A Market Lift Model for Assessing Net-to-Gross

Scott Dimetrosky, Apex Analytics, Boulder, CO

ABSTRACT

The lack of reliable and comprehensive sales data has been the "Achilles heel" of upstream-based market transformation program evaluations. This paper presents the result of a joint effort, representing ten utilities in four states, to collect and analyze lighting sales data to determine if upstream lighting programs are impacting the market. The underlying theory behind the analysis is that states that have strong upstream lighting program activity, relative to those with little to no program activity, should have higher market share (via sales) of efficient lighting products (CFLs and LEDs). This paper describes the objectives, data sources, methods, and findings for the sales data modeling effort, ultimately concluding that states that spend more on promoting energy efficient lighting have a corresponding increase in market share of efficient lighting products.

Introduction

The lack of reliable and comprehensive sales data has been the main difficulty of upstream-based market transformation program evaluations.[1] Historically, evaluators have attempted to address this challenge by using alternative methods to understand program net impacts, including using program sales data to estimate price elasticity of demand, and to conduct customer intercept and telephone surveys, retailer and manufacturer interviews, Delphi panels, or some combination of all the above approaches. Ultimately, however, the goal of upstream program evaluation is to measure the increase in sales of energy efficient bulbs over what would have occurred in absence of the program (known as the program lift).

Apex Analytics, with support from the Cadmus Group, Demand Side Analytics, and the NMR Group (collectively referred to as the Team), developed a dataset of lighting sales, as well as program activity. The Team then developed a regression model to estimate efficient market share as a function of program activity, while also controlling for other factors that might also impact efficient lighting sales (e.g., household and demographic characteristics). The result of the modeling is a comprehensive net-to-gross (NTG) estimate that captures freeridership, participant spillover, and nonparticipant spillover. The findings from this effort served to inform NTG in a number of states, including Connecticut, Maryland, and Wisconsin.

Study Objectives

The primary objective of the model is to quantify the relationship between program intensity (e.g., program spending per household) and efficient lighting sales (the percentage of light bulb purchases that are efficient), which can then be used to estimate a statewide Residential Lighting Program NTG estimate.

In addition to estimating NTG, the data provides helpful insights into other factors that drive purchases of efficient lighting, and it provides opportunities for benchmarking lighting efficiency shares and program spending across states. These additional analyses are also presented in this paper.

[1] By upstream, the Team is referring generically to lighting programs that pay down the cost of lighting equipment to either retailers (midstream) or manufacturers (upstream).

Data Sources

The Evaluation Team leveraged a variety of data sources for model development, but relied primarily on 2015 sales data prepared by the Consortium for Retail Energy Efficiency Data (CREED) LightTracker initiative.[2] These sales data were primarily generated from two sources: point-of-sale (POS) state sales data (representing one group of retail channels) and National Consumer Panel (NCP) state sales data (representing a different group of retail channels). These two sources collectively represent the majority of bulb sales across the United States. Besides these sales data being available through LightTracker, the model inputs are a combination of Program data collected by the Evaluation Team and household and demographic data collected through various publicly available websites. The primary model input data sources are listed here, and outlined in more detail below:

- National bulb sales
  - POS data (grocery, drug, dollar, discount, mass merchandiser, and selected club stores)
  - Panel data (home improvement, hardware, online, and selected club stores)
- US Census Bureau import data (CFLs)
- ENERGY STAR shipment data (imports and ENERGY STAR market share)
- North American Manufacturers Association shipment data
- American Community Survey (ACS) data (household characteristics and demographic data)
- Retailer square footage per state (based on the two primary retailer channel data sources)
- General population surveys, lighting saturation studies, and other primary data collection made publicly available through evaluation reports

Lighting Sales

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

The NCP represents a panel of approximately 100,000 residential households that are provided a handheld scanner for their home and instructed to scan every purchase they make that has a bar code. For Wisconsin, the NCP included approximately 1,500 households in 2015. The use of a scanner avoids the potential recall bias that is prevalent in self-report methods that ask about lighting purchases.

Though the dataset the Evaluation Team received included detailed records of lighting data purchases, the data required a considerable effort to ensure data integrity and the inclusion of all

[2] CREED serves as a consortium of program administrators, retailers, and manufacturers working together to collect the necessary data to better plan and evaluate energy efficiency programs. LightTracker is CREED's first initiative, focused on acquiring full-category lighting data—including incandescent, halogen, CFL, and LED bulb types—for all distribution channels in the entire United States. As a consortium, CREED speaks as one voice for program administrators nationwide as they request, collect, and report on the sales data needed by the energy efficiency community. There are more details available online: https://www.creedlighttracker.com. Note that 2015 data was the most recent year available at the time of this study. The information contained herein is based in part on data reported by IRI through its Advantage service, interpreted solely by LightTracker. 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

necessary bulb attributes. For example, not all records had some of the more critical variables populated, including bulb type, style, and wattage, and some clearly had erroneous values (e.g., 60-watt CFLs).

LightTracker then merged the Team's UPC bulb database with the POS/panel data, populating fields based on a hierarchy of data sources based on reliability, prioritized in the following order: manufacturer specifications, UPC lookups, and original IRI-based database values. The Evaluation Team also conducted many manual website lookups of individual bulbs to determine final assignments.

The final model ended up representing 39 states, excluding some smaller states that lacked sufficient sample size from the panel data.[3] Key aspects of the lighting dataset include:

- 2015 sales volume and pricing for CFLs, LEDs, halogens, and incandescent bulbs for all retailer sectors combined, and broken out by POS and non-POS channels
- Data reporting by state and bulb type
- Inclusion of all bulb styles and controls

As discussed below, the dependent variable of the model used percentage of efficient bulb sales, rather than total efficient bulb sales, to normalize for states with greater or lesser bulb sales (efficient or standard) due to differences in number of households, number of sockets, existing saturation, and other factors that drive lighting sales.

Program Activity

To research program activity, the Evaluation Team used internal resources and conducted a literature review of publicly available reports found on the internet or provided by program administrators or their evaluators.[4] The Team contacted local utilities in each given area when reports with the relevant information were not available. Additionally, the Evaluation 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.[5]

Where available, the Evaluation Team leveraged actual program expenditures; otherwise, ENERGY STAR reported expenditures were used as a proxy.[6] The Team 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. As an example, any state with no program activity was assigned a "0." The Team assigned a "1" to states where we successfully collected all program activity data points from every program administrator (including municipalities and cooperatives). States assigned a "2" had some program administrator data captured and some derived from ENERGY STAR (usually overall program expenditures). The Team assigned a "3" to the remaining states where the sole data points were derived from ENERGY STAR. The Evaluation Team was then able to iterate through the model using states with the most accurate data (with flags of 0 or 1), then to open the model up to including additional states (with flags of 2 or 3).

[3] The Team excluded states that had low sample sizes (typically 30 homes or less that scanned in LEDs or other lighting products purchased), since extrapolating these to the population would not be reliable.

[4] In particular, the Evaluation Team began by searching the ENERGY STAR Summary of Lighting Programs website and referenced the Database of State Incentives for Renewables & Efficiency.

[5] E Source. "DSM Insights." July 2016.

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

Presence and Absence of Retailers (Channel Variables)

The Evaluation Team conducted secondary internet research in order 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. These data were used as explanatory variables in the model since these retailers sell a large quantity of energy efficient bulbs, thus the percentage of efficient bulbs may differ in states with more or less of these retailers.

State-Level Household and Demographic Characteristics

The Evaluation Team gathered state-level demographic data from the ACS, including annual state-level data for the population, total number of households, household tenure (own versus rent), home age, education, income, and average number of rooms in the home. As explained below, the Team then combined these data with other potential explanatory variables, including political index, average cost of living, and average electric retail rates.

Modeling Methods

The primary goal of the model is to quantify the impact of state-level program activity on the sales of efficient lighting. Clearly, there are other factors that influence the sales of efficient lighting, and as noted above, the Evaluation Team considered a number of demographics, household characteristics, and retail channel variables to capture and control for the unique characteristics of each state that potentially affect the uptake of efficient lighting products.

The general form of the model is specified below, followed by a more detailed discussion of the data sources for each variable. Note the list of variables below is comprehensive of those considered; the final model, with summary statistics presented below in Table 1, lists the set of variables that were ultimately selected for inclusion based on their statistical significance and ability to improve the model specification.

$$EE\ Market\ Share_i = \beta_0 + \beta_1 * Program\ Spending\ per\ HH + \beta_c * \sum_{1}^{c} Channel\ Variables +$$

$$\beta_d * \sum_{1}^{d} Demographic\ Variables\ + \epsilon$$

Where:

- *EE Market Share$_i$* = Proportion of total bulb sales in state 'i' that are efficient. Equal to [(CFL sales + LED sales)/total bulb sales]
- β_0 = The model intercept
- β_1 = The primary coefficient of interest. This represents the marginal effect or program intensity, or the expected increase in the market share of efficient bulbs for each $1 in additional program spending per household
- *Program Spending per HH$_i$* = The number of 2015 retail lighting program dollars per household in state 'i'. Equal to total retail lighting program expenditures in state 'i' (incentive and nonincentive) divided by the number of households in state 'i'
- β_c *and* β_d = Array of regression coefficients for the channel variables and demographic variables

- *Channel Variables* = Numeric variables summarizing state-level retailer characteristics (additional detail is provided in Table 1)
- *Demographic Variables* = Numeric variables that summarize state-level population, housing, and economic attributes in (additional detail is provided in Table 1)
- ϵ_i = Error term

Table 1. Channel and demographic variables

Type of Variable	Description
Channel Variables	
Sqft NonPOS per HH_i	The average non-POS retail square footage per household in state 'i.' Equal to non-POS square footage divided by the number of households 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)
Demographic Variables	
Political $Index_i$	A state-level partisan voter index developed by Cook Political Report, 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 $Pre\text{-}1980_i$	All of these state-level demographic and household variables were derived from the most current U.S. Census ACS4
Percentage of Renters Paying $Utilities_i$	
Median $Income_i$	
Percentage Owner $Occupied_i$	
Percentage of Population with College $Degree_i$	

Model Weighting

One key consideration in the model was the weighting of states. One option is to weight all 39 states equally. However, since each state is one observation in the model, the Evaluation Team wanted to account for larger states that have larger sample sizes in the panel data and bigger impacts on the lighting market as a whole. Ultimately, the team chose to weight by the number of households in each state (based on census data).

Model Functional Form

Another critical decision in the modeling process is selecting the functional form of the model. A key input in this decision is the distribution of the dependent variable. Figure 1 contains a histogram and a standardized normal probability plot for the energy efficient market share of the 39 states in the analysis dataset, showing that the data are approximately normally distributed.

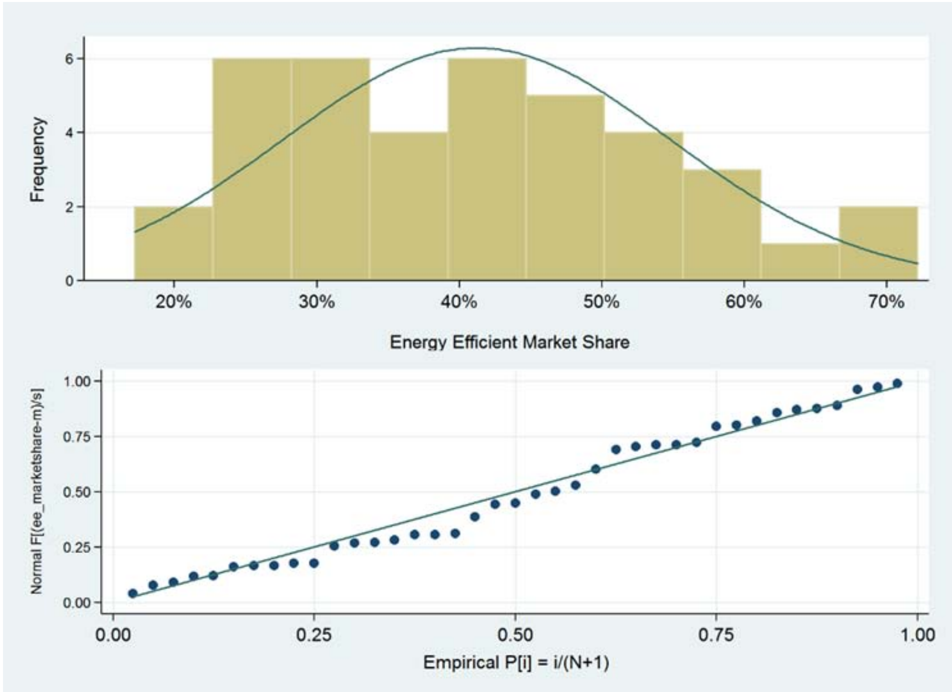

Figure 1. Histogram and standardized normal probability plot. *Source*: LightTracker analysis.

Energy efficient market share has practical bounds on both ends of the distribution. It cannot be less than 0% and it cannot be greater than 100%. The Evaluation 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. Ultimately, the Team elected to estimate the model using ordinary least squares (OLS) regression because the observed relationship between program spending and market share is relatively flat across the observed program intensity levels, and the results are easier to interpret (e.g., for every dollar increase in spending per household there is a constant increase in efficiency share).

Figure 2 illustrates the basis of this decision by presenting the fitted marginal effect values (increase in energy efficient market share per $1 of spending per household) from a non-linear beta regression model. In 2015, retail lighting program spending ranged from $0 to $15 per household. Even though the beta regression is equipped to estimate a non-linear trend, the estimated effect through the observed spending levels only curves slightly, indicating that the linear fit is a reasonable approximation. Ultimately, therefore, the Team selected to go with an ordinary least squares (OLS) regression.

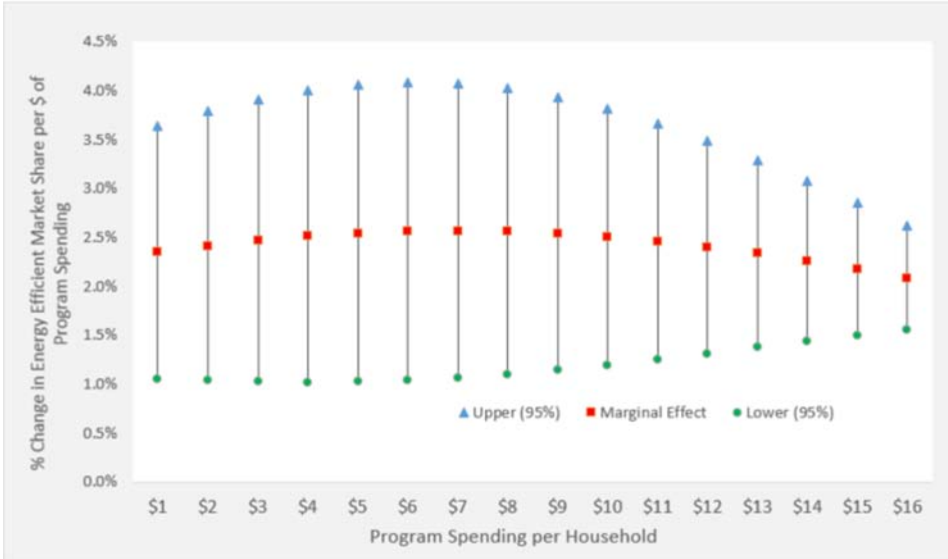

Figure 2. Shape of marginal effect across observed program spending levels – beta regression. *Source*: LightTracker Analysis.

NTG Estimates

Using the results of the regression models, efficient bulb sales data, and the program tracking databases, the Evaluation Team estimated NTG ratios for all efficient bulbs (CFLs and LEDs), CFLs only, and LEDs only in 2015. The Team derived NTG ratios by first using the model to predict the share of efficient bulbs with and without a program (determining the counterfactual of no program activity by setting the program variable to zero). This change in share represents the program lift, or net increase in the share of efficient bulbs resulting from program activity.

To then calculate NTG, the Team multiplied the change in share by the total number of bulbs—for all bulb types—sold in 2015, as determined by the sales data analysis described above. This value represents the net impact of the program (i.e., the total lift in the number of efficient bulbs sold), which the Team then divided by the total number of program bulbs sold (i.e., the gross number of bulbs) to determine NTG:

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

Key Findings

While the primary objective of this study was to determine the impacts of Program spending on the market share of efficient lighting, allowing for deriving state-level NTG estimates, a secondary objective was to understand national lighting sales and program activity and assess some of the key drivers behind the efficient lighting market share in program vs. non-program states. By having access to the national sales data and the largest known compilation of state program activity (incentives, overall expenditures, bulb volumes), the Evaluation Team was able to analyze and summarize lighting program activity in a way that has not been possible before. The following sections present the findings from analyzing descriptive data statistics as well as the multivariate regression model.

Analysis of the Combined Dataset (Descriptive Statistics)

Some of the key attributes the Evaluation Team was able to develop include:

- ***Program intensity***: efficient lighting market share relative to overall Program expenditures per household (binned by four tiers of magnitude of spending)
- ***Market share distribution***: efficiency market share distribution across each state
- ***Program incentives***: average efficient lighting program incentives per CFL and LED bulb

Figure 3 shows the state-level efficient bulb share as a function of program spending. As demonstrated in this graphic, efficient lighting sales share increases as program spending increases. In the program activity dataset of 39 states, seven states did not run an upstream lighting program, and had an average 28% of bulb sales that were efficient bulbs.

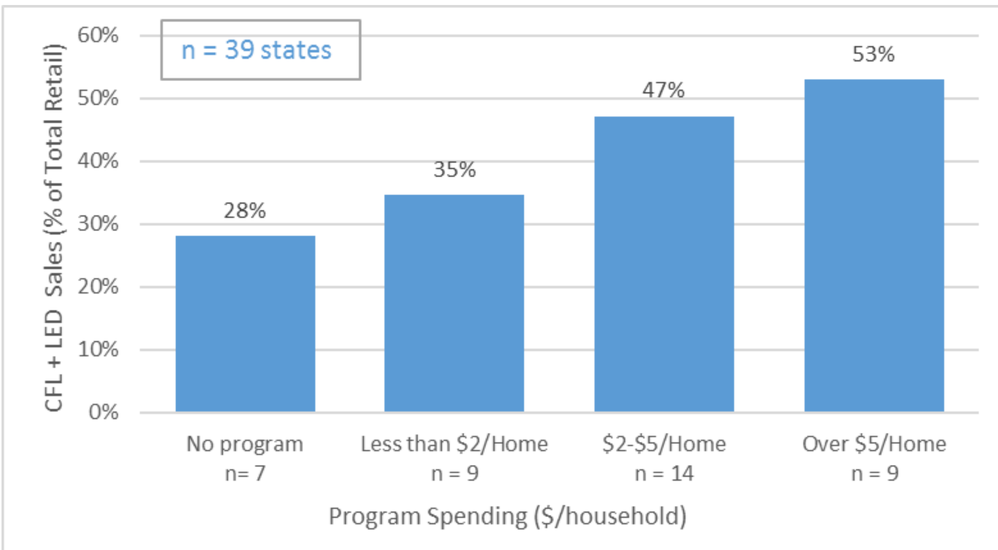

Figure 3. Relationship between program spending and efficient bulb sales (2015). *Source*: LightTracker analysis.

Similarly, Figure 4 shows efficient bulb sales in the 39 modeled states. States with a blue bar offer aggressive programs, spending more than $5 per household. Orange bars represents states that did not offer a lighting program. States with gray bars spent an average greater than $0 and less than $5 per household. Consistent with the analysis above, states that spend more per home on energy efficient lighting tend to have higher market share for efficient lamps.

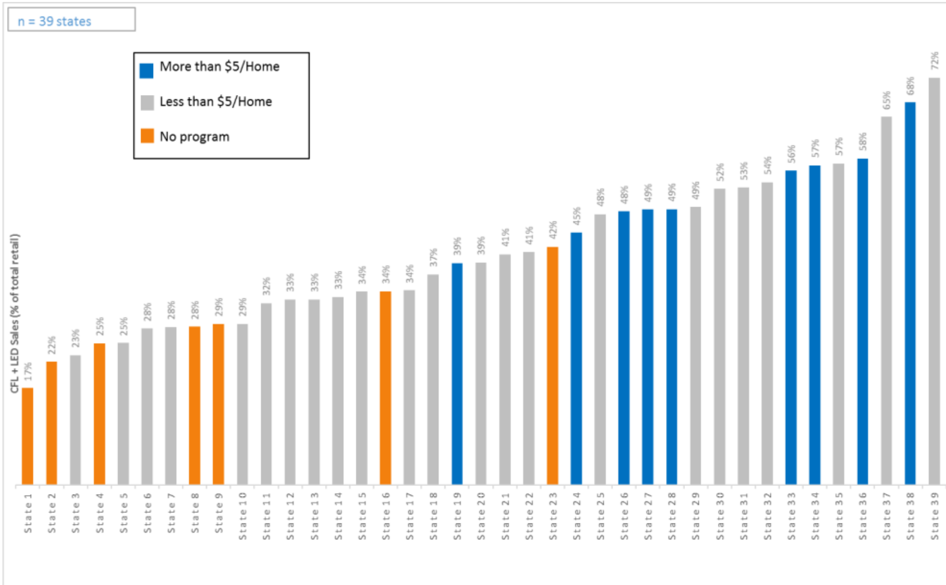

Figure 4. Efficient sales distribution across states (2015). *Source*: LightTracker analysis.

The Evaluation Team also compared the average incentive offered per efficient bulb type across states. A simple calculation of incentive dollars divided by bulb units yielded average incentives per state, shown in Figure 5 for CFLs and Figure 6 for LEDs. The average CFL incentive was $1.20, while LED incentives ranged from $1.59 to $6.92 per LED bulb, with most states offering between $3 and $5 per LED (with an average of $4.30).

Figure 5. Average upstream lighting incentive spending per CFL bulb. *Source*: LightTracker analysis.

Figure 6. Average upstream lighting incentive per LED bulb. *Source*: LightTracker analysis.

It is clear from the data used for the national sales model that program spending is at least partially responsible for an increased market share in efficient bulb sales. While these graphics help illustrate program activity in relation to CFL and LED sales, the regression helps show other factors that may be influencing the marketplace, as well as the associated programmatic impacts. The key findings from the national sales model are discussed next.

Multivariate Regression Model

The regression coefficients for the program intensity variables, and subsequent estimates of the NTG ratio, proved relatively stable across a number of model specifications. The Evaluation Team explored both forward and backward stepwise regression procedures to allow different combinations of independent variables to enter and exit the model. Table 2 displays the relevant statistics and outcomes from the best fit model specification. The table shows the regression coefficient and its associated p-value for each independent variable included in the model (non-POS square foot per household, political index, median income, percentage owner occupied homes, and an interaction term between political index and median income). The p-values are all below 0.1, meaning all the coefficients are significant at the 90% confidence level.

Table 2. Model Summary Statistics (n=39 States)

Independent Variables	Model Coefficient	P-value of Coefficient
Intercept	(2.814)	0.015
Program Spending per Household	0.024	0.001
Percentage Square Feel Non-POS	0.057	
Political Index	0.032	0.010
Median Income	0.0000494	0.020
Political Index * Median Income	(0.0000005)	0.011
Model R-Squared		0.64

Source: LightTracker Analysis

An example of the NTG calculations for Wisconsin are shown in Table 3. The Evaluation Team determined NTG using a "modeled:modeled" calculation as opposed to a "modeled:actual" calculation. This means the Team compared the counterfactual scenario (which can only be modeled) to a modeled energy efficient market share rather than the actual energy efficient market share. As shown in the table, the estimated 2015 NTG modeled ratio for CFLs and LEDs combined is 72%.

Table 3. NTG Calculations

Calculation Term	Value
Total Bulbs in 2015	32,830,300
Program $ per Household Actual	$4.80
Program $ per Household with Manufacturer Incentives	$5.29
Program $ per Household Counterfactual	$0.00
Energy Efficient Market Share Counterfactual	38.0%
Energy Efficient Market Share Modeled	50.6%
Energy Efficient Market Share Actual	53.6%
Efficient Bulbs Counterfactual	12,488,631
Efficient Bulbs Modeled	16,604,330
Efficient Bulbs Actual	17,602,011
Program Bulbs Sold in 2015	5,737,096
Net Bulbs Modeled	4,115,700
NTG Ration Modeled	72%

Source: LightTracker analysis.

The Evaluation Team also developed separate models for CFLs and LEDs, but robustness of the models suffered because only 19 states had sufficiently granular data to estimate a lamp-specific model. This lack of data was largely due to LEDs still gaining market share in 2015, and it was challenging to gain technology specific program spending for a number of states. As LED market share increases in 2016 and 2017, and more states emphasize LEDs and phase out program CFL support, the findings from LED-only models will be more robust.

Although the Evaluation Team ultimately elected to employ a linear (OLS) regression to estimate the regression model and calculate NTG ratios, alternative specifications can provide some useful information for program planning purposes. A theoretical issue with a linear fit is that it produces impossible estimates at out-of-sample program spending levels (e.g., at program spending above $30 per household, the estimated energy efficient market share is greater than 100%). A non-linear beta regression model imposes a ceiling of 100% market share. Figure 7 shows the same beta regression model output as Figure 5, but across a larger range of program spending. This model estimates a gradual diminishing return on program investment that begins around $7 per household and accelerates at about $9 per household. As program expenditures increase to extremely high levels, the expected increase in energy efficient market share per dollar spent per household drops sharply. This is largely because the estimated market share is approaching 100%.

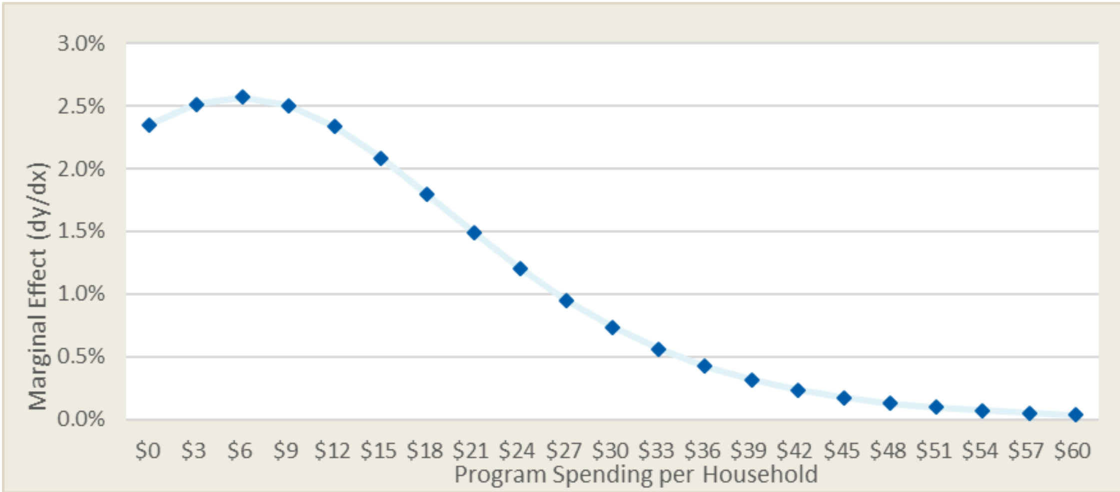

Figure 7. Marginal Effect Plot Showing Extending Spending Range. *Source*: LightTracker analysis.