerce's estimates of compact fluorescent lamp (CFL) imports, NEMA shipment data, and ENERGY STAR estimates of bulb shipments.

LightTracker then 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 in the following order: manufacturer specifications, UPC lookups, original IRI-based database values. The team also conducted manual web lookups on individual bulbs to determine final assignments.

In addition, the team investigated the bulb assignment and the quantity of bulbs per package by examining the average price per unit and by identifying outliers in terms of per bulb prices. This process helped us identify misclassification of certain bulb types (e.g., bulbs that were flagged as low cost LEDs but were really LED nightlights, so they needed to be moved under the *other* category), and misclassification of bulb counts that 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).

The final model ended up with 38 states (see Appendix A), which accounted for the smaller states that did not have a sufficient sample size from the panel data or had incomplete program data available. Key aspects of the lighting dataset include:

- 2016 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 (with 48 states included) and bulb type
- Inclusion of all bulb styles and controls

1.2.2 Longitudinal Sales and Shipment Data

The Massachusetts PAs and EEAC Consultants also desired longitudinal analyses of bulb sales and shipments. Therefore, NMR supplemented the full 2016 LightTracker data with POS data from 2009 to 2016 (obtained from CREED), which captured about 40% of the residential lighting bulb sales.[10] We also examined quarterly NEMA bulb shipment data, derived from a survey of NEMA members, which provided information for January 2011 to March 2017.[11]

1.2.3 Program Activity

To research program activity, the LightTracker team used internal resources and conducted a literature review of publicly available reports that were found on the internet or provided by program administrators or their evaluators.[12] The team contacted local utilities in each given area when reports with the relevant information were not available. Additionally, the team accessed DSM Insights, an E Source product that provides a detailed breakdown of program-level spending, including incentives, marketing, and delivery for over 100 program administrators around the country.[13]

The program data collection activity included:

- Total number of claimed LED upstream program bulbs reported by each program
- Upstream LED incentives
- Total upstream program budget

Where available, the team used actual program data; in other cases, it turned to DSM Insights, ENERGY STAR reported expenditures, or planning values as proxies.[14]

All states with at least some program activity in 2016 were designated *program states; the* remaining states were designated *non-program states*. The descriptive data analysis of bulb sales, market share, and prices examined sales by presence of programs.

The NTGR modeling effort required a more nuanced approach to program activity to provide the variability in program intensity necessary to assess its impact on LED sales. Therefore, the model inputs include actual program information for each state. Because many states have more than one administrator and not all of them work cooperatively as in Massachusetts, the team

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[10] The POS data cover the grocery, drug, dollar, discount, and merchandise stores, and represents approximately 40% of the Massachusetts market, 33% of the New York market, 38% of the US and program states markets, and 41% of the non-program states market.

[11] http://www.nema.org/Intelligence/Pages/Lamp-Indices.aspx

[12] Specifically, the Evaluation Team began by searching the ENERGY STAR Summary of Lighting Programs website https://www.energystar.gov/ia/partners/downloads/2016%20ENERGY%20STAR%20Summary%20of%20Lighting%20Programs.pdf and referenced the Database of State Incentives for Renewables & Efficiency (www.dsireusa.org).

[13] E Source. "DSM Insights." April 2017.

[14] Note that because the ENERGY STAR report only included expenditure ranges, the midpoints of the ranges were used to represent the expenditures.

aggregated data from each utility by state, and assigned a modeling flag to each state based on the source of, and confidence in, the data provided across all major utilities and program administrators. The aggregated assigned hierarchy flag was weighted based on the number of customers for each program administrator. As an example, any state with program activity provided by the program administrator or publicly available in a report was assigned a *one*, which means it is considered the most reliable in the hierarchy of data available. The higher the assigned value, the less confidence the team had in the estimates of program data. The team iterated through the model using states with the highest quality data, then opened the model to include states with data from third party sources or planning documents.

Massachusetts was among the states scoring a *one* on the hierarchy. The LightTracker team used information on program budget, incentives, and sales obtained directly from the PAs or their fulfillment vendor EFI. Appendix A lists all states, their classification as program or non-program, and their score on the data quality hierarchy.

As explained more in Section 2.2, efficient bulbs such as CFLs and LEDs last longer than incandescent and halogen bulbs, which reduces how often households need to replace bulbs. As the adoption of efficient bulbs increases, the need to buy bulbs decreases, which would affect model estimates of bulb sales. Ideally, the team would include an estimate of state-level household socket saturation, but it does not have this information for all 48 states in the database. Instead, the team developed an estimate of program age based on information from program administrators or publicly available sources.

1.2.4 Retail Channel Variables

The team conducted secondary internet research to determine the number and total square footage of store locations in each state for five primary energy-efficient bulb retailers: Home Depot, Lowes, Wal-Mart, Costco, and Menards (a home improvement retailer in the Midwest). These data were used as explanatory variables in the model since these retailers sell a large quantity of energy efficient bulbs. The percentage of efficient bulbs may differ in states based on the concentration of these retailers.

1.2.5 Additional Model Inputs

The NTG modeling effort allowed the LightTracker analysts to assess the impact of program intensity on LED sales after controlling for other factors. The model explored the influence of state-level demographic, economic, political, and energy-related characteristics.

The team gathered state-level *demographic* data from the American Community Survey (ACS), including annual state-level data for the population, total number of housing units[15], household tenure (own versus rent), home age, education, income, and average number of rooms in the home.[16] The Missouri Economic Research and Information Center provided data on state-level *cost of living index*.[17] The team drew information on *average electric costs* from the Energy

[15] The LightTracker team decided to use housing units, which includes vacant homes and seasonal homes, rather than households, which are limited to occupied homes.
[16] http://factfinder2.census.gov/faces/nav/jsf/pages/searchresults.xhtml?refresh=t
[17] https://www.missourieconomy.org/indicators/cost_of_living/

Information Agency (EIA).[18] Finally, the team turned to the Cook Political Report and Gallup to develop political index variables.[19] The political index variable used presidential election voting results as a state-level partisan proxy. Values higher than one represent greater democratic influence, while values less than one indicate greater republican influence.

1.2.6 Summary of Model Data Sources and Inputs

Table 5 lists the comprehensive set of variables that were considered in the national LED sales data NTG model. The final model, presented in Section 3, included only the subset of variables ultimately selected for inclusion in the model based on their statistical significance and ability to improve the model specification.

[18] https://www.eia.gov/electricity/data/state/
[19] http://cookpolitical.com/house/pvi and http://www.gallup.com/poll/125066/state-states.aspx

Table 5: NTG Model Variable Descriptions

Type of Variable	Description
Dependent Variable	
LED Market Share	Proportion of total bulb sales in state 'i' that are LEDs. Equal to [LED sales/total bulb sales]
Program Activity Variables	
Program Spending per HH	The number of 2016 retail lighting program dollars per housing unit in state 'i.' Equal to total retail lighting program expenditures in state 'i' (incentive and non-incentive) divided by the number of housing units in state 'i'
Program Age	The number of years state 'i' has been running an upstream lighting program
Channel Variables	
Sqft NonPOS per HHi	The average non-POS retail square footage per housing unit in state 'i.' Equal to non-POS square footage divided by the number of housing units in state 'i'
Percent Sqft NonPOS$_i$	The percentage of total retail square footage belonging to non-POS retailers in state 'i.' Equal to non-POS square footage divided by (POS sqft + non-POS sqft)
Sqft POS per HH$_i$	The average POS retail square footage per housing unit in state 'i.' Equal to POS square footage divided by the number of housing units in state 'i'
Demographic Variables	
Political Index$_i$	A state-level partisan voter index developed by Cook Political Report (used for 2015 index) and Gallup (used for 2016 index) using presidential election voting results 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
Cost of Living$_i$	State-level cost of living indices developed by the Missouri Economic Research and Information Center
Percentage of Homes Built Pre-1980$_i$	These state-level demographic and household variables were derived from the most current US Census ACS
Percentage of Renters Paying Utilities$_i$	
Median Income$_i$	
Percentage Owner Occupied$_i$	
Percentage of Population with College Degree$_i$	

1.3 Approaches

NMR and LightTracker Initiative analysts performed descriptive analyses of light bulb sales, shipments, and prices. They then developed statistical models to explore the impact of program activity on LED sales.

1.3.1 Bulb Sales, Shipment, and Bulb Price Analyses

The team examined the full LightTracker database to compare 2016 light bulb sales and market share in Massachusetts with those from New York (a program state for this study), states with lighting programs, states without lighting programs, and the entire US. We also analyzed market share for these same areas by lumen bins to assess the distribution of bulb sales by current and future EISA exemption. This analysis assumed that bulbs at 2,600 or more lumens are most likely currently exempt from EISA, and those with more than 3,300 lumens will remain exempt when EISA Phase 2 goes into effect in January 2020. On the other end, bulbs with lumens less than 310 are likely currently exempt and will remain so in 2020. Additional descriptive analyses explored general (not statistical) relationships between program spending, per household bulb sales, and other factors that lay the groundwork for the statistical modeling approach. We also examined the proportion of LED sales that are ENERGY STAR.

NMR also described trends in bulb sales per household in Massachusetts compared to other areas for 2009 to 2016, as reported in the POS data obtained through CREED. We also presented national NEMA shipment market share for January 2011 through March 2017. The POS data suffer from coverage bias in terms of which channels report; these channels account for about 40% of Massachusetts bulb sales. NEMA data may suffer from non-response bias as some members may not respond to the organization’s survey; if non-response varies by the types of bulbs they manufacturer, it could affect estimates of shipment share. NEMA shipments and LightTracker sales data should also be expected to be somewhat out of sync, as shipments precede sales and could end up being stockpiled in retailer warehouses.

Drawing on the LightTracker database, an bulb price analysis involved comparing prices for all light bulbs in Massachusetts, non-program states in the US, and the nation. The analysis then highlighted sales of standard (A-line) bulbs by lumen bins and LEDs by ENERGY STAR qualification (defined as ever qualified as of December 2016).[20]

1.3.2 Statistical Modeling

The primary goal of the model is to quantify the impact of state-level program activity on the sales of LEDs while controlling for other factors that may also affect LED sales. The general form of the model is specified below.

$$LED\ Market\ Share_i = \beta_0 + \beta_1 * Program\ Spending\ per\ HH + \beta_2 * Program\ Age$$

[20] In other words, we considered any bulb qualified under ENERGY STAR Specification 2.0, and all previous specifications, as ENERGY STAR.

$$+\sum_{A=1}^{3}\beta_A * Channel\ Variables + \sum_{B=1}^{4}\beta_B * Demographic\ Variables$$

Where:

LED Market Share$_i$ = Proportion of total bulb sales in state 'i' that are LEDs. Equal to [LED sales/total bulb sales]

β_0 = The model intercept

β_1 = The primary coefficient of interest. This represents the marginal effect of program intensity, or the expected increase in the market share of LEDs for each $1 in additional program spending per household.

β_2 = Another coefficient of interest. This represents the marginal effect in additional program years since inception.

Program Spending per HH$_i$ = The number of 2016 retail lighting program dollars per household in state 'i'. Equal to total retail lighting program expenditures in state 'i' (incentive and nonincentive) divided by the number of households in state 'i' [21]

Program Age = The number of years state 'i' has been running an upstream lighting program

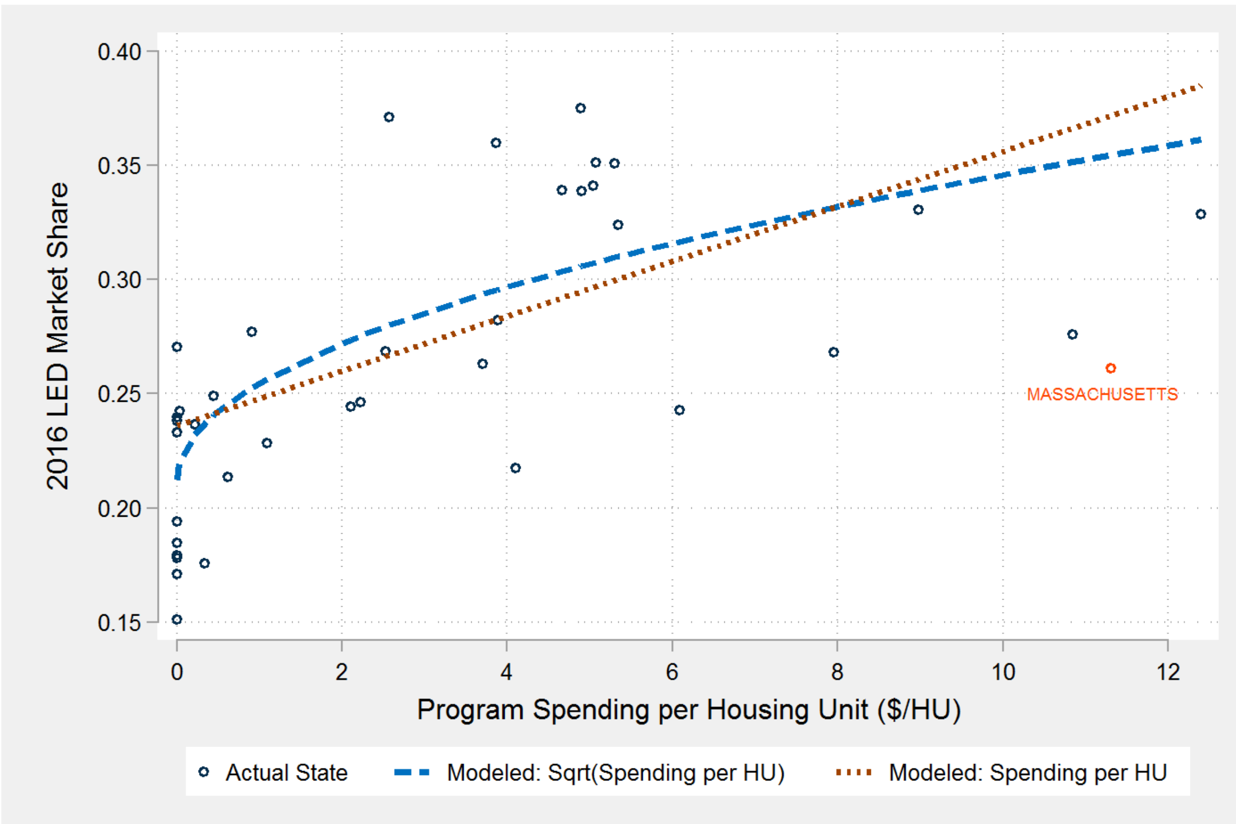
β_A *and* β_B = Array of regression coefficients for the channel variables and demographic variables

The team applied analytic weights to the states in the model based on number of housing units in the state.[22] The team felt that using analytic weights in the model was appropriate because the data set consists of a series of purchase transactions that have been condensed into an observed mean. The weighting approach recognizes that the number of housing units varies considerably across states. This variation is problematic because more housing units typically translate to more bulb sales, and could disproportionately affect the results (See Figure 19 in Section 2.2 for a graphical description of this relationship). Analytic weights in the model helped to control for this. See Appendix B for more detail on the weighting approach.

[21] Note the team attempted to only collect LED program spending, but was only successful at collecting for a limited number of states (n=24). For the model, the team used total program spending to include more states.
[22] http://www.stata.com/help.cgi?weight

As explained in more detail in Appendix B, the team used non-linear modeling to estimate NTG. We opted for the square root of spending as the program intensity variable instead of using spending without the transformation. Figure 9 shows that the square root model tapers LED market share as the square root of spending increases. This likely reflects “diminishing returns” in terms of market share as program spending increases, and graphically provides a good fit for the data.

Figure 9: Linear vs. Non-Linear Modeling



1.3.3 Net-to-Gross Ratio Estimation

Using the results of the regression models, the sales data on LEDs, and the program-tracking databases, the team estimated NTGRs for LEDs in 2016. These NTGRs are derived by first using the model to predict the share of LEDs with the program (modeling actual program spending, as well as the actual program age) and without the program (the counterfactual of no program activity is determined by setting the program spending variable to zero and the program age variable to the current age less one, which reflects the market share as if there was no program activity in the current year). This change in share represents the *lift*, or net increase, in the share of LEDs resulting from program activity. To then calculate the NTGR, we multiplied the change in share by the total number of LEDs sold in 2016, as determined by the sales data analysis described above.[23] This resulting number represents the net impact of the program (i.e., the total lift in the number of LEDs), and is then divided by the total number of program bulbs sold (i.e., the gross number of bulbs) to determine NTG:

$$NTGR = \frac{(\#\ LEDs\ sold\ with\ program - \#\ LEDs\ sold\ with\ no\ program)}{\#\ of\ program\ incented\ bulbs\ sold}$$

[23] Table 11 in Section 3.3 provides calculations based on the model results for Massachusetts.

2

Section 2 Sales Data Analysis Results

The team examined trends in market share, ENERGY STAR market share for LEDs, bulb sales, and bulb prices using the LightTracker and NEMA shipment data. Table 4 above summarizes the data sources and their coverage, and the bullets below serve as a reminder (we also footnote coverage in each figure):

- **Full category:** used for full 2016 market share and 2016 bulb sales, and represents all channels
- **Grocery, drug, dollar, discount, and mass merchandise retail channels:** used for analysis of market share over time, market share by ENERGY STAR qualification and lumen bins, and the bulb price analysis (31 states only); data reflect 40% of the Massachusetts market, 38% of the US, 33% of New York, 38% of program states, and 41% of non-program states

  Shipments: used for assessment of shipment share over time; represent 100% of shipments from reporting retailers, but coverage is unknown

The results discussed in this section refer solely to Massachusetts, New York, program states, non-program states, and the nation. The discussion does not consider the market share or sales in other states in the nation. Section 3 does consider all available states.

2.1 Market Share

The team assessed market share in Massachusetts, New York, program states, non-program states, and the nation in five different ways, as summarized in Table 6. We note the percentage of the market covered under each figure in the discussion that follows.

Table 6: Summary of Market Share Analyses

Type of Analysis	Dataset	Year(s) Addressed	Retail Channels
Annual	LightTracker Full Category	2016	All
Over time	LightTracker POS	2009 to 2016, 2016	Grocery, dollar, discount, mass merchandise
By Lumen Bins			
By ENERGY STAR			
Over time	NEMA	2011 to 2017[1]	All

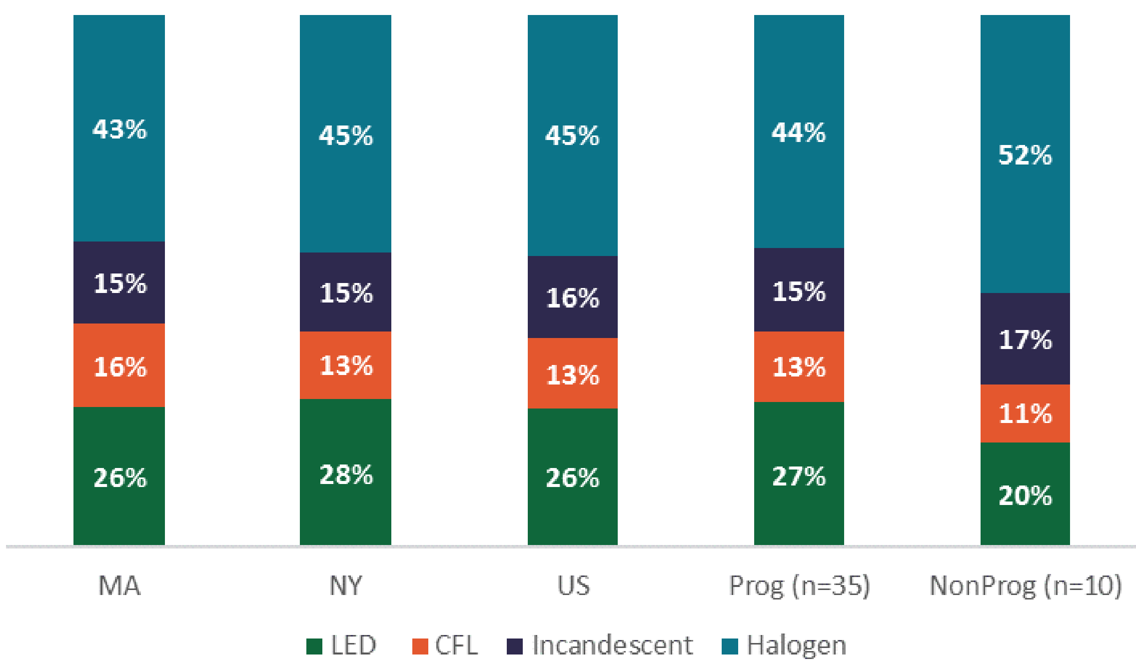
[1] Quarterly data from 2011 to March 2017.

2.1.1 Market Share by Bulb Type

Massachusetts had the highest combined market share of energy-efficient bulbs among the five areas considered in 2016; market share in non-program states lagged behind other areas.

Market share of energy-efficient bulbs in Massachusetts, New York, program states, and the US all stood at about 40% in 2016, with Massachusetts edging the others out at 42% (Figure 10). Less than one-third (31%) of the bulbs sold in non-program states were energy-efficient. Mirroring results from the recent shelf-stocking study, the data suggest that the PAs' continued support of CFLs boosted their market share, perhaps at the slight expense of LEDs.[24] Specifically, CFL market share was 16% in Massachusetts in 2016, while it was 13% in NY, program states, and the US, and 11% in non-program states.

Figure 10: 2016 Market Share in Massachusetts and Comparison Areas[1]



[1] All retail channels

Halogens and LEDs appear poised to dominate the lighting market—a complete shift from 2009, when incandescents and CFLs drove the market share.

LightTracker is not able to provide full market channel data for all channels prior to 2016. Therefore, NMR turned to the subset of data from grocery, drug, dollar, discount, and

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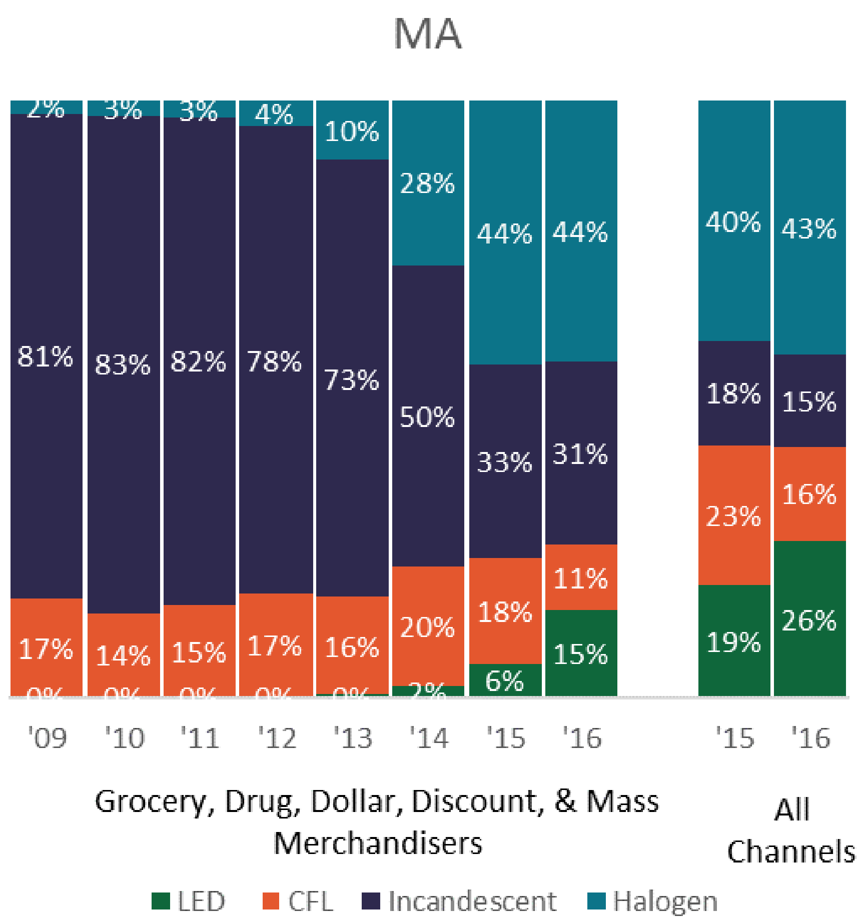
[24] NMR Group. 2017. *MA RLPNC 16-6: Lighting Shelf Stocking*. http://ma-eeac.org/wordpress/wp-content/uploads/RLPNC-16-6-%E2%80%93-Lighting-Shelf-Stocking-Report.pdf. See Figure 3. The body of work from recent Massachusetts lighting evaluation studies collectively suggest that the continued support of CFLs boosted overall adoption of energy-efficient bulbs, which diversified the types of households—especially low-income ones—with access to and installing energy-efficient bulbs.

merchandise stores to describe changes in market share in Massachusetts from 2009 to 2016 (Figure 11).[25] We present both the full category and subcategory market share estimates for 2015 and 2016 side by side in Figure 11, not for comparison, but for clarity. The data suggest the continued expansion of LED and halogen market share and the contraction of incandescent and CFL market share. The contraction of CFL market share is due, in part, to changes in ENERGY STAR specifications, but also to rapid consumer adoption of LEDs.[26]

Figure 11: Massachusetts Market Share by Bulb Technology Type 2009-2016[1]



[1] Includes grocery, drug, dollar, discount, and merchandise stores, and represents approximately 40% of the Massachusetts market.

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[25] Trends for the nation, New York, and program and non-program states mirror those for Massachusetts.

[26] The new specifications went into effect in January 2017, but manufacturers could pre-qualify and label bulbs as early as Summer 2016. These specifications increased the types—and price points—of LEDs qualified for the ENERGY STAR and greatly limited the CFLs that qualified. Many manufacturers and retailers greatly reduced their production and sales of CFLs, with some exiting the CFL market entirely.

- ***Shipment data suggest that halogens have accounted for the greatest portion of shipments since 2014, and LEDs exceeded both CFLs and incandescents shipments throughout 2016. CFLs and incandescents currently comprise a small and diminishing portion of shipments.***

NMR also tracked NEMA lamp indices and shipments.[27] Figure 12 and Figure 13 present the shipment market share trends in two different ways. Figure 12 shows a simple line graph of each bulb's market share over time, highlighting the change in trends for incandescents and halogens. Figure 13 displays the same data, but as an area graph of the entire market; this presentation highlights the long-term market shift to halogens and LEDs. Like the market share sales data, NEMA data point to strong decreases in shipments of incandescents and CFLs, and strong increases in shipments of halogens and LEDs. In the first quarter of 2017, halogens garnered the greatest market share (44.1%) followed by LEDs at 32.0%; incandescent shipments (9.6%) fell below those of all other bulb types. At 13.3% of shipments, CFLs deviated from their long-term decline in the first quarter of 2017. This likely reflects an uptick in shipments as manufacturers sought to unload the stock that no longer achieved ENERGY STAR qualification.

[27] Unlike the other data sources, NEMA only reports A-line bulbs (but would include bulbs such as rough service). NEMA explains that the shipment data are based on surveys of its members, but, as with every survey, not everyone responds. This means that we do not know the percentage of the market covered by NEMA nor the nature of the *nonresponse bias* (how respondents differ from non-respondents and its impact on shipment estimates).

Figure 12: A-line Shipment Market Share Q1 2011 to Q1 2017, Line Graph

(All Channels. 100% of Market)

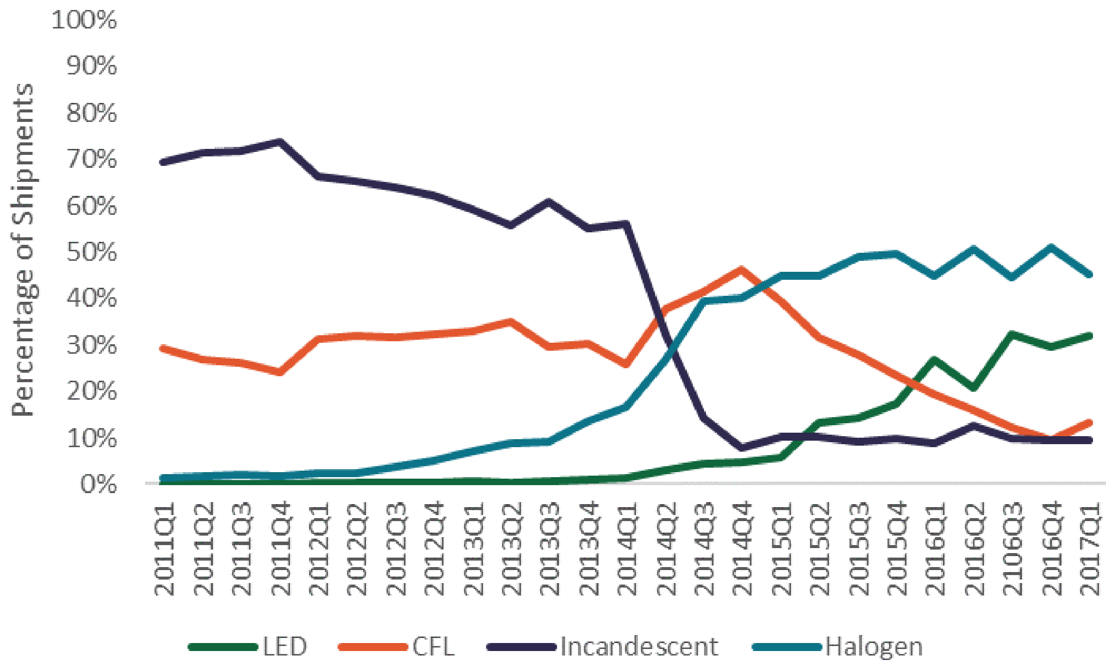
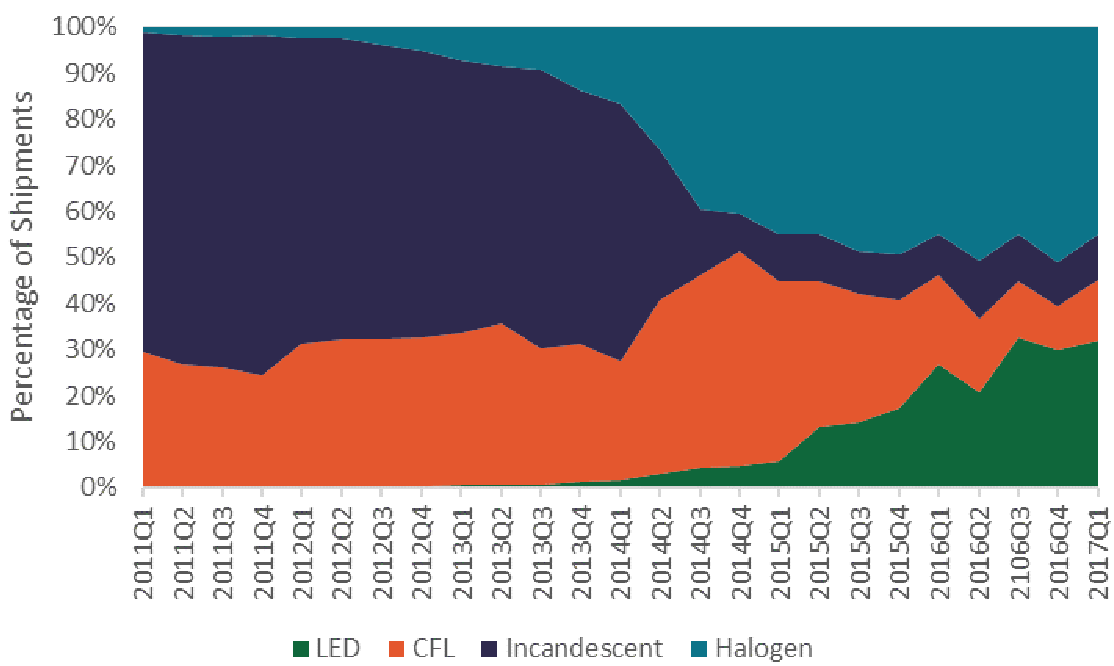


Figure 13: A-line Shipment Market Share Q1 2011 to Q1 2017, Area Graph

(All Channels. 100% of Market)

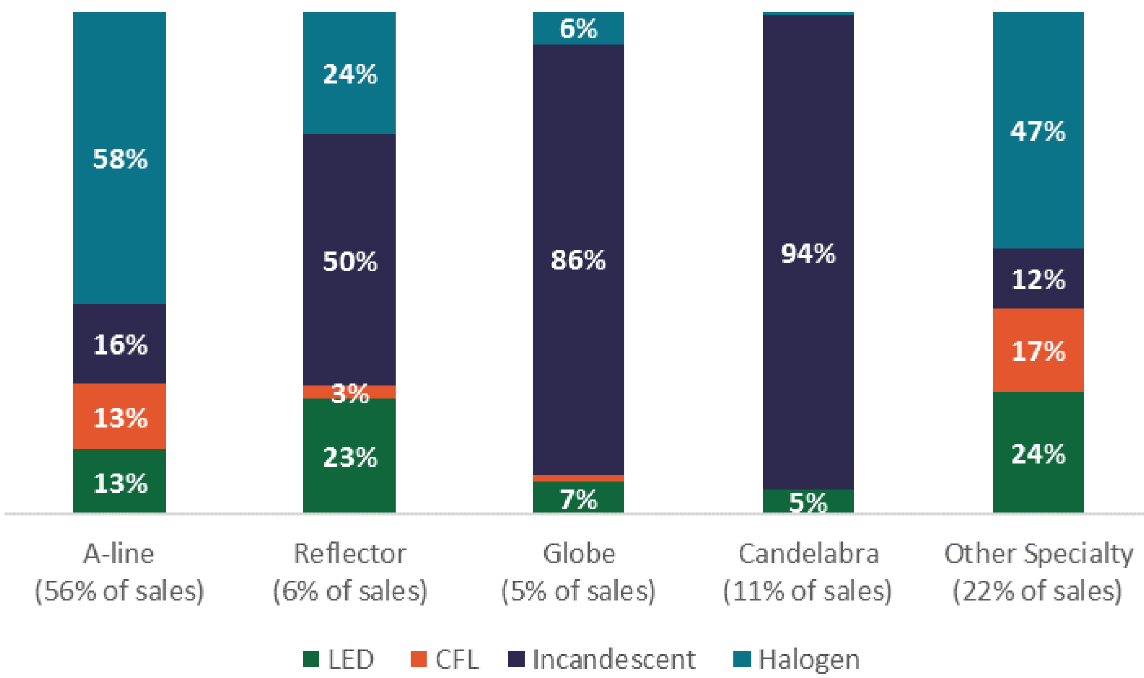


2.1.2 Market Share by Bulb Shape

Energy-efficient market share stood at 26% for A-line and reflector bulbs and 41% for other specialty bulbs in 2016, far higher than for globe (9%) and candelabra (6%).

In the grocery, drug, dollar, discount, and merchandise channels, the LightTracker data suggest that A-lines, reflector, and other specialty bulbs (e.g., two- and three-way, colored bulbs) are largely responsible for the progress in energy-efficient bulb share (Table 14). These bulb shapes collectively account for 84% of overall market share, and they had the highest percentages of LED and CFL sales in 2016. In contrast, fewer than one out of ten globe and candelabra bulbs purchased in these channels was energy efficient. Sales of globe and candelabra bulbs in the excluded home improvement and hardware channels could tend more towards energy-efficient bulbs, but the LightTracker do not allow us to assess this possibility directly.

Figure 14: 2016 Massachusetts Market Share by Bulb Type and Bulb Shape[1,2]



[1] Includes grocery, drug, dollar, discount, and merchandise stores, and represents approximately 40% of the Massachusetts market.
[2] Columns sum to 100%, but data labels of 2% or less have been hidden for aesthetic purposes.

2.1.3 LED Market Share by ENERGY STAR Qualification

The LightTracker Initiative identified ENERGY STAR qualification (under any prior specification) for many LEDs in the database. They used a mixture of information to identify ENERGY STAR qualification:

- Webscraping and shelf-stocking of stores in Massachusetts and New York conducted through the RLPNC 16-6 Shelf Stocking study
- Webscraping conducted by LightTracker analysts
- Reviews of ENERGY STAR qualification lists (current and prior) that had previously been downloaded and saved by NMR and other LightTracker analysts
- Supplemental internet searches

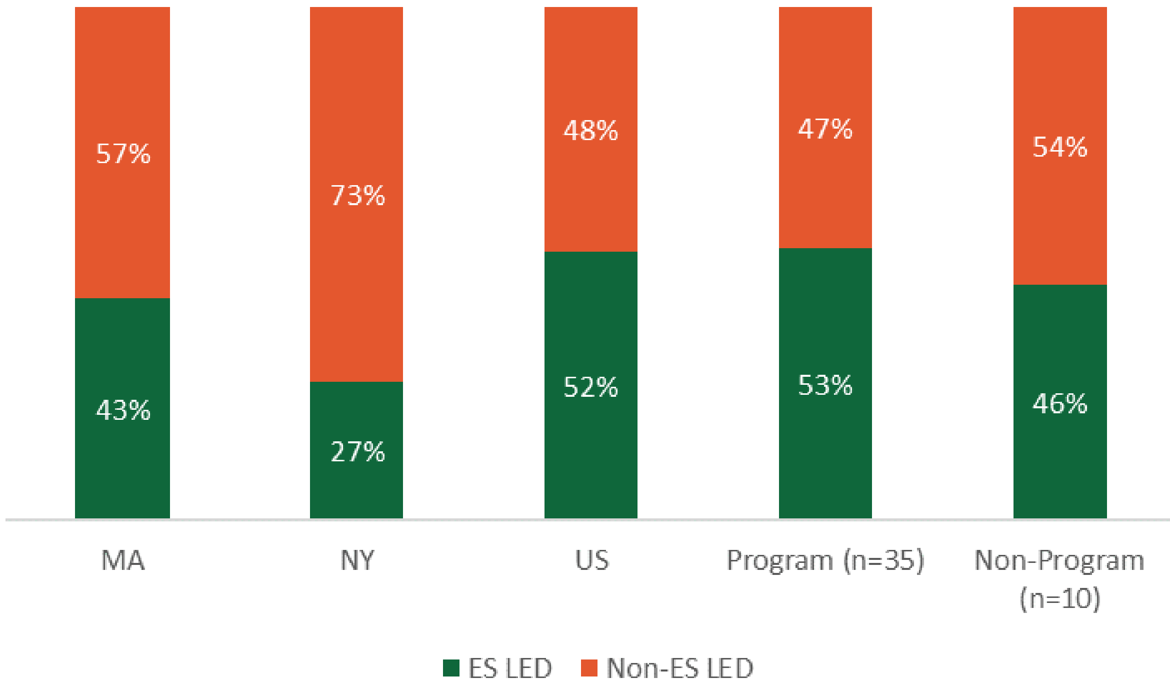
The analysis confirmed ENERGY STAR status (yes or no) for 79% of 2016 LED sales in Massachusetts, 72% in New York, 65% in the US, 66% in program states, and 63% in non-program states.[28]

Market share of ENERGY STAR qualified LEDs in Massachusetts exceed those of New York but fall short of those in other areas.

The analysis found that, among those of verified status, the percentage of ENERGY STAR qualified LEDS stood at 43% in Massachusetts in 2016. This is lower than in the US (52%), program states (53%), and non-program states (46%), but higher than in New York (27%) (Figure 15). The data do not allow us to explain the relatively low market share of ENERGY STAR LEDs in Massachusetts compared to larger areas of the nation. One possible explanation reflects the fact that the ENERGY STAR analysis reflects sales in a subset of channels. The excluded channels tend to carry a large percentage of ENERGY STAR products in Massachusetts, whereas the opposite could be true in other parts of the nation with a greater concentration of included retailers. It is also the case that Massachusetts had the highest proportion of LEDs of verified status. While it may be tempting to suggest the unverified bulbs could be more likely to be non-ENERGY STAR qualified—which would increase the percentage of non-qualified bulbs in other areas—we have no evidence to support this argument. We can say, however, that the higher rates of verification instill greater confidence in estimates of ENERGY STAR qualified LEDs for Massachusetts and New York than in other areas.

[28] Frequent changes to, and recycling of, universal product codes (UPCs) and model numbers, as well as the lack of a comprehensive list of bulbs that have ever been qualified for ENERGY STAR, underlie the inability to verify qualification for so many LEDs.

Figure 15: LED ENERGY STAR Status by Area[1]



[1] Includes grocery, drug, dollar, discount, and merchandise stores, and represents approximately 40% of the Massachusetts, 38% of the US market, 33% of the New York market, 38% of the program state market, and 41% of the non-program state market.

2.1.4 Market Share by Lumen Bins

The Energy Independence and Security Act (EISA) of 2007 originally allowed many bulbs to be exempt from increased efficiency standards. Specialty bulbs, such as two-way, three-way, reflector[29], globe, and candelabra bulbs, accounted for many of the exempt bulbs, but the list also included *rough service* and other A-line bulb types that functioned almost identically to general service bulbs. Some argued that these exemptions created loopholes through which consumers could continue to purchase and use incandescent bulb technology instead of switching to more efficient bulbs in compliance with EISA. To close these loopholes, the December 29, 2016 Department of Energy (DOE) Rulemaking expanded the definition of general service bulbs to include many of these previously exempt categories, including not only rough service and similar bulb types but also the reflectors, globes, candelabra, and other types of specialty products (e.g., two- and three-way, colored bulbs) included in the Massachusetts Lighting Core Initiative. This expanded definition is scheduled to go into effect in January 2020.

Additionally, the original phase of EISA bars the manufacture and import of bulbs that do not comply with EISA, yet some of these remain on store shelves. This could reflect retailers and manufacturers selling through large stockpiles of incandescent bulbs manufactured or imported

[29] While exempt from the first phase of EISA, reflector bulbs must adhere to their own set of efficiency standards that vary by size and shape. See https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=23.

prior to the enactment of EISA. It may also reflect illegal importation of non-compliant incandescents, since Congress has opted not to allocate funds to enforce EISA.

The PAs and EEAC Consultants asked NMR to examine 2016 market share in the LightTracker sales data to assess the percentage of bulbs sold by type that are EISA exempt by the current and EISA 2020 definitions. Because the LightTracker dataset does not consistently report the characteristics that distinguish exempt from non-exempt bulbs, we used a combination of lumen bins and bulb shape to serve as proxies, as follows:

- Currently exempt from EISA: bulbs of any shape that exceed 2,600 lumens or fall below 310 lumens.
- Exempt from EISA 2020: bulbs of any shape that exceed 3,300 lumens or fall below 310 lumens.

Nine percent of the bulbs sold in Massachusetts in 2016 fell into lumen bins that currently are and will remain exempt in 2020. Another one percent of bulbs sold in 2016 are currently in exempt lumen bins, but will be subject to EISA in 2020. Assessing market share by lumens also highlights the market share of incandescent bulbs being sold that fall between 310 and 2,600 lumens. However, we are unable to determine which are being sold from stockpiles or illegal importation, or which remain exempt (e.g., rough service). We also discuss lumen to wattage equivalents, but the reader will note that equivalents vary considerably by bulb style and manufacturer so these are approximations only.

Given the number of lumen bins and bulb types examined, we present the information in a series of four graphs for Massachusetts and non-program states to streamline reporting. The first two graphs (Figure 16) present market share by bulb shape and by lumen bins for all combined bulb types. The *specialty* category includes two- and three-way bulbs, colored bulbs, and any other type not captured by the other categories. The second two graphs (Figure 17) focus more narrowly on market share for A-line bulbs, showing lumen bins by bulb type. The figure also denotes which lumen bins are currently EISA exempt and which will remain exempt in 2020. Appendix C provides tables for Massachusetts that lists market share by bulb shape, lumen bins, and bulb type.

Lumen bins vary considerably by bulb shape, with A-line and miscellaneous specialty bulbs showing greater lumen variation than reflector, globe, and candelabra.

As expected, A-line bulbs and other specialty bulbs (two- and three-way, colored bulbs) fall mostly into the 450 to 1,489 lumen range, which roughly coincides with the 40 to 100 Watt incandescent equivalent (Figure 16).[30] In contrast, most reflectors fall into the 450 to 749 lumen range, while globe and candelabra bulbs mainly fall below 450 lumens.

[30] The current EISA standards include bulbs with lumens as low as 310 and as high as 2,600; the incandescent wattage equivalence of such bulbs varies. For example, most online sources list 450 lumens for the brightness of 40 watt incandescents but the actual lumens of 40 watt incandescents, and the bulbs meant to replace them, vary considerably. Figure 2 in Chapter 6 of the *Uniform Methods Project* provides a visual depiction of these ranges. https://energy.gov/sites/prod/files/2015/02/f19/UMPChapter21-residential-lighting-evaluation-protocol.pdf.

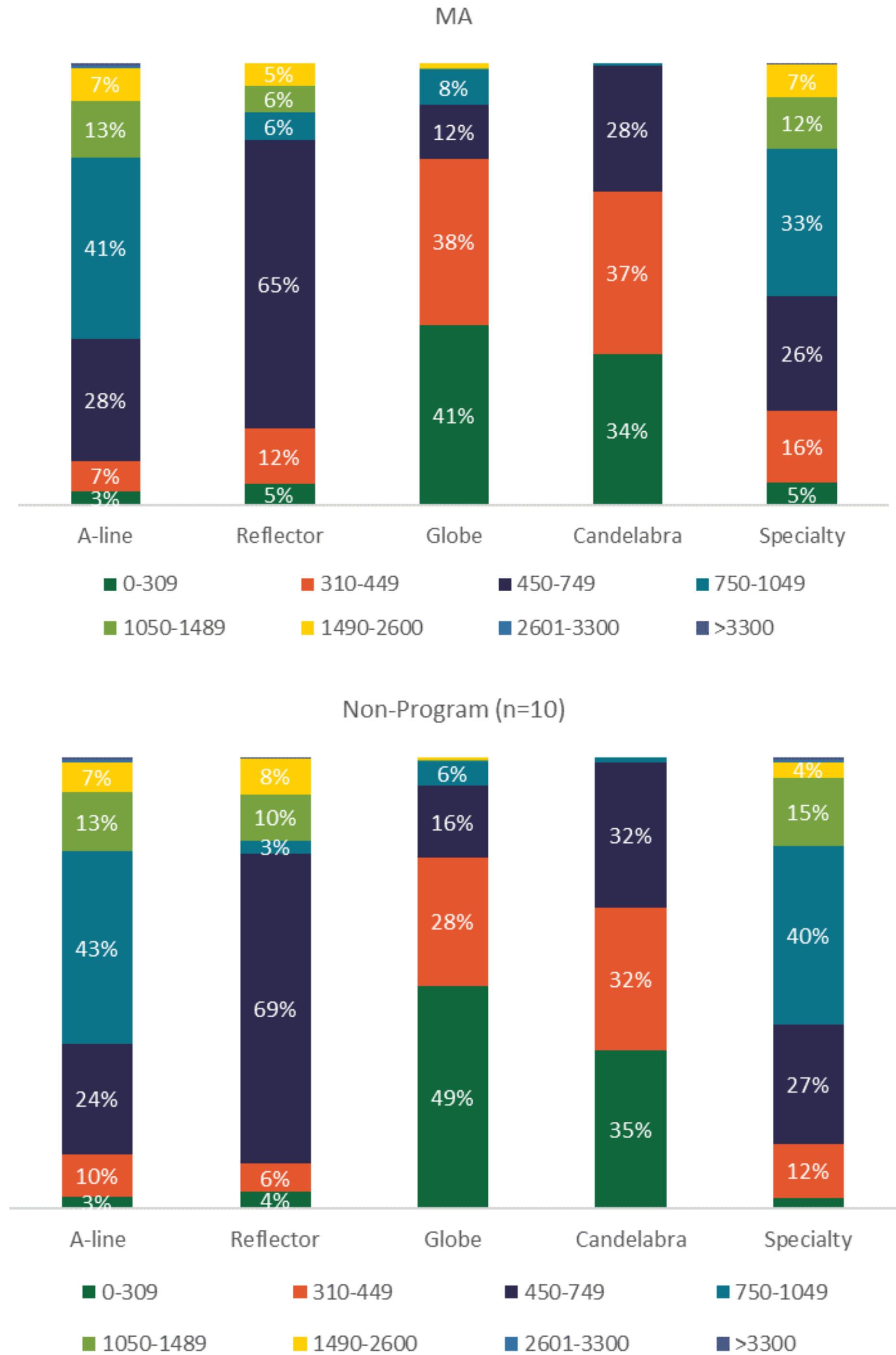
Incandescent and halogen bulbs account for nearly all A-line bulb sales in current and future EISA exempt lumen bins.

Manufacturers and retailers may have embraced halogens, CFLs, and LEDs in the lumen ranges subject to EISA, but they remain committed to incandescents in the current exempt lumen ranges (less than 310 and greater than 2,600), as well as the 310 to 449 lumen range (Figure 17). As Figure 16 made clear, globes and candelabras are more common among the lowest lumen ranges, while A-line and specialty bulbs tend to fall into the highest lumen bins. **This finding suggests that low and high lumen bulbs may offer current and future program opportunity.** This finding falls short of a recommendation, however, as the future program opportunity will also depend on the results of the net-to-gross study, the market adoption model, and their impact on the PAs' cost effectiveness worksheets.

Incandescents account for relatively few sales in the 750 to 2,600 lumen range; however, their sales in the 310 to 749 lumen range (i.e., 40 to 60 Watt equivalent) exceed that of CFLs and LEDs combined.

The search for incandescents being sold from stockpile, illegal importation, or *loophole* exemptions suggests the biggest concern rests in the 450 to 749 lumen range, where they account for 13% of sales in Massachusetts, and in the 310 to 440 range, where they account for 29% of sales. Incandescents also account for about 10% of Massachusetts' sales in the 1,050 to 1,489 lumen range (roughly 75 to 100 Watt equivalent). Incandescents are virtually non-existent in the lumen ranges in Massachusetts most closely associated with 60 to 75 Watt and 100 to 150 Watt equivalent ranges.

Figure 16: Market Share by Lumen Bins by Area[1,2,3]

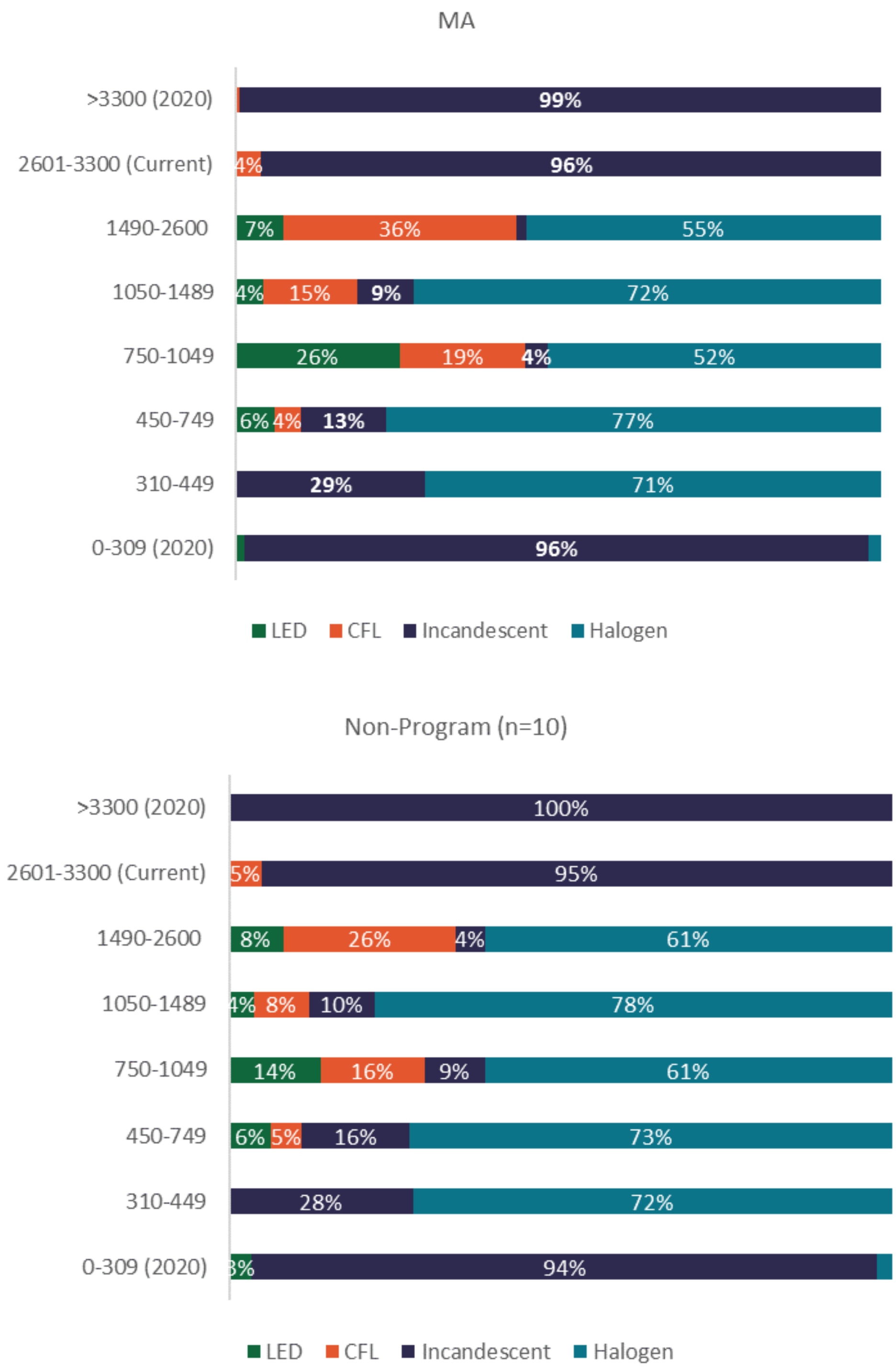


[1] Includes grocery, drug, dollar, discount, and merchandise stores, and represents approximately 40% of the Massachusetts market, 38% of the US, and 41% of non-program states.

[2] Columns sum to 100%, but data labels of 2% or less have been hidden for aesthetic purposes.

[3] The specialty category includes two- and three-way bulbs, colored bulbs, and any other type not captured by the other categories.

Figure 17: A-line Bulb Market Share by Lumen Bins and Bulb Type[1,2,3]



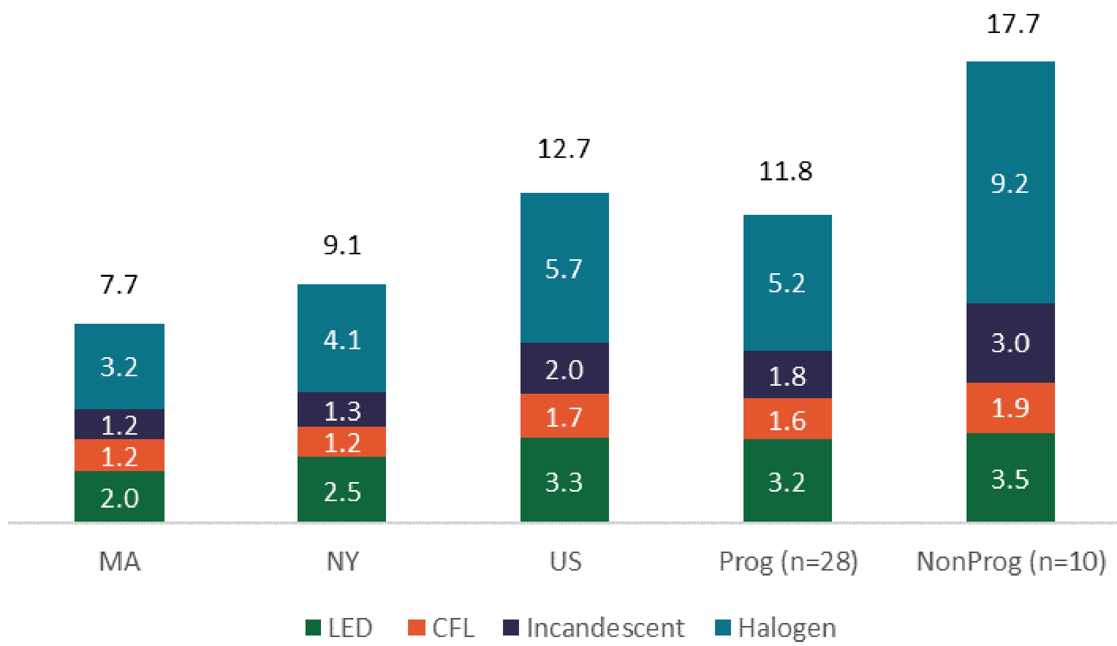
[1] Includes grocery, drug, dollar, discount, and merchandise stores, and represents approximately 40% of the Massachusetts market and 41% of non-program states.
[2] Columns sum to 100%, but data labels of 2% or less have been hidden for aesthetic purposes.
[3] *Current* refers to bulbs that are currently exempt from EISA but will cease to be in 2020. *2020* refers to bulbs that are currently exempt from EISA and will remain exempt in 2020.

2.2 Bulb Sales

Bulb sales per household differed widely across the US. This finding is likely influenced by socket saturation and market share of energy-efficient bulbs (LEDs and CFLs).

The full LightTracker dataset, developed by CREED, provides estimates of 2016 bulb sales per household, as shown in Figure 18 for Massachusetts, New York, program states, non-program states, and the entire US. At just under eight bulbs, Massachusetts had the lowest sales per household of these five areas, while non-program states had the highest sales per household, at nearly 18. New York had sales of about nine per household. Program states had smaller sales per household than non-program states (12 vs. 18, respectively). Bulb sales largely depend on households needing to replace bulbs that have burned out. Given the longer life of efficient bulbs, as socket saturation of CFLs and LEDs increases, households need to buy fewer bulbs, which leads to lower bulb sales.

Figure 18: Bulb Sales per Household Across Areas[1]



[1] All retail channels

The team lacked socket saturation data for most states in the nation, but did have data for Massachusetts and Upstate and Westchester County New York. Table 7 shows the observed in-home socket saturation rates for a sample of households in Massachusetts and a portion of New

York from 2009 to the first half of 2017.[31] Massachusetts started with a larger proportion of efficient sockets in 2009 and has seen the saturation of efficient sockets increase by more percentage points than in the portion of New York. This may help to explain the smaller overall efficient bulb sales per household in Massachusetts compared to the entire state of New York and the other areas; households in Massachusetts may simply not need to buy bulbs because previously installed CFLs and LEDs have not burned out.

Table 7: Saturation Rates in Massachusetts and NY, 2009 to Early 2017

Sockets Containing[1]	2009	2010	2012	2013	2014	2015	2016	2017
Massachusetts (#of Households)	100	150	151	150	261	354	420	465
Total Inefficient	**63%**	**64%**	**64%**	**60%**	**51%**	**49%**	**45%**	**41%**
Incandescent	62%	57%	53%	55%	45%	43%	37%	33%
Halogen	5%	7%	11%	5%	6%	6%	8%	8%
Total Efficient	**32%**	**35%**	**36%**	**39%**	**45%**	**47%**	**51%**	**54%**
CFLs	26%	26%	27%	28%	33%	32%	31%	29%
LEDs[2]	<1%	<1%	1%	2%	3%	6%	12%	18%
Portion of New York[3] (#of Households)	203	100	N/A	127	N/A	101	150	255
Total Inefficient	**70%**	**63%**	**N/A**	**57%**	**N/A**	**59%**	**54%**	**53%**
Incandescent	65%	57%	N/A	53%	N/A	51%	46%	44%
Halogen	5%	6%	N/A	4%	N/A	8%	8%	9%
Total Efficient	**19%**	**24%**	**N/A**	**27%**	**N/A**	**25%**	**34%**	**32%**
CFLs	19%	24%	N/A	26%	N/A	22%	24%	22%
LEDs[2]	<1%	<1%	N/A	1%	N/A	3%	7%	10%

[1] Some columns do not sum to 100% due to the exclusion of empty sockets, fluorescent tubes, and other bulb types (e.g., xenon and metal halide).
[2] The LED category includes both LED bulbs and integrated LED fixtures.
[3] Includes Upstate New York and Westchester County, which lack programs. The LightTracker data cover the entire state of New York, parts of which do have residential lighting programs.

Figure 19 addresses the relationship between overall bulb sales and efficient bulb sales. It plots the housing units in each state in the dataset by their total bulb sales and highlights the proportion of inefficient bulb sales for Massachusetts, New York, and two outlying states—California and Texas. In Figure 19, the *percent inefficient* refers to the percent of 2016 sales of halogens or incandescent bulbs. While the national average was approximately 60%, Massachusetts and California were below this average at 57.9% and 51.6%, respectively. Texas was above this average at 64.2%. New York was nearly equivalent to the national average at 59.4%. These

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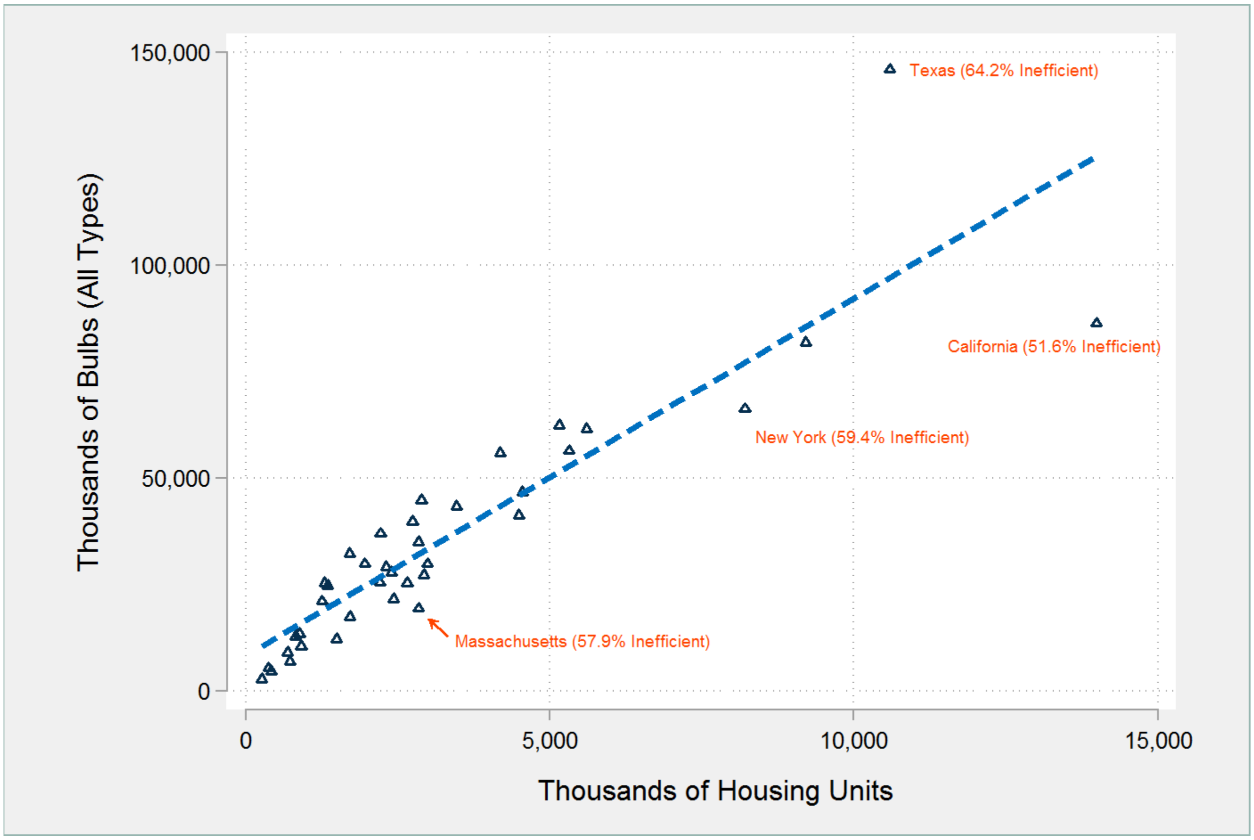
[31] Data for this table are taken from *2016-17 Lighting Market Assessment Consumer Survey and On-site Saturation Study* by NMR Group, Inc. April 7, 2017. Available at: http://ma-eeac.org/wordpress/wp-content/uploads/Lighting-Market-Assessment-Consumer-Survey-and-On-Site-Saturation-Study.pdf. Additional data are from *IMPACT EVALUATION: NYSERDA CFL Expansion Program: Random Digit Dial and Onsite Survey Results.* Note that the 2009 and 2010 estimates include the entirety of NY State (minus New York City and Long Island). Data were not collected on other bulb types in NY in 2009 and 2010. While the bulb sales and market share estimates presented throughout this report include all of NY, the saturation estimates for all years include only portions of the state.

data—although based on sales and not saturation of efficient lamps—provide further confirmation that higher efficient bulb use and sales reduce the need to buy any bulbs at all, no matter the type.

Figure 19: Total Bulbs and Number of Housing Units[1]



[1] The percent inefficient refers to the percent of 2016 sales of halogens or incandescent bulbs. See Section 1.1 for additional discussion of this graph.

2.3 Bulb Price Analysis

NMR also conducted a bulb price analysis using the LightTracker dataset. This analysis compared the average price of different groups of light bulbs sold in Massachusetts, non-program states, and the entire US for the subset of retail channels comprising of grocery, drug, dollar, discount, and merchandise stores. Pricing data was available for bulb type across areas, but not for other groupings, so Figure 20 shows both sources for bulb type. Specific groupings of prices considered include the following:

- Bulb type
- Bulb shape
- Lumen bins
- ENERGY STAR status

The prices in the LightTracker dataset *do reflect* the application of program incentives. However, the third-party sources do not report prices for *private label* bulbs, also known as store brands. Store brands usually sell for less than brand name models, so the prices reported in this section should be considered on the high end of what consumers pay at the register.

LEDs and CFLs remain the most expensive bulb on shelves, even when considering program price supports.

In 2016, LEDs continued to be the most expensive bulb type nationally. LED prices at all channels stood at $4.45 nationally and $4.02 in the subset of retail channels (Figure 20). In Massachusetts, the price in all channels was $4.44 but only $3.87 in the subset of retail channels, perhaps reflecting that Massachusetts aggressively supports LEDs in a wider range of channels than some other program administrators. CFLs were the next most expensive bulb, with prices hovering around $2.00 per bulb depending on the dataset and area. Prices were lowest for halogens and incandescents, which generally sold for about the same price per bulb.

Reflector bulbs had the highest price in 2016, while A-line bulbs had the lowest price. LED and CFL models still cost more than incandescent and halogen models for all bulb types, except candelabra bulbs.

In Massachusetts, LEDs and CFLs were more expensive than the inefficient lamp options (halogen and incandescent) across all bulb shapes (Figure 21). The prices of LEDs and CFLs varied across bulb types. CFL reflectors were the most expensive bulb on the market, at a price of $7.66 per bulb. LED reflectors came in second at $6.45, followed by CFL globes at $6.77. LED medium screw base (MSB) A-line bulbs ($3.80) and candelabras ($4.02) were more expensive than CFLs of the same types ($2.63 and $1.90, respectively). Halogens offered the lowest priced MSB A-line ($1.78), while incandescent bulbs had the lowest prices (sometimes much lower) for all other shapes.

ENERGY STAR LEDs cost more than non-ENERGY STAR models across the nation and in non-program states. This is not the case in Massachusetts, where program price supports help to make ENERGY STAR models the least expensive LED option.

ENERGY STAR labeled LEDs cost $4.16 nationally, while non-ENERGY STAR LEDs cost $3.63. In non-program states, ENERGY STAR labeled LEDs cost almost $2.00 more than non-ENERGY STAR (Figure 22). Massachusetts, however, reversed this: ENERGY STAR LEDs cost $3.46 compared to $3.95 for non-ENERGY STAR models, and $4.38 for models of unknown qualification. Program incentives almost certainly explain the lower price of ENERGY STAR models in Massachusetts compared to the other areas.

Even with program support, LEDs and CFLs remained the most expensive bulbs in each lumen range.

Figure 23 shows that the price of Massachusetts LED MSB A-line bulbs vary widely by lumen compared to the other bulb types. A-line LEDs with 1,490 to 2,600 lumens are the most expensive bulb on the market at a price of $10.21 per bulb, followed by those with 1,050-1,489 lumens at $8.49, and less than 310 lumens at $8.06. A-line LED lumen prices appear most competitive between 310 and 1,049, roughly corresponding to the 40 Watt to 100 Watt incandescent equivalents targeted by the first phase of EISA. The prices of other bulb types (CFL, halogen, and incandescent) are relatively flat across lumens. Some Massachusetts prices for lumens are not available because there were no recorded sales for that bulb type.

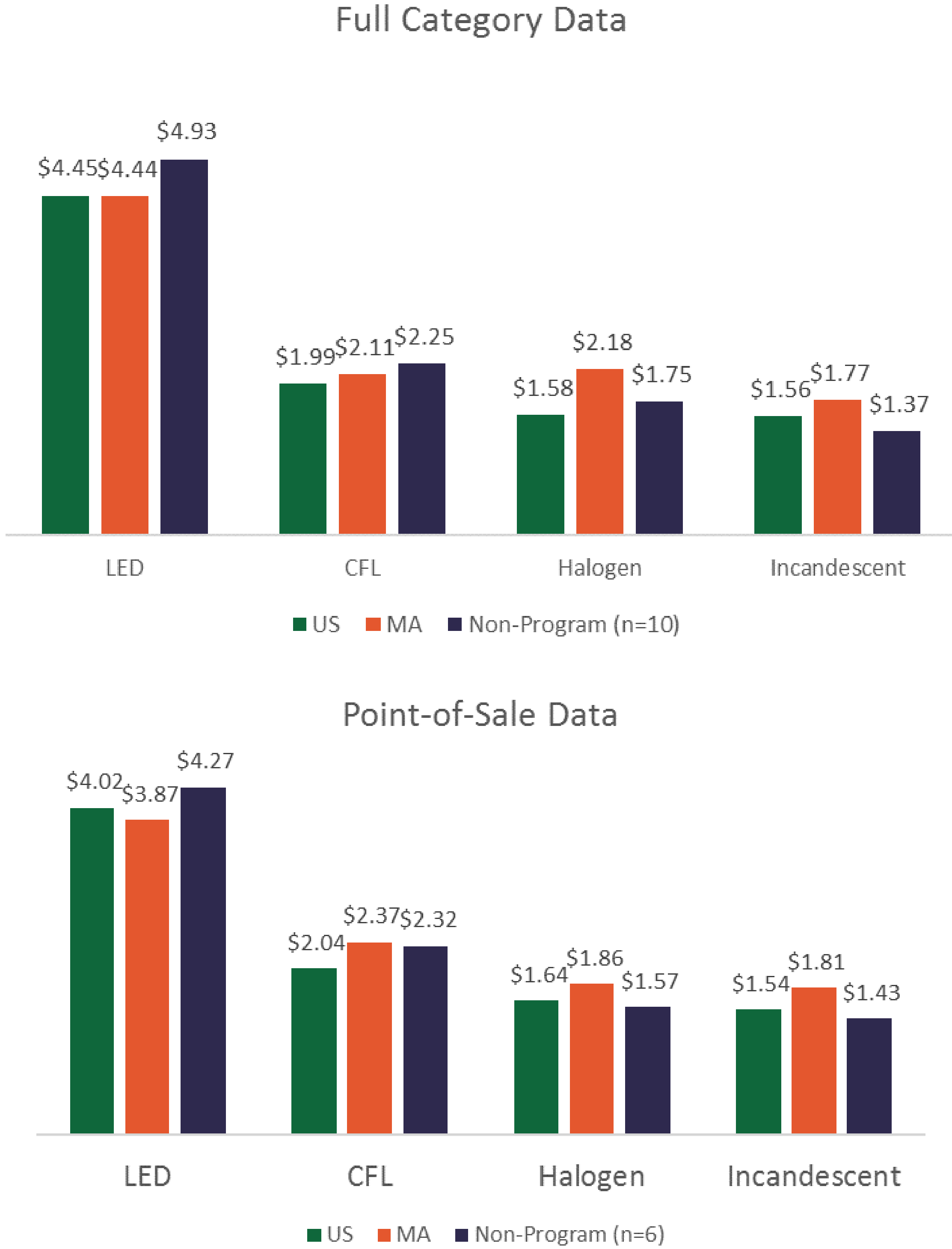
Massachusetts bulb prices for mid-range lumen bins were slightly lower compared to average US and non-program prices.

[2] MSB = medium screw base

[3] Does not include *private label* bulbs sold at specific retailers, so the prices reported here are likely somewhat higher than actual prices

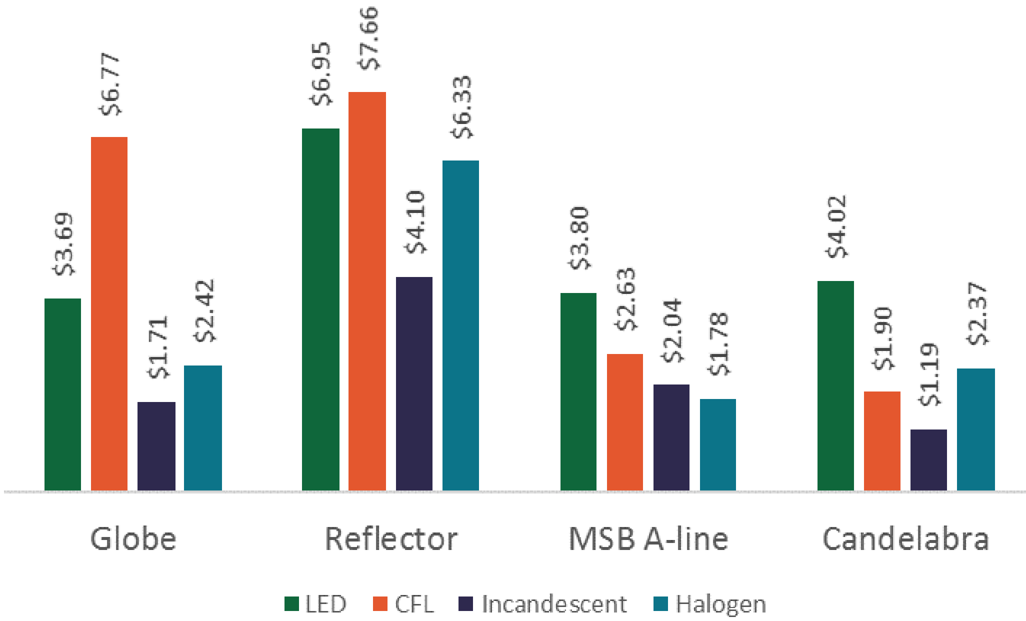
Figure 24 shows that the prices of LED MSB A-line bulbs in Massachusetts are slightly lower for mid-range lumen bins compared to average US and non-program prices. On average, a LED A-line with 310-749 lumens costs $3.58 per bulb in Massachusetts, but $3.80 across the US and $3.78 across non-program states. This price includes all bulb types, not just program-supported ones or ENERGY STAR models, which may partially explain why the price difference is lower than the average $3 discount offered by the PAs. The lack of hardware and home improvement stores also likely influences the price findings. The results are similar for LED A-line with 750-1049 lumens. Massachusetts prices are comparable to non-program states for bulbs with 1,050 to 2,600 lumens; both fall below those of the US. Some Massachusetts prices for lumens greater than 2,600 are not available because there were no recorded sales for that bulb type.

Figure 20: Average Price per Bulb by Bulb Type and Geography[1,2]



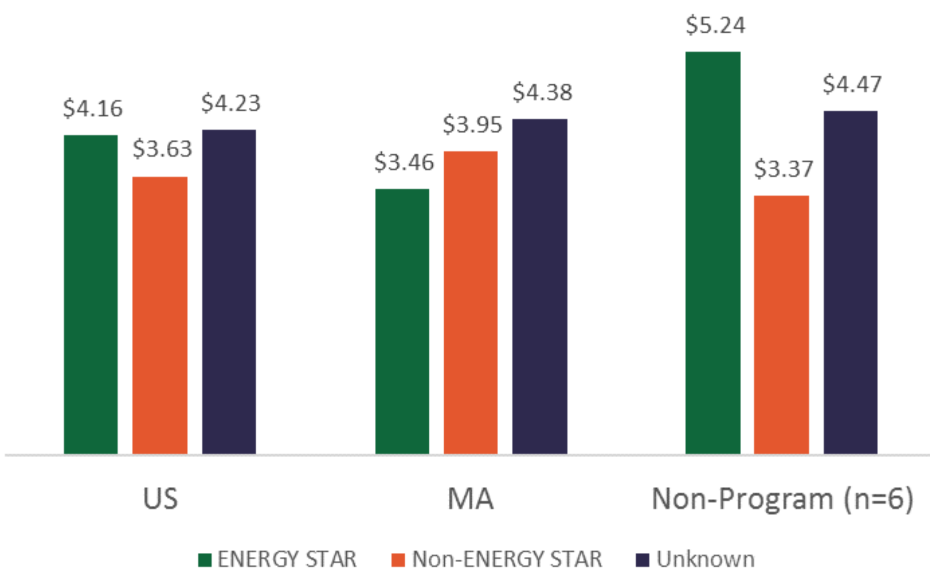
[1] Full category data includes all channels. Point-of-sale data includes grocery, drug, dollar, discount, and merchandise stores, and represents approximately 40% of the Massachusetts market, 38% of the US market, and 41% of the non-program states market.
[2] Does not include *private label* bulbs sold at specific retailers, so the prices reported here are likely somewhat higher than actual prices

Figure 21: Average Price per Bulb by Bulb Type and Style in Massachusetts[1,2,3]



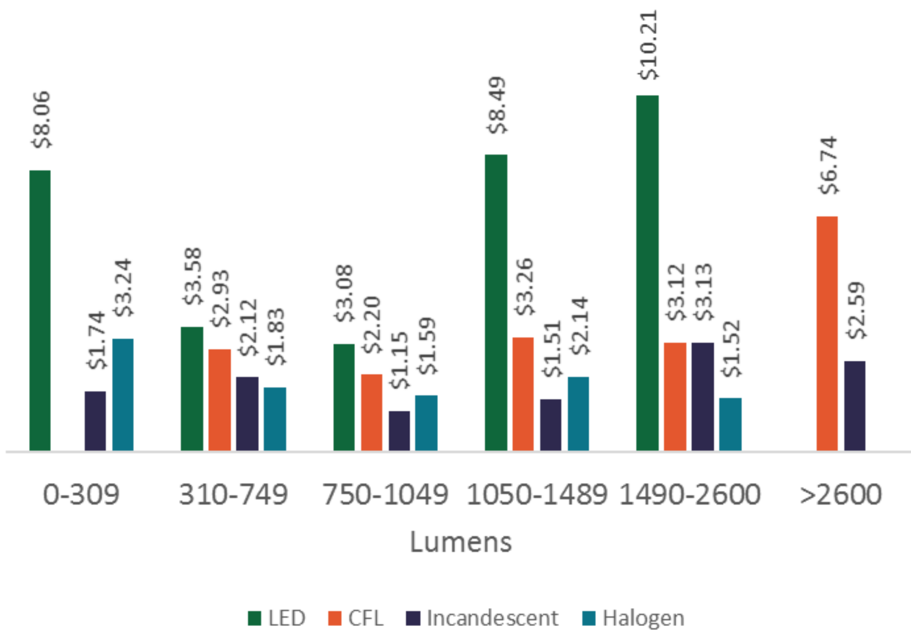
[1] Includes grocery, drug, dollar, discount, and merchandise stores, and represents approximately 40% of the Massachusetts market.
[2] MSB = medium screw base
[3] Does not include *private label* bulbs sold at specific retailers, so the prices reported here are likely somewhat higher than actual prices

Figure 22: Average Price per LED by ENERGY STAR Qualification[1,]



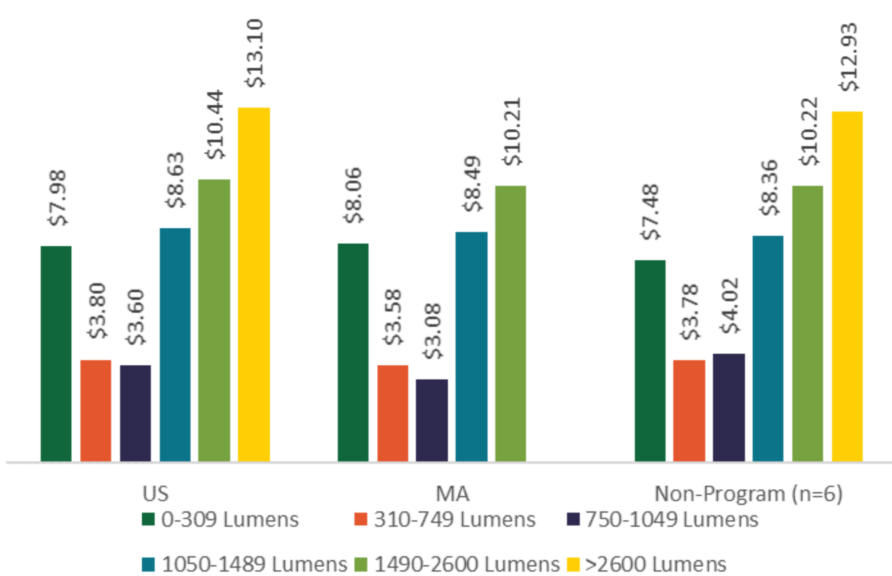
[1] Includes grocery, drug, dollar, discount, and merchandise stores, and represents approximately 40% of the Massachusetts market.
[2] Does not include *private label* bulbs sold at specific retailers, so the prices reported here are likely somewhat higher than actual prices

Figure 23: Average Price in Massachusetts for MSB A-line Bulbs[1,2,3]



[1] Includes grocery, drug, dollar, discount, and merchandise stores, and represents approximately 40% of the Massachusetts market.
[2] MSB = medium screw base
[3] Does not include *private label* bulbs sold at specific retailers, so the prices reported here are likely somewhat higher than actual prices

Figure 24: Average Price per LED MSB A-line Bulb by Geography[1,2,3]



[1] Includes grocery, drug, dollar, discount, and merchandise stores, and represents approximately 40% of the Massachusetts market.
[2] MSB = medium screw base
[3] Does not include *private label* bulbs sold at specific retailers, so the prices reported here are likely somewhat higher than actual prices

3

Section 3 Net-to-Gross Modeling Results

The underlying theory behind the national lighting sales data NTG model is that states with strong upstream lighting program activity, relative to those with little to no program activity, should have higher market share (via sales) of efficient lighting. The model leverages full category lighting sales data to estimate market lift as a function of program activity while also controlling for other factors (e.g., household and demographic characteristics) that might impact efficient lighting sales. The modeling presents comprehensive NTGR estimates that capture free-ridership, participant spillover, and non-participant spillover. This section first explores the data for relationships among the variables in the model and then turns to the actual modeling effort.

3.1 Data Exploration

Table 8 shows the correlation between the dependent variable (LED market share) and 12 potential channel and demographic/household variables. Nine of the variables are positively correlated with LED market share and three are negatively correlated. Correlation coefficients can range from -1 to +1 and the magnitude of the absolute value indicates the degree of correlation. The shading offers a second indication of magnitude, with red denoting negative correlations and blue representing positive ones. This means that program age is the most correlated variable with LED market share (i.e., higher LED market shares typically occurring in states with older efficient lighting programs).

Table 8: Correlations between Independent Variables and LED Market Share

Variable	LED Market Share
Sqft NonPOS per HH	0.34
Sqft POS per HH	-0.39
Percent Sqft NonPOS	0.49
Political Index (2015)	0.51
Political Index (Gallup 2016)	0.32
Median Income	0.50
Average Electricity Cost	0.36
Cost of Living	0.36
Percentage of Homes Built Pre-1980	0.27
Percentage of Renters Paying Utilities	-0.37
Percentage Owner Occupied	-0.10
Percentage of Population with College Degree	0.49
Program Age	0.66
Program Spend per Household	0.60

Table 9 provides a correlation matrix among the potential independent variables. While political index and cost of living are both positively correlated with energy efficient market share, they are highly correlated with one another (correlation coefficient=0.7). The same is true for other relationships between independent variables. When a regression model includes multiple independent variables that are correlated with one another (i.e., multicollinearity), it will have difficulty precisely estimating the effect of either of the correlated terms. This issue is compounded by the relatively low number of observations in the data set. For this study, we examined the variance inflation factors, statistics which help to assess multicollinearity, and they indicated that multicollinearity was not a concern.

Because of the complexity of the relationships and numerous options of these channel, demographic, and household characteristic variables, the team developed and tested different model options, adding and dropping variables to reduce collinearity but still explain LED market share. The results focus on the final best fit model option discussed below.

Table 9: Correlations Among Independent Variables

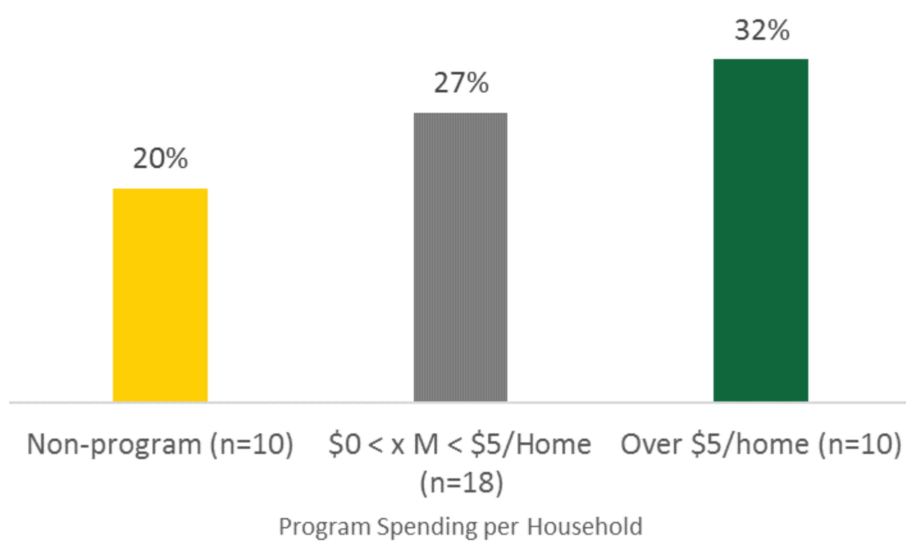
Variable	Sqft NonPOS per HH	Sqft POS per HH	Percent Sqft NonPOS	Political Index (2015)	Political Index (Gallup 2016)	Median Income	Average Electricity Cost	Cost of Living	Percentage of Homes Built Pre-1980	Percentage of Renters Paying Utilities	Percentage Owner Occupied	Percentage of Population with College Degree	Program Age	Program Spend per Household
Sqft NonPOS per HH	1.00													
Sqft POS per HH	0.01	1.00												
Percent Sqft NonPOS	0.36	-0.91	1.00											
Political Index (2015)	0.03	-0.78	0.75	1.00										
Political Index (Gallup 2016)	-0.12	-0.76	0.68	0.92	1.00									
Median Income	0.27	-0.66	0.74	0.62	0.58	1.00								
Average Electricity Cost	-0.09	-0.56	0.53	0.62	0.57	0.60	1.00							
Cost of Living	-0.18	-0.75	0.67	0.71	0.69	0.72	0.83	1.00						
Percentage of Homes Built Pre-1980	0.02	-0.39	0.41	0.42	0.35	0.38	0.48	0.45	1.00					
Percentage of Renters Paying Utilities	-0.10	0.25	-0.26	-0.20	-0.06	-0.47	-0.39	-0.45	-0.52	1.00				
Percentage Owner Occupied	0.35	0.43	-0.32	-0.32	-0.36	-0.25	-0.30	-0.50	-0.08	-0.06	1.00			
Percentage of Population with College Degree	0.14	-0.66	0.68	0.70	0.64	0.91	0.60	0.71	0.32	-0.39	-0.34	1.00		
Program Age	-0.02	-0.59	0.56	0.58	0.49	0.52	0.65	0.70	0.40	-0.41	-0.34	0.54	1.00	
Program Spend per Household	-0.11	-0.50	0.44	0.59	0.52	0.46	0.45	0.54	0.27	-0.34	-0.08	0.51	0.68	1.00

As noted above, some of the key attributes the team included in the best fit model include the following:

- **Program intensity**: LED lighting market share relative to overall program expenditures per household (binned by three tiers of magnitude of spending)
- **Market share distribution**: LED market share distribution across each state and across retail channels
- **Program incentives**: Average LED lighting program incentives per bulb
- **ENERGY STAR market share distribution:** LED market share distribution in Massachusetts compared to non-program states

Figure 25 shows LED market share as a function of program spending. As clearly demonstrated in this graphic, LED share increases as program spending increases. In the program activity dataset of 38 states, ten states did not run an upstream lighting program and, on average, 20% of bulb sales are LEDs in these non-program states.[32] States with aggressive program activity (including Massachusetts) spent over $5 per household in upstream lighting programs, with 32% of total 2016 bulb sales being LEDs for these states.

Figure 25: Program Spending and LED Market Share (2016)

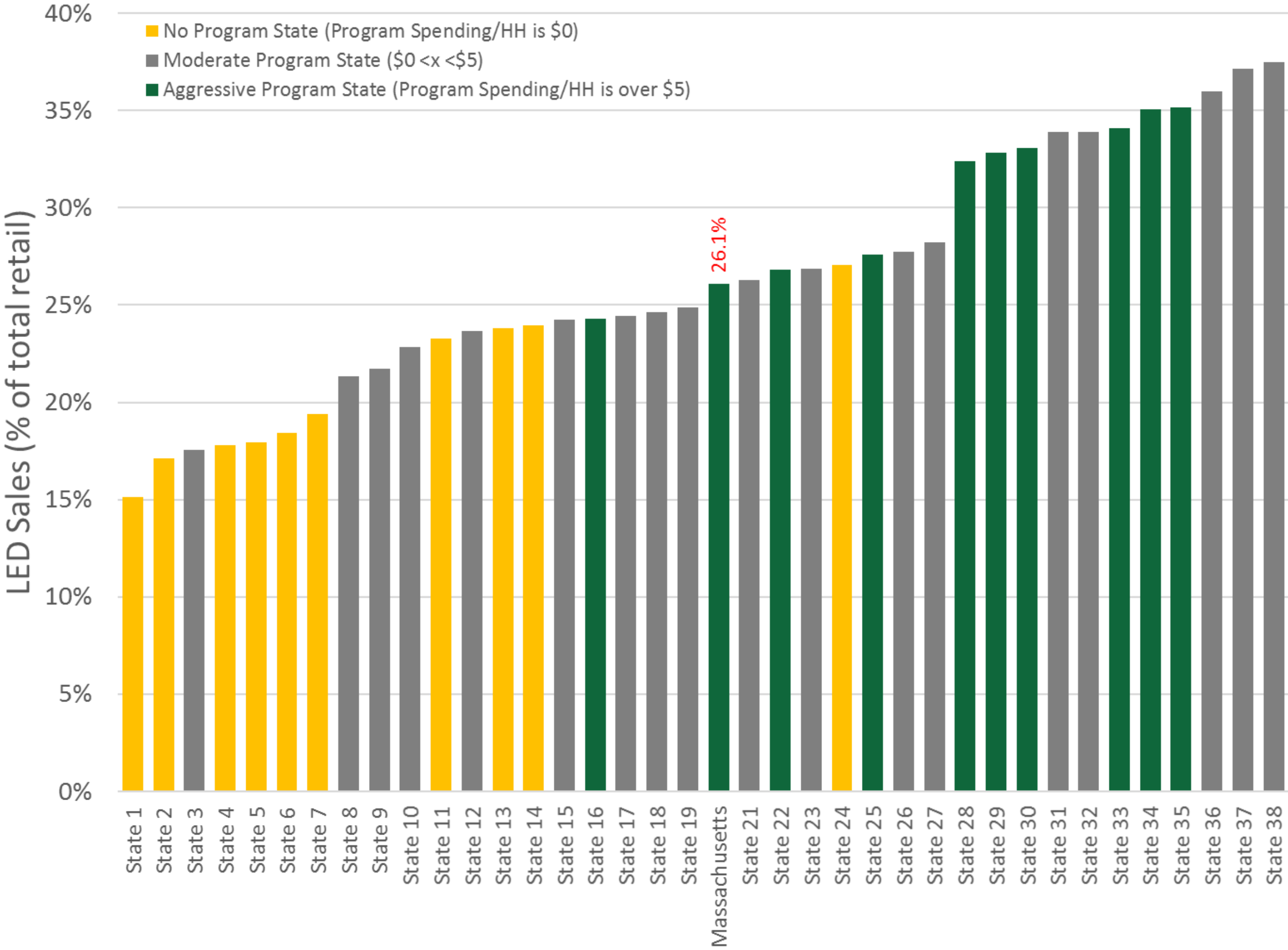


[32] See Appendix A for details on which states are included.

Similarly, Figure 26 shows Massachusetts' relative LED market share compared to the other modeled states (n=38). States highlighted in green represent those with aggressive programs (spending more than $5 per household). LED market share in Massachusetts falls below most other aggressive program states, perhaps due to its continued support of CFLs, which may have dampened LED sales (see Section 2.1.1). Gold bars represent the non-program states, and gray bars represent states with spending between zero and less than five dollars. As expected, LED market share tends to be low for most states lacking upstream lighting programs, but market share of states with moderate spending varies considerably.

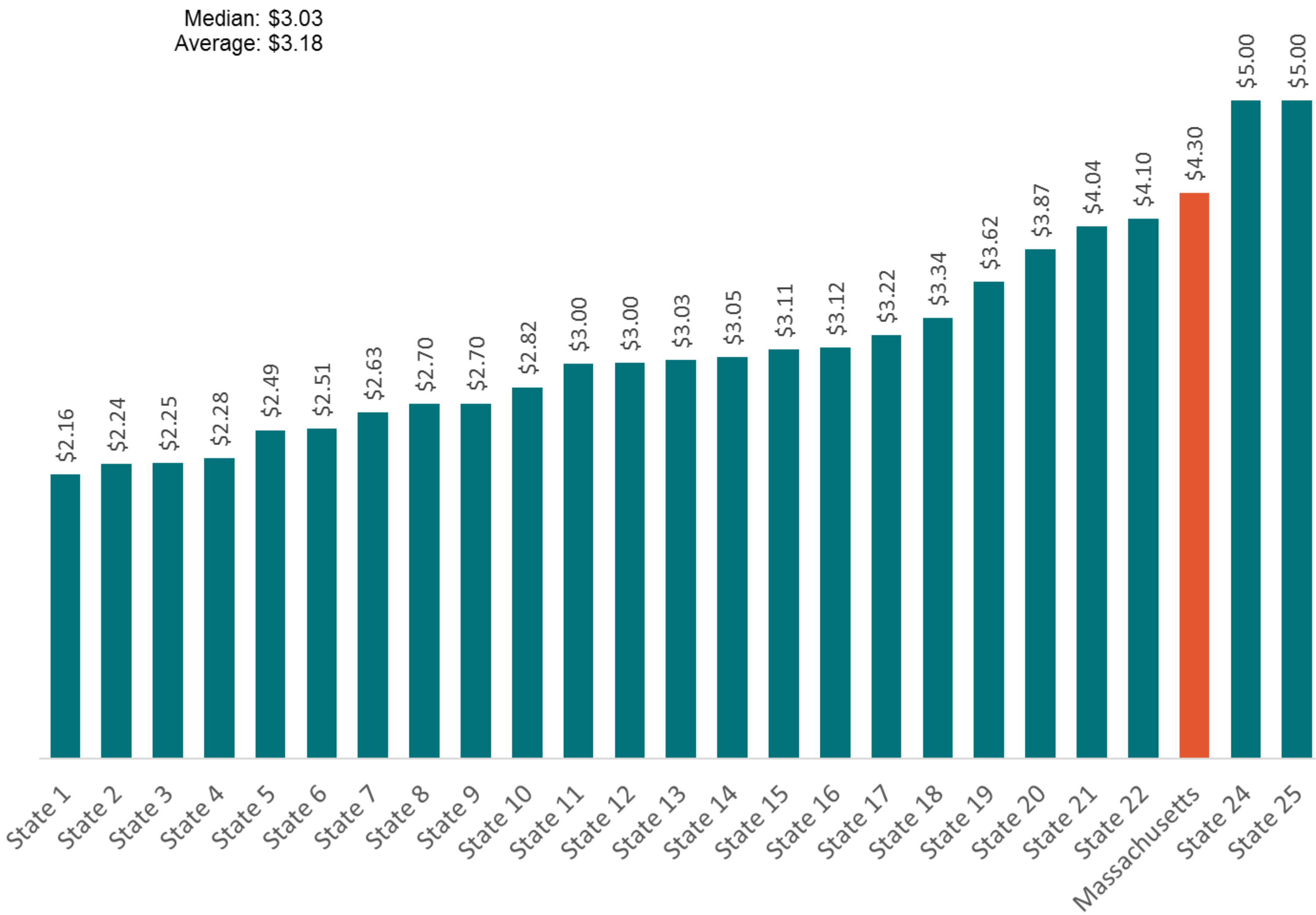
The LightTracker team also compared the average incentive offered per LED across states in which the team successfully collected this information. A simple calculation of incentive dollars divided by bulb units yielded average incentives per state. As shown below in Figure 27, LED incentives ranged from $2.16 to $5 per LED bulb in the 24 states that had sufficient data, with most states offering between $2.50 to $4 per LED (the average LED incentive was $3.18). Massachusetts ranks near the top of incentives per bulb, offering $4.30 per LED in the upstream lighting program.

Figure 26: LED Market Share Across States (2016)[1]



[1] Excludes three states with no direct spending on LEDs.

Figure 27: Average Upstream Lighting Incentive per LED (Program States)



3.2 REGRESSION MODEL

The regression coefficients for the program intensity variables, and subsequent estimates of the NTGR, proved relatively stable across several model specifications. The team explored both forward and backward stepwise regression procedures to allow different combinations of independent variables to enter and exit the model. As noted above, the team has weighted the OLS model by the number of homes for each state. The final model is shown in Table 10, along with regression coefficients and their p-values. P-values of all variables except non-POS sqft per HH are below alpha = 0.1, meaning they are statistically significant at the 90% confidence level.[33] As shown in the model, the final set of explanatory variables included program spending per household, political index, median income, an interaction term between political index and median income, non-POS sqft per HH, and program age.[34] This model has the highest explained variance (adjusted R^2) of the models tested for the LightTracker Initiative, and it is the model recommended to all CREED members engaging in the NTG modeling effort. Appendix B presents the strongest of the alternative models.

Table 10: Model Summary Statistics (n=38 States)

Independent Variable	Model Coefficient	*p*-value of Coefficient
Intercept	-0.908	0.013
Program Spending per Household (Sqrt)	0.029	0.001
Political Index	0.010	0.005
Median Income	<0.001	0.007
Political Index * Median Income	<-0.001	0.006
Non-POS sqft per HH	0.011	0.187
Program Age	0.002	0.068
Model Adjusted R^2		**0.677**

The positive and significant coeffient for program age indicates that, on average for the country and controlling for other factors, prior program activity positively influences current year efficient market share. Nationally, this may reflect a number of factors. These factors include "momentum" in terms of customer awareness, education, and preference for efficient lighting, as well as retailer knowledge and promotion of efficient lighting. Program age might also be thought of as market effects. Market effects here mean the portion of efficient lighting sales that are due to potentially permanent changes in the market as a result of ongoing program activity. As we have seen, however, Massachsuetts seems to counter this relationship: it has one of the oldest programs in the nation but its LED market share was moderate compared to other

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[33] The non-POS sqft per HH was included in the model because the distribution of market share suggests that non-POS stores have a substantially larger share of LED bulbs (see **Error! Reference source not found.** and Figure 16), so this variable was included as a proxy to capture that observed relationship.

[34] As stated above, program spending in not limited to LED program spending. Some upstream programs incentivize CFLs but did not track spending by bulb type. The variable for program spending per household may understate the importance of programs with significant CFL programs.

program states. Based on the market share data and prior evaluation results presented in Section 2.1, the LightTracker team believes that Massachusetts' continued aggressive support of CFLs through most of 2016 may provide at least some explanation for its somewhat unique experience of moderate LED market share among other older, aggressive lighting programs.

3.3 Net-to-Gross Estimation

The NTGRs suggested by the recommended model are 55% when assuming the Massachusetts program never existed (i.e., there was no program activity in 2016 or any years prior), and 39% when assuming the program existed through 2015 but not in 2016.

Table 11 shows the NTGR calculations. The LightTracker team developed the NTGR using a "modeled:modeled" calculation as opposed to a "modeled:actual." This means that the counterfactual scenario (which can only be modeled as it never actually happened) was compared to a *modeled* LED market share rather than the actual LED market share for Massachusetts in the data set. This allows for a more comparable calculation.

For estimating the NTGR, the evaluation team presented two options for treating the program age counterfactual:

1) Programs have never existed (Program Age is set to 0); or
2) Programs existed through 2015 (Subtract one year from the Program Age).

The NTGR including both current and past program influence (i.e., setting past programs to zero in the counterfactual scenario) is 55%; if only examining influence of the current program, and assuming that past influences would have continued even if the current program was terminated, the NTGR is 39%.

Table 11: Massachusetts NTGR Calculations

	Counterfactual	
Calculation Term	**No Massachusetts Programs Ever**	**No Massachusetts Program in 2016**
Total Massachusetts Bulbs 2016 (A)	19,460,804	19,460,804
Program $ per HH Actual (B)	$11.31	$11.31
Program $ per HH Counterfactual (C)	$0.00	$0.00
Program Age Actual (D)	18	18
Program Age Counterfactual (E)	0	17
LED Market Share Counterfactual (F)	17.5%	21.7%
LED Market Share Modeled (G)	31.8%	31.8%
LED Qty Modeled (H=A*G)	6,188,536	6,188,536
LED Qty Counterfactual (I= A*F)	3,405,641	4,222,994
Net LEDs Modeled (J=H-I)	2,782,895	1,965,541
Program LED Bulbs 2016 (K)	5,096,082	5,096,082
NTGR Modeled (L=J/K)	55%	39%

3.4 Net-to-Gross Ratio Next Steps

As explained in the Introduction, the market information (bulb sales, market share, and prices) and NTGR estimates calculated from this study will be considered together with findings from other lighting evaluation studies as evidence in the 17-6 Market Adoption Model Study and the 17-11 LED Net-to-Gross Consensus study. Therefore, we refrain from making any specific recommendations stemming from this study's findings.

A Appendix A State Program Activity Designation and Data Quality Hierarchy

Table 12 lists the states included in the NTG modeling dataset by program status and the LightTracker team's confidence in the data quality for each state. The dollar signs next to a state indicate that it was also considered a non-program state in the bulb price analysis.

Table 12: Program Strength and Data Quality Confidence

Program States		Non-Program States	Lacking Sufficient Data[1]
High	Moderate		
Colorado	Arizona	Alabama[$]	Alaska
Connecticut	Arkansas	Delaware	Hawaii
Illinois	California	Kansas[$]	Iowa
Maine	Florida[*$]	Kentucky	Louisiana
Maryland	Georgia	Mississippi[$]	Montana
Massachusetts	Idaho	Nebraska	Nevada
Michigan	Indiana	South Dakota	New Jersey
New Mexico	Minnesota	Tennessee[$]	North Dakota
Oregon	Missouri	Virginia	Oklahoma
Washington	New Hampshire	West Virginia	Rhode Island
	New York	Virginia[$]	Utah
	North Carolina	West Virginia	Vermont
	Ohio		
	Pennsylvania		
	South Carolina		
	Texas		
	Wisconsin		
	Wyoming		

[1] The states either lacked sales data or LightTracker had little confidence in the program data for the state.

[*] A small program existed in Florida, but spending was only three cents per household when extrapolated to the state.

[$] State included as non-program in the bulb price analysis, with the lower number reflecting reliance on the NCP dataset, which included only 31 states in total.

B Appendix B Additional Net-to-Gross Ratio Modeling Information

This appendix provides more detail on the NTGR modeling effort.

B.1 WEIGHTING

Weighting of states within the model served as a key consideration in the modeling. One option was to weight each of the 38 states equally. However, since each state is one observation in the model, the team wanted to account for larger states having larger sample sizes in the panel data and bigger impacts on the lighting market as a whole. This would be accomplished by either using the number of households or total bulb sales as the weight. The team felt that using analytic weights[35] in the model was appropriate because the data set consists of a series of purchase transactions that have been condensed into an observed mean. Estimating the following regression model with analytic weights, where each state's average market share is based on n observations:

$$LED\ Market\ Share_i = \beta_0 + \beta_1 * Program\ Spending\ per\ HH_i$$

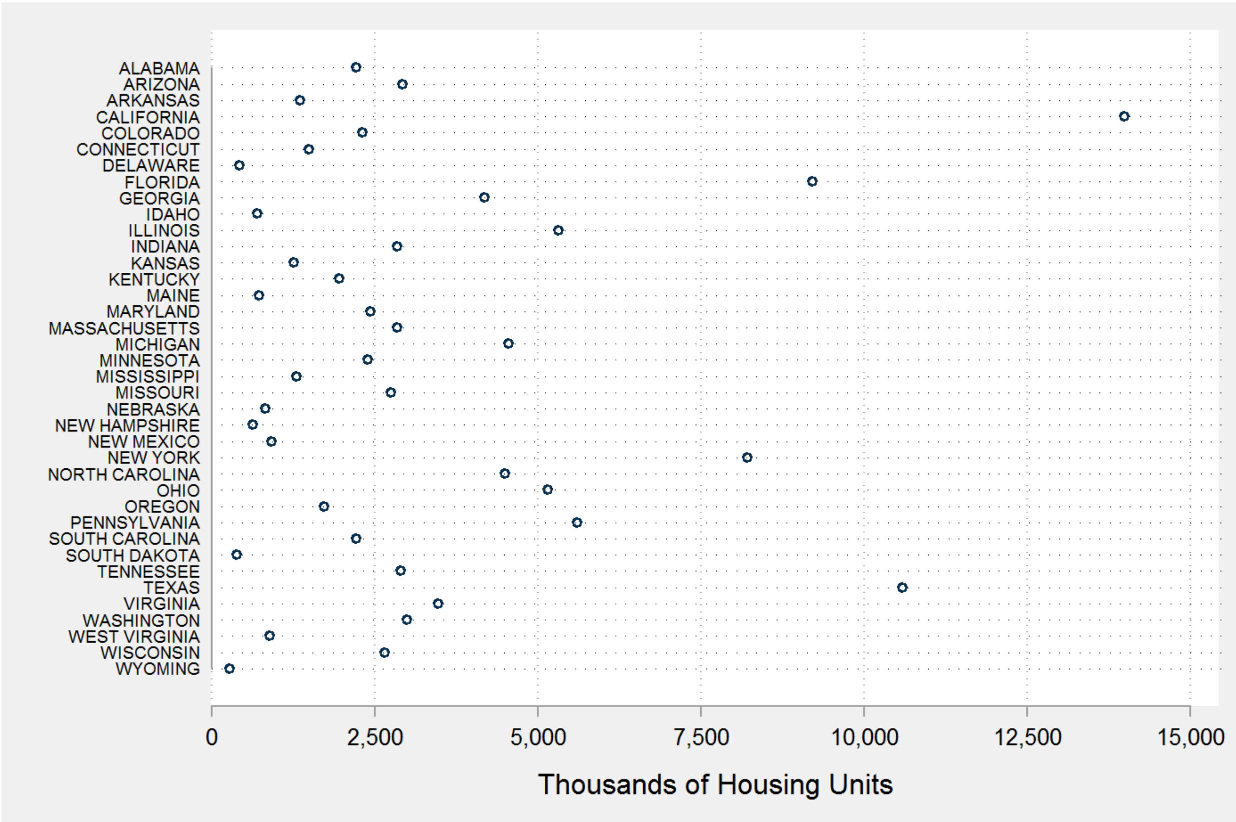
Would be analogous to estimating:

$$LED\ Market\ Share_i * \sqrt{n_i} = \beta_0 * \sqrt{n_i} + \beta_1 * Program\ Spending\ per\ HH_i * \sqrt{n_i}$$

The square root term means that the weights were proportional to the inverse of the variance. Because our analysis data set consisted of multiple data streams, the definition of an observation was inconsistent, so a proxy is needed for the weighting variable. The sample size in the panel data was generally proportional to state population and large states also represented a larger share of the overall US lighting market than smaller states. This also meant the team was generally more confident in the non-POS lamp shares for larger states compared to smaller states because the average lighting share value in large states was based on more measurements than small states, which should make the market share estimate more precise. Figure 28 shows the number of households for each of the 38 states included in the model.

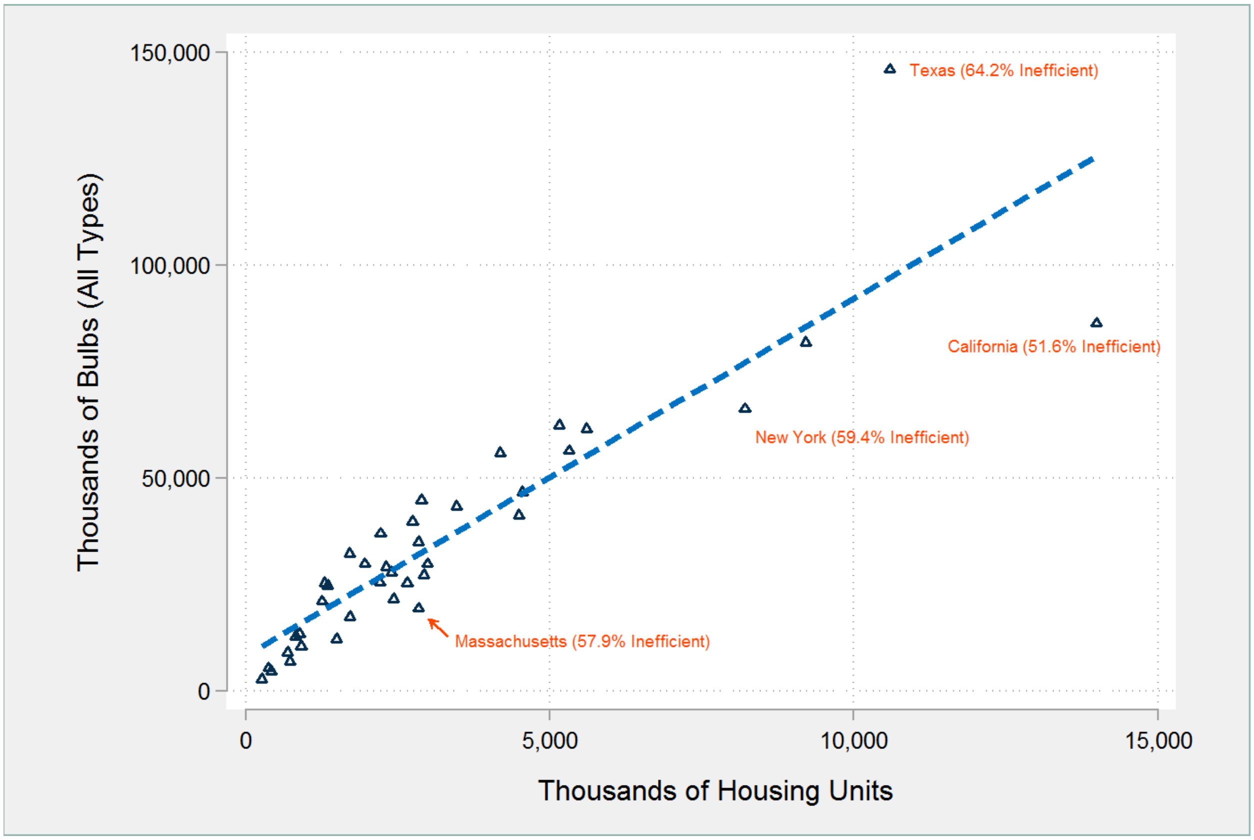
[35] http://www.stata.com/help.cgi?weight

Figure 28: Number of Housing Units by State



Another weighting option the team considered was the total number of bulbs sold in 2016. This approach would result in similar weights compared to the number of households. As shown in Figure 29, the relationship between total bulbs and number of households varies across states, but is highly correlated. The team, however, was concerned that weighting by the number of bulbs could potentially create a situation where the weighting variable was correlated with some of the independent variables, the program intensity variable, or income. For example, programs may influence bulb sales either positively (by encouraging more sales and increasing the total number of bulbs sold) or negatively (by increasing the LED saturation of longer life bulbs and thus decreasing the number of bulbs sold); in addition, states with higher income may have larger homes, and thus more sockets. For this reason, the team selected to go with household, rather than bulb, weights.

Figure 29: Scatter Plot of Total Bulbs and Number of Housing Units[36]



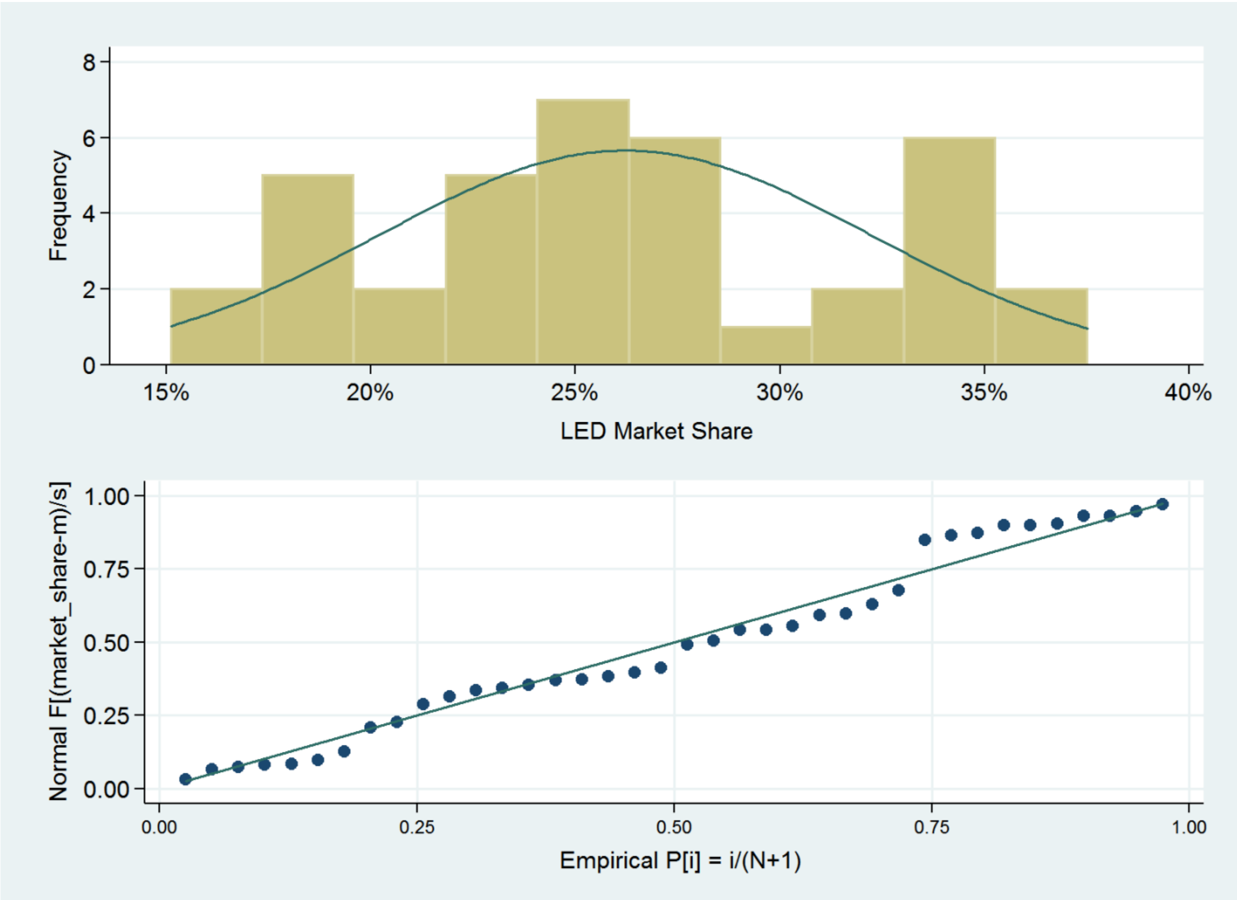
B.2 MODEL FUNCTIONAL FORM

Another critical decision in the modeling process is the selection of the functional form of the model. A key input in this decision is the distribution of the dependent variable. Figure 30 contains a histogram and a standardized normal probability plot for the LED market share of the 38 states in the analysis data set and indicates that the data are approximately normally distributed.[37]

[36] The percent inefficient refers to the percent of 2016 sales of halogens or incandescent bulbs.

[37] The team also ran a Shapiro-Wilk test for normality, where the null hypothesis is that the data are normally distributed. The p-value of this test was 0.18 at the 95% confidence so there is no reason to reject the hypothesis that LED market share is normally distributed.

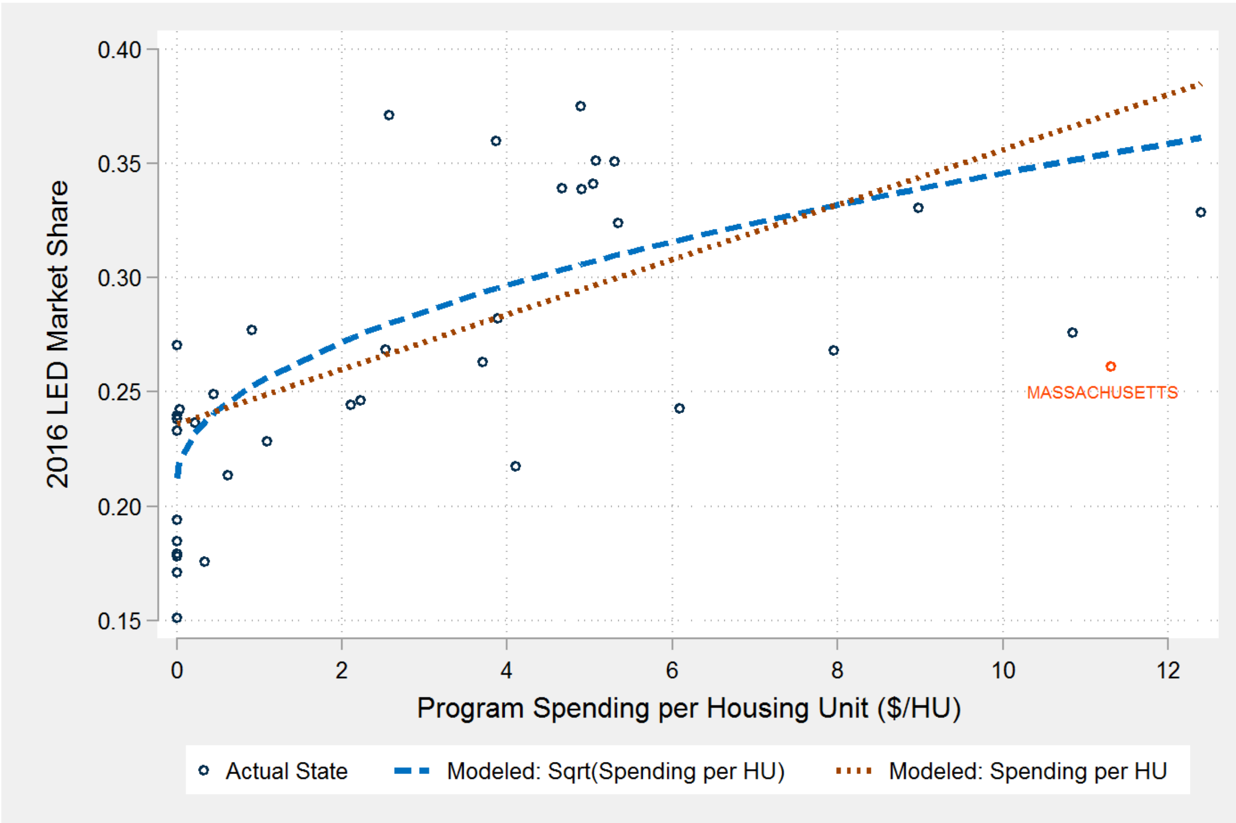
Figure 30: Histogram and Standardized Normal Probability Plot



LED market share has practical bounds on either end of the distribution. It cannot be less than 0%, and it cannot be greater than 100%. The team considered beta regression as well as fractional regressions (both probit and logit) to explicitly address this limitation and impose the theoretical limitations on the model.

In the recommended models, the team used a non-linear transformation of the independent predictor variables in the modeling exercise, including the square root of spending as the program intensity variable. Figure 31 shows that the square root model tapers LED market share as sqrt (spending) increases. This likely reflects a “diminishing returns” in terms of market share as program spending increases, and graphically provides a good fit for the data.

Figure 31: Linear vs. Non-Linear Modeling



B.3 Alternative Models

The LightTracker analysis team selected these nine models, which show the progression of model development via the included predictor variables, as well as the strongest alternatives to the recommended model discussed in Section 3.2 and presented as the “preferred model” in Table 13. This appendix presents the alternative models, along with explained variance (adjusted R^2). We do not present the estimated NTGR estimates because we want to dissuade potential temptation to select the recommended model based solely on the NTGR. The recommended model yielded a NTGR that fell in the middle of possible estimates for Massachusetts, based on all the strong alternatives considered. The range of NTG ratios produced from these models was 43% to 62% then setting program age equal to zero in the counterfactual and 27% to 42% when setting the counterfactual age equal to actual minus one.

Table 13: Model Summary Statistics (n=38 States)

Independent Variable	Model Coefficient (*p*-value of Coefficient)								
	Preferred Model	Model A	Model B	Model C	Model D	Model E	Model F	Model G	Model H
Intercept	-0.908 (0.013)	0.236 (<0.001)	0.212 (<0.001)	0.207 (<0.001)	0.136 (<0.001)	-0.952 (0.014)	-1.032 (0.004)	-1.112 (0.003)	-0.907 (0.018)
Program Spending per Household		0.012 (<0.001)				0.008 (0.005)			
Program Spending per Household (Sqrt)	0.029 (0.001)		0.042 (<0.001)	0.030 (0.001)	0.025 (0.005)		0.033 (<0.001)	0.039 (<0.001)	0.029 (0.005)
Program Age	0.002 (0.068)			0.003 (0.042)	0.004 (0.006)	0.004 (0.007)	0.002 (0.119)		
Program Age (Sqrt)									0.009 (0.212)
Non-POS sqft per HH	0.011 (0.187)				0.019 (0.019)	0.015 (0.091)			0.010 (0.253)
Political Index	0.010 (0.005)					0.011 (0.005)	0.012 (0.001)	0.013 (0.001)	0.010 (0.009)
Median Income	<0.001 (0.007)					<0.001 (0.005)	<0.001 (0.001)	<0.001 (0.001)	<0.001 (0.010)
Political Index * Median Income	>-0.001 (0.006)					>-0.001 (0.007)	>-0.001 (0.001)	>-0.001 (0.001)	>-0.001 (0.011)
Model Adjusted R^2	**0.677**	**0.375**	**0.519**	**0.561**	**0.616**	**0.645**	**0.669**	**0.653**	**0.658**

C Appendix C Massachusetts Market Share by Lumen Bins and Bulb Type

The tables in this appendix provide detailed market share for Massachusetts by lumen bin, bulb type, and bulb shape. We also note which lumen bins are currently EISA exempt and which will remain exempt in 2020. Cells marked *N/A* mean that no sales occurred for that bulb type in that lumen bin.

Table 14: A-line Bulbs by Lumen Bins and Bulb Type

Lumens	LED	CFL	Incandescent	Halogen	Currently Exempt	EISA 2020 Exempt
0-309	1.5%	0.0%	96.4%	2.1%	Yes	Yes
310-449	0.1%	0.2%	29.0%	70.6%	Yes	No
450-749	6.2%	3.9%	13.3%	76.6%	No	No
750-1049	25.6%	19.3%	3.5%	51.7%	No	No
1050-1489	4.4%	14.5%	8.8%	72.3%	No	No
1490-2600	7.5%	36.1%	1.4%	55.0%	No	No
2601-3300	0.0%	4.0%	96.0%	0.0%	Yes	No
>3300	0.0%	0.6%	99.4%	0.0%	Yes	Yes

Table 15: Reflector Bulbs by Lumen Bins and Bulb Type

Lumens	LED	CFL	Incandescent	Halogen	Currently Exempt[1]	EISA 2020 Exempt
0-309	14.5%	0.0%	16.1%	69.5%	Yes	Yes
310-449	8.6%	0.8%	28.7%	61.8%	Yes	No
450-749	27.5%	1.4%	13.6%	57.5%	Yes	No
750-1049	58.8%	22.0%	19.0%	0.3%	Yes	No
1050-1489	11.4%	5.0%	83.5%	0.0%	Yes	No
1490-2600	0.6%	0.0%	99.4%	0.0%	Yes	No
2601-3300	N/A	N/A	N/A	N/A	Yes	No
>3300	0.0%	0.0%	100.0%	0.0%	Yes	Yes

[1] While exempt from the first phase of EISA, reflector bulbs must adhere to their own set of efficiency standards that vary by size and shape. See https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=23.

Table 16: Globe Bulbs by Lumen Bins and Bulb Type

Lumens	LED	CFL	Incandescent	Halogen	Currently Exempt	EISA 2020 Exempt
0-309	1.7%	0.6%	5.1%	92.6%	Yes	Yes
310-449	6.9%	0.0%	0.3%	92.8%	Yes	No
450-749	7.6%	2.0%	31.0%	59.4%	No	No
750-1049	38.0%	1.1%	13.5%	47.4%	No	No
1050-1489	0.0%	1.3%	0.0%	98.7%	No	No
1490-2600	0.0%	73.2%	1.3%	25.4%	No	No
2601-3300	N/A	N/A	N/A	N/A	Yes	No
>3300	N/A	N/A	N/A	N/A	Yes	Yes

Table 17: Candelabra Bulbs by Lumen Bins and Bulb Type

Lumens	LED	CFL	Incandescent	Halogen	Currently Exempt	EISA 2020 Exempt
0-309	11.6%	0.0%	0.2%	88.2%	Yes	Yes
310-449	1.0%	0.1%	0.2%	98.7%	Yes	No
450-749	4.7%	0.3%	0.5%	94.6%	No	No
750-1049	0.0%	0.0%	85.8%	14.2%	No	No
1050-1489	N/A	N/A	N/A	N/A	No	No
1490-2600	N/A	N/A	N/A	N/A	No	No
2601-3300	N/A	N/A	N/A	N/A	Yes	No
>3300	N/A	N/A	N/A	N/A	Yes	Yes

Table 18: Other Specialty Bulbs by Lumen Bins and Bulb Type

Lumens	LED	CFL	Incandescent	Halogen	Currently Exempt	EISA 2020 Exempt
0-309	67.2%	0.0%	16.1%	16.8%	Yes	Yes
310-449	3.7%	0.1%	66.1%	30.1%	Yes	No
450-749	17.7%	5.4%	72.7%	4.2%	No	No
750-1049	39.8%	22.5%	25.2%	12.4%	No	No
1050-1489	7.8%	26.0%	63.4%	2.8%	No	No
1490-2600	18.3%	66.6%	10.0%	5.1%	No	No
2601-3300	0.0%	0.0%	0.0%	100.0%	Yes	No
>3300	22.2%	0.2%	69.7%	7.9%	Yes	Yes