Appendix C:

LED Lighting Pricing Trial Results

10/22/2018

LED Lighting Pricing Trial Results

Prepared for Efficiency Maine Trust

By Demand Side Analytics, LLC

and NMR Group, Inc.

May 2017

1 EXECUTIVE SUMMARY

In 2016, Efficiency Maine chose to design and implement an LED lighting pricing trial to understand the response of the retail lighting market to changes in price caused by efficiency program discounts. The trial included every Maine location of two retail partners and multiple types of LED lighting products. Understanding the price elasticity of demand for lighting is important for program planning because it is the underlying principle upon which Efficiency Maine's Retail Lighting initiative operates. By working with participating retailers and manufacturers to buy-down the upfront cost of efficient lighting products, the initiative increases the adoption of high-efficiency lighting products in Maine. LED lighting products use a fraction of the electricity of standard incandescent or halogen bulbs, so increasing their adoption leads to significant cost-effective energy savings.

A fundamental program design and policy question for Efficiency Maine's lighting programs is to what extent Maine shoppers would purchase LED lighting products without program discounts. The percentage of program subsidized LED sales that would have happened anyway is referred to as the freeridership rate. This portion of sales is subtracted from the total number of program incented bulbs to calculate the net impact of the program, or "lift". Because LEDs are an elastic product, when the customer-facing pricing goes down, demand increases. The more aggressive program discounts are, the greater the sales lift and the lower the freeridership rate is. Conversely, low incentive levels lead to high freeridership because the program produces a limited amount of "lift" compared to the natural sales volume.

The research team estimated a price elasticity of demand coefficient of -1.54 for the four standard LEDs analyzed. This means a 1% decrease in price will produce a 1.54% increase in sales volume. Table 1 shows how this result can be used to inform savings targets and expected levels of freeridership. The current cost assumptions in Efficiency Maine's Residential Technical Reference Manual[1] (TRM) are $3.09 for a standard LED bulb and $1.34 for a comparable halogen bulb. The difference between these two values is the incremental cost of $1.75. The rows of Table 1 show what the customer-facing price, expected sales volume per retail partner, and freeridership rate are at different discount levels. Discount levels are expressed as a percentage of incremental cost and range from 0% (no discount) to 125%. When the discount is greater than 100% of incremental cost, the LED is the cheaper first-cost option for the consumer. As the discount amount increases, the predicted weekly sales volume increases sharply and the freeridership drops.

[1] http://www.efficiencymaine.com/docs/EMT-TRM_Retail_Residential_v2017_4.pdf

Table1: Modeled Program Metrics Standard LEDs

Assumed Halogen Cost	MSRP Standard LED	Incremental Cost	Discount(% Incremental)	Customer Facing Price	Predicted Weekly Volume (per Retailer)	Free Ridership
$1.34	$3.09	$1.75	0%	$3.09	272	100%
$1.34	$3.09	$1.75	50%	$2.22	455	60%
$1.34	$3.09	$1.75	78%	$1.73	669	41%
$1.34	$3.09	$1.75	90%	$1.52	818	33%
$1.34	$3.09	$1.75	100%	$1.34	989	28%
$1.34	$3.09	$1.75	110%	$1.17	1,227	22%
$1.34	$3.09	$1.75	125%	$0.90	1,821	15%

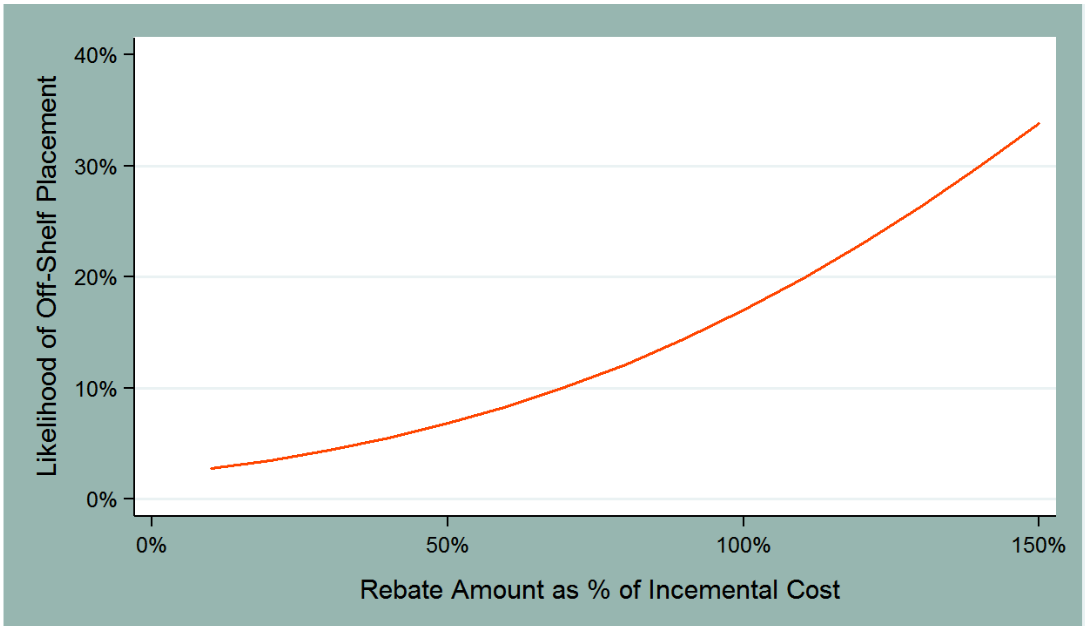
The LED pricing trial also included two specialty LEDs – both bulbous reflector lamps that would typically be installed in recessed can or track lighting fixtures. The price elasticity of demand coefficient for these products was lower at -0.76. Reflectors are more expensive products with average TRM cost values of $6.40 for LEDs and $3.89 for halogens. The combination of a lower elasticity coefficient and a smaller difference between baseline and efficient led to a diminished sales response through the discount levels and higher modeled freeridership rates.

Table2: Modeled Program Metrics–Reflector LEDs

Assumed Halogen Cost	MSRP Standard LED	Incremental Cost	Discount(% Incremental)	Customer Facing Price	Predicted Weekly Volume (per Retailer)	Free Ridership
$3.89	$6.40	$2.51	0%	$6.40	37.0	100%
$3.89	$6.40	$2.51	50%	$5.15	43.6	85%
$3.89	$6.40	$2.51	78%	$4.44	48.8	76%
$3.89	$6.40	$2.51	90%	$4.14	51.4	72%
$3.89	$6.40	$2.51	100%	$3.89	53.9	69%
$3.89	$6.40	$2.51	110%	$3.64	56.7	65%
$3.89	$6.40	$2.51	125%	$3.26	61.7	60%

The LED pricing trial also examined the interaction between discount amount and product placement within participating retailers. Off-shelf placement in store areas with higher visibility or more foot traffic is desirable and leads to higher sales volume. The program delivery team collected detailed records of product placement during weekly store visits. The research team analyzed the relationship between discount level and the frequency of off-shelf placement and found that the probability of favorable placement increases as program discount levels increase. Figure 1 shows the modeled relationship between discount level and the likelihood of favorable product placement for the two standard long-life LEDs in the trial. The price elasticity analysis also suggests a potential interactive effect, where the combination of off-shelf placement and aggressive discounts produce higher sales volume than the discount alone.

Figure1: Standard LED Likelihood Model



The following list summarizes some key takeaways from the study.

¶ There is a clear relationship between incentive levels and customer demand for LEDs. Sales volume increased for all products as the incentive level increased and the customer-facing price dropped.

¶ Increased incentive levels lead to lower levels of freeridership.

¶ The likelihood of favorable product placement increased with program incentive levels and securing "off-shelf" placement has a positive impact on sales.

¶ Lower freeridership improves the cost-effectiveness of the Retail Lighting initiative according to the TRC test because a reduced share of program funds is used to provide discounts to shoppers who would have purchased LED bulbs anyway.

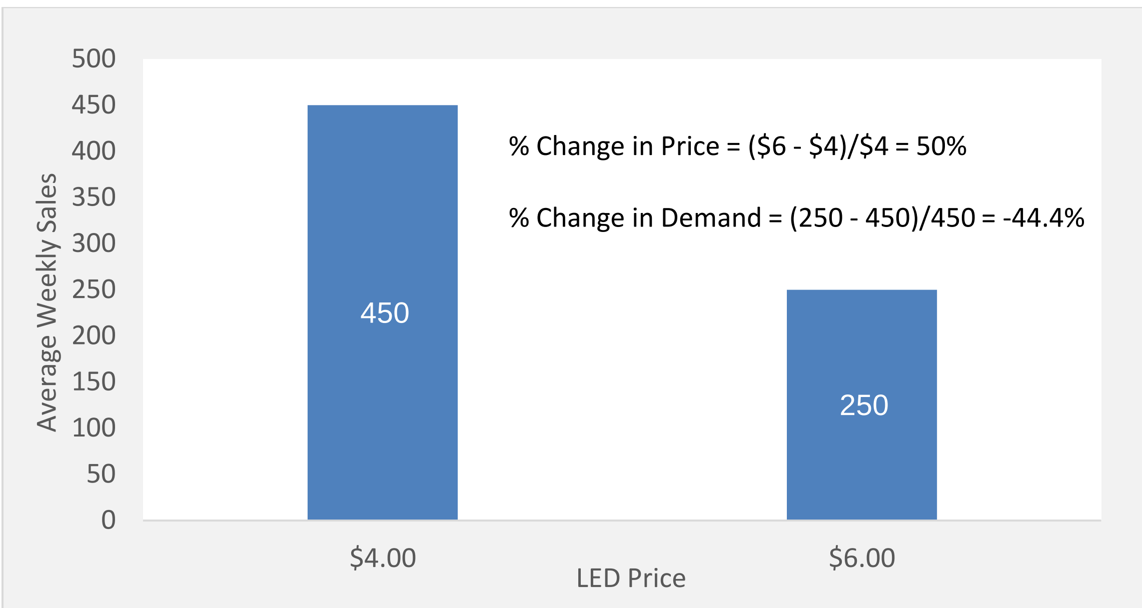
2 INTRODUCTION

Given the rapidly changing residential lighting market, the limitations of prior analyses, and the importance of retail lighting in Efficiency Maine's 2017-2019 Triennial Plan, Efficiency Maine decided to conduct a dedicated pricing trial to understand price elasticity of demand for LED lighting in Maine. The goal of the study was to provide robust primary data on the price response of LEDs in the retail lighting market that could be used to sharpen program design and implementation by Efficiency Maine.

2.1 PRICE ELASTICITY OF DEMAND ANALYSIS

An elastic product is defined as a good or service for which the quantity demanded is responsive to changes in its price. The Retail Lighting Initiative within Efficiency Maine's Consumer Products program leverages the price elasticity of demand for efficient lighting and discounts the cost of qualifying LED lamps at participating retailers across the state. The result of these discounts is increased sales of high-efficiency LED lighting compared to the levels that would be observed absent program discounts. Figure 2 illustrates the relationship between price and sales for a hypothetical LED product.

Figure2: Price Elasticity Example



In this example, the price elasticity of demand is calculated as:

Ὀ ὰ ῷ ί ὸ ῞Ω ῷ ῞Ω ὰ ώ = Þ ὄ῞Ω ῷ ὲ ῞ΩΩΏ Ὼ ά ῷ ὲ Ὶ τ ἇ Þ / Þ ὄ῞Ω ῷ ὲ ῞ΩΩὓ ὶ ῞Ω ῷ Ὶ υ π Þ πᾤ ω

Absent discounts from Efficiency Maine, some purchasers would still purchase high-efficiency LED lighting products. Estimating what the sales volume for efficient lighting would be absent program discounts has always been challenging for program administrators because retailers are only obligated to share sales data for products the program is subsidizing. However, when price variation exists in program records –

either through changes in discounts, or Manufacturer Suggested Retail (MSRP) – it is possible to estimate what sales volume would be absent any program discounts. Consider the hypothetical product in Figure 2 that was offered – after program discounts – at a customer-facing price of $4.00 per package and $6.00 per package at different periods. If the MSRP of the product is $8.00 per package, what average weekly sales volume would we expect given the observed relationship between price and sales? The elasticity of demand formula can be rearranged to estimate the percentage change in demand, which can then be used to estimate sales volume. This process is illustrated below:

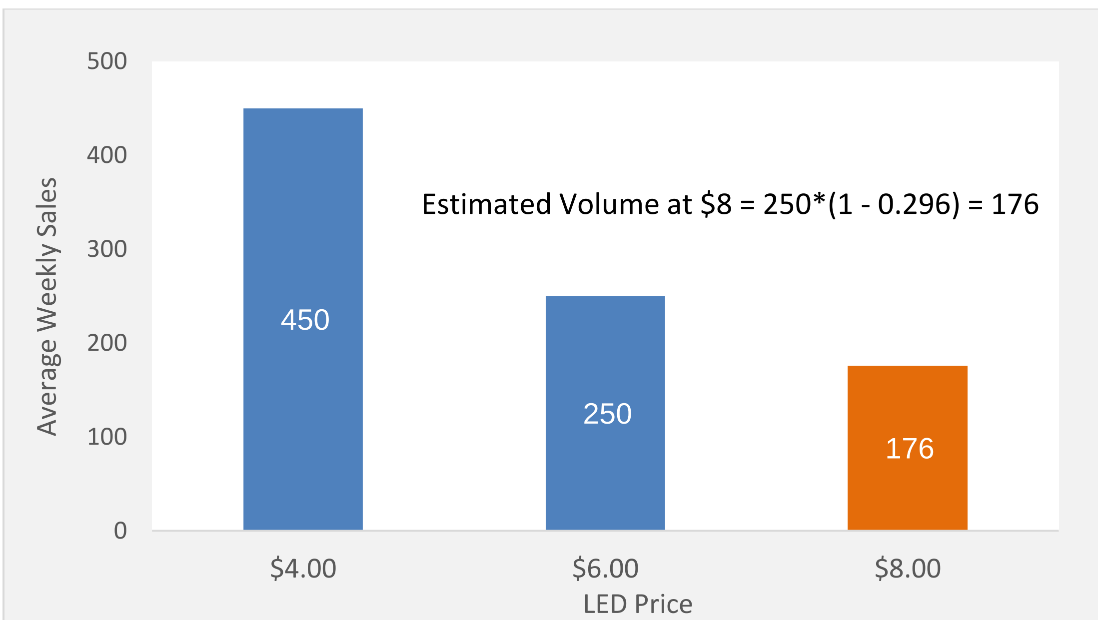
Þ ὅΏΏ ὲ ῎ΏΏΏ Ὼ ά ῴ ὲ Ὼ ὰ ῴ ί ὸ ᶻΦ ῴ ὅΏ ὼ ὲ ῴ ΏΏ ὶ Ώ ῷ Ώ

Þ ὅΏΏ ὲ ῎ΏΏΏ Ὼ ά ῴ ὲ Ὼ π ȿψ ω ᶻ (Α ψ Α φ) / (Α φ)

Þ ὅΏΏ ὲ ῎ΏΏΏ Ὼ ά ῴ ὲ Ὼ ς ȿφ Þ

Figure 3 shows the estimated weekly sales volume if the LED is at $8.00 per package. This average weekly sales volume absent program discounts represents freeridership – or efficient sales that would have happened absent program activity. The net impact of the program, or "lift" is the difference between the observed sales volume at program discount levels and the estimated sales absent the program.

Figure3: Estimated Sales Volume Absent Program Discounts



When program discounts are $2.00 per package (customer-facing price = $6.00), the freeridership rate is 176/250 = 70%. However, when program discounts are $4.00 per package (customer-facing price = $4.00), the freeridership rate is only 176/450 = 39%. This illustrates a key point about program incentive levels. Low incentive levels lead to high freeridership because the program produces a limited amount of "lift" compared to the natural sales volume.

Understanding the elasticity of demand for LEDs provides valuable program design intelligence and helps programs balance program goals or objectives, savings targets, and freeridership. Setting discount levels in a way that aligns objectives is critical and this requires understanding the responsiveness of the market to price. The relationship between price and demand follows a non-linear trend, so it's important to gather data at a variety of pricing levels in order to develop a robust mathematical relationship between the two.

2.2 PRIOR EFFICIENCY MAINE PRICE ELASTICITY RESEARCH

Efficiency Maine studied the price elasticity of demand of LEDs in the 2014-2015 Retail Lighting evaluation and found a large elasticity for LEDs (-1.55). However, the previous study has several limitations.

- In Fiscal Years (FY) 2013 and 2014, the Retail Lighting program was still dominated by CFLs. Therefore, LEDs were only a small subset of the available sales data.
- LED prices (non-discounted) have dropped significantly since FY2014.
- Incentive levels were high requiring extensive extrapolation to non-discounted price.

The price elasticity of demand can be analyzed on a customer-facing price basis like the example above, or on an incremental cost basis. The incremental cost of an LED is defined as the difference between the efficient LED and a comparable halogen or incandescent bulb. If an LED lamp retails for $4.00 per bulb and a comparable halogen bulb retails for $1.34, the incremental cost (based on first cost only, not lifecycle cost) of the LED is $2.66. Discount levels in the Retail Lighting program are currently based on percentage of incremental cost. Prior to FY2017, the Retail Lighting program typically set incentives equal to or greater than 100% of incremental cost, making the program discounted efficient bulb the least expensive option on the shelf for shoppers. At the beginning of FY2017, discounts were set below 100% of incremental costs for the new Triennial Plan.

2.3 REPORT ORGANIZATION

This report presents the results of the price elasticity analysis conducted during FY2017. The report is organized in the following sections

- Section 3 of the report presents the design and implementation of the study
- Section 4 discusses the modeling approaches used to analyze the collected sales data
- Section 5 explores several ways the findings from this study might be used in program delivery

3 STUDY DESIGN

In July 2016, Efficiency Maine engaged Demand Side Analytics and NMR ("the research team") to design and analyze an LED pricing trial that would provide current and robust price elasticity of demand estimates. The study design phase of the project was an iterative process that required close collaboration between the research team and the program delivery team (Efficiency Maine and CLEAResult), and ultimately the participating retailers and manufacturers as well. The result was a pricing trial that was rigorous from an experimental design standpoint, but also manageable from an implementation perspective and revenue-positive[2] for retailers and manufacturers. The six central elements of the study design are discussed in detail in the following sections.

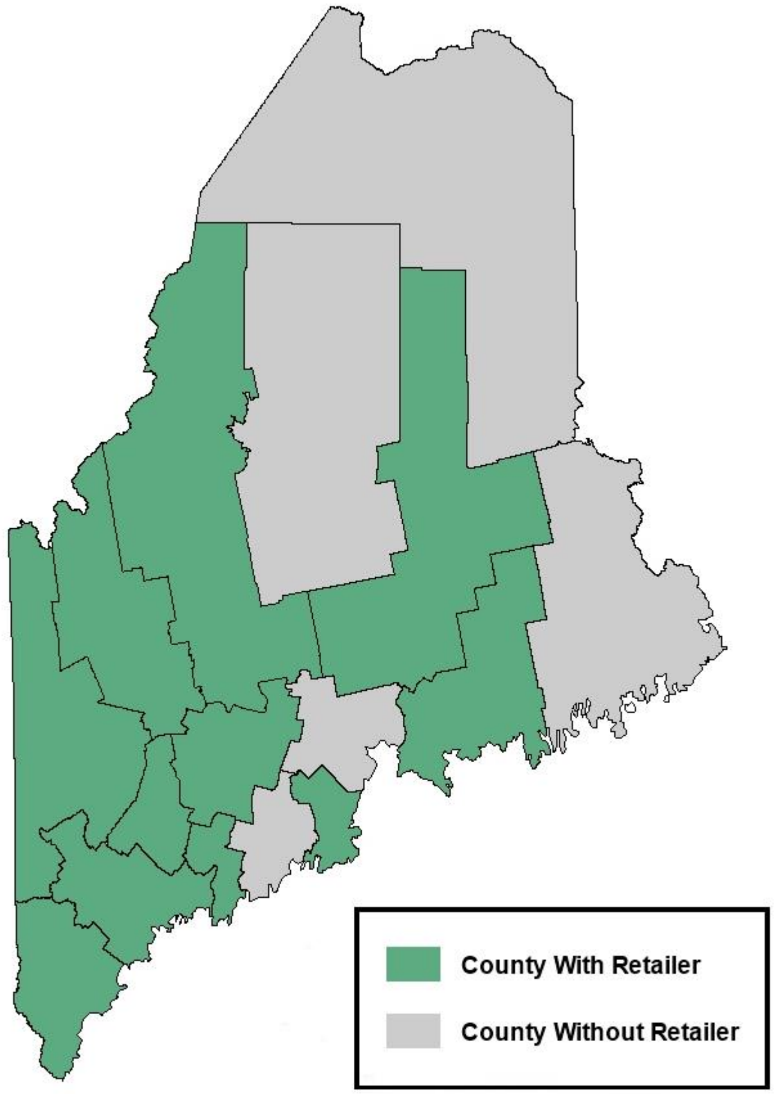
3.1 RETAILER SELECTION

The Retail Lighting initiative partners with several dozen retailers across Maine to offer point-of-sale discounts on efficient lighting products to consumers. The financial agreement between the program delivery team and each of these retailers to reimburse the program discounts is called a "memorandum of understanding" or MOU. The pricing levels of the study had to be negotiated and contracted separately with each participating retailer. It was clear early in the study design phase of the project that the number of retailers selected for the pricing trial would need to be limited, or else the administrative requirements on the program delivery team would be insurmountable.

Although the Retail Lighting initiative has dozens of retail partners, a small sub-set account for most of the sales volume and energy savings. MOUs for the study were negotiated at the retailer level, so by targeting two major partners, the study included multiple storefronts with locations throughout the state as shown in Figure 4. Including retailers with a presence across the state helps to control for potential regional differences in purchasing behavior.

[2] Revenue-positive refers to the impact on a retailer's bottom line associated with participating in the trial. While it is impossible to know with certainty, it is believed that participating in the trial for certain products led to retailers selling more LED bulbs and realizing more revenue than they would have operating at the standard program incentive levels for the same period.

Figure4: Participating Retailer Map



Since these two retailers represent such a large share of program activity (4 of every 5 bulbs sold), the research team believes it is reasonable to base program design decisions on the observed price response in these channels. While price elasticity may be different in other stores, these retail channels make up a limited portion of program expenditures and impacts.

3.2 PRICE PERSPECTIVE

To design and implement this type of study, the varying pricing levels of the trial need to be established in advance and communicated clearly to retail partners and manufacturers. The research team chose to set discount levels as a function of the MSRP. Setting pricing levels based on MSRP is simpler than using the incremental cost, which requires a second value (assumed cost of a baseline bulb) in the calculation. This decision was made in part because baseline costs are revisited quarterly by the implementation team. When the assumed baseline costs changed mid-study, the MOUs did not need to be revisited with study partners.

3.3 DISCOUNT LEVELS

A key weakness of most lighting price elasticity of demand studies to date has been limited price variation, and an inability to gather sales at prices that are at or close to the MSRP. Retail partners are not obligated to share sales data unless the program administrator is providing a discount, so estimates of what sales volume would be absent program discounts are needed. Often the observed price variation is across two or three price levels that are all very distant from MSRP, so models are required to estimate sales volume at a price that is well out-of-sample (e.g., extrapolation). The research team knew at the outset of the study that gathering data at low discount levels (closer to MSRP) would be one of the biggest challenges of the study. Low program discounts are unattractive to retailers because they impose the administrative requirements of the program without a significant increase in sales volume and revenue. In discussions with the program delivery team it was determined that a 15% discount was likely the minimum discount level needed to secure retailer participation.

Another key study element to securing buy-in from retailers was symmetric pricing levels. For certain phases of the study, the discounts would be greater than the program would otherwise offer and for other phases the discounts would be lower. The additional sales revenue during the aggressive discounting phases was anticipated to offset the reduced revenue at discount levels lower than normal program operations. During the study design phase, the Retail Lighting initiative was operating using a 78% of incremental cost discount formula. A standard LED lamp with an MSRP of $4.00 per bulb is compared to a halogen bulb assumed to cost $1.34, so the incremental cost of the LED is $2.66. The program discount for this product would be 0.78*$2.66 = $2.07 and the customer-facing price would be $1.93.

The research team reviewed product pricing data from the Efficiency Maine Reporting and Tracking System (effRT) and found that the 78% incremental cost formula would result in discounts between 40% and 60% off MSRP on average. This 'business-as-usual' discount level was deemed the base case. Two discount levels above the base case were selected and two discount levels below the base case were selected. The final discount levels for the pricing trial are presented in Table 3.

Table3: LED Pricing Trial Discount Levels

Discount Level	Percent Discount (from MSRP)	Standard LED Percent Discount (Incremental)	Specialty LED Percent Discount (Incremental)
Lowest	15%	22%	31%
Low	35%	52%	73%
Base Case	40-60%	78-90%	78-90%
High	60%	85%	112%
Highest	80%	123%	149%

Table 3 also expresses the discounts as an average percent discount of incremental cost. Incremental cost discounts are shown separately for standard and specialty[3] bulbs. A similar percent discount of MSRP for a reflector bulb will generally result in a higher percent discount when expressed as a function of incremental cost because the ratio of efficient price to baseline price is generally lower for specialty bulbs (approximately 2:1 for specialty bulbs vs. 3:1 for standard long-life LEDs).

3.4 PRODUCT SELECTION

During early conversations with the program delivery team and retail partners, it was clear that the study would need to focus on a limited number of products to move forward. The Efficiency Maine Residential Technical Reference Manual and effRT assigns LEDs into one of two primary categories – standard and specialty. The research team reviewed program sales data and found that standard A-lamp bulbs were the highest volume product category and accounted for approximately 80% of program sales. Directional (reflector) lamps typically found in recessed can fixtures (PAR and BR)[4] are the most common products within the specialty category and represent approximately 10% of total program sales. The research team worked with the implementation team to select one of each product type for inclusion in the pricing trial. The attributes of the products in the study are detailed in Table 4. All four products in the trial were ENERGY STAR certified.

Table4: LED Pricing Trial Product List

Category	Standard	Standard	Specialty	Specialty
Lifetime	Long	Long	Long	Long
Style	A19	A19	BR30	BR30
Pack Size	4-pack	4-pack	2-pack	2-pack
Wattage	9.5	10	13.5	10
Wattage Equivalent	60	60	75	65
MSRP (per-bulb)	$4.99	$3.66	$7.49	$9.92*
Retailer	Retailer B	Retailer A	Retailer B	Retailer A
*** Product MSRP changed from $9.92 per bulb to $8.42 per bulb in February 2017**				

Efficiency Maine further classifies program-supported LED products according to rated lifetime. Lamps with a rated lifetime of greater than or equal to 20,000 hours are considered 'Long Life'. Lamps with a rated lifetime of less than 20,000 hours are considered 'Short Life'. The four products shown in Table 4 are all considered long-life products.

Standard Short Life LEDs were not included in the trial, but the program delivery team believes this product sub-category is likely to account for a significant share of program volume moving forward. Although not included in the designed pricing trial, the research team felt it was important for this category of lamps be included in the analysis – if possible. Through a review of program tracking records

[3] The specialty bulb tested in the pricing trial was a reflector bulb.
[4] PAR = Parabolic Aluminized Reflectors. BR = Bulbous Reflectors.

in effRT, the research team identified two Standard Short Life LEDs that were offered at very different customer facing prices in FY2016 and F20Y17. Changes to the product MSRP and baseline cost assumptions led to two additional customer-facing prices in 2017. Table 5 provides relevant attributes for the two products, which are identical other than the color spectrum of the light.

Table5: Standard Short Life Lamps Selected for Analysis

Category	Standard	Standard
Lifetime	Short	Short
Style	A19 – Soft White	A19 – Daylight
Pack Size	8-pack	8-pack
Wattage	9	9
Wattage Equivalent	60	60
MSRP (per-bulb)	$2.25	$2.25*
Retailer	Retailer C	Retailer C
* Product MSRP increased to $2.50 in September 2016 around the time it became ENERGY STAR certified		

3.5 PRODUCT PLACEMENT

Price is not the only determining factor of sales volume. Placement within the store can also have a significant impact on purchase behavior. When product is displayed "off-shelf" in an area of the store more visible to shoppers, there is typically a positive effect on sales. As a result, off-shelf placement is highly coveted by manufacturers of all types of products, and retailers typically reserve the favorable spots for products they believe will move a lot of volume and increase revenue. It is important to recognize that a program administrator cannot easily contract for favorable placement for discounted bulbs.

Most lighting price elasticity of demand studies completed to date have considered product placement as an independent variable in the model. Sales periods where program product is given off-shelf displays are coded with an indicator variable and the model then estimates the increase is sales volume attributable to favorable product placement. The problem with this approach is that off-shelf placement is highly correlated with aggressive discounting. In discussions with the program delivery team, it was clear that securing off-shelf placement at low incentive levels would be extremely unlikely. At aggressive discount levels, the off-shelf placement would happen naturally because retailers recognize the product is priced attractively and the combination of low price and visible product placement would lead to increased revenue. Instead of including location as a predictor of sales volume, the research team decided to view product placement as a *dependent variable* in an alternate set of models. These models look at the likelihood of receiving favorable placement within the store as a function of incentive level. Since off-shelf placement is essentially free promotion for program products, the research question becomes "at what incentive level does the program begin to secure favorable product placement and the associated lift in sales volume?"

To support this analysis, the implementation team gathered detailed information on the location of the study products during their routine store visits. In addition to which stores had inventory in stock, the implementation team tracked product placement in the five fields defined below.

1. Percent of Stores on Shelf: On-shelf placement means the product was on display in the lighting aisle of the store. This is not considered favorable placement.
2. Percent of Stores on Fenceline: The “Fenceline” in a retail store is the corridor between the entrance and the sales floor. This is highly favorable product placement as the product is visible to all shoppers.
3. Percent of Stores on End Cap: An end-cap is a type of favorable placement located at the end of an aisle as shown in the figure to the right. An end-cap exposes the product to a greater number of shoppers because the product faces the major arteries of the store, rather than the aisle. The end cap could be located at the end of the lighting aisle or an unrelated product aisle. An end cap near the front of the store is more desirable than an end cap near the rear of the store.

4. Percent of Stores with Wingstack: A ‘wingstack’ is a free-standing product display that can be set up in high-traffic aisles of a store – see the figure to the left. The product is more visible to shoppers and affords the retailer additional space to store product compared to on-shelf displays. The added space to store inventory on the sales floor is advantageous when sales volume is high because it reduces the amount of time the product is not visible to shoppers (e.g., in a stock room, but not on the sales floor).

5. Percent of Stores with Pallet-Display: A pallet display is like a wingstack in that it is a temporary feature capable of housing large quantities of product on the sales floor. Pallet displays are often sited towards the front of a store near the checkout lines, so most shoppers will see them during their visit.

3.6 SCHEDULE

Lighting products, like many products, compete for retailer attention and display space depending on the season as retailers seek to maximize revenues. The research team felt it was important to control for the potential impact of seasonality as much as possible by cycling through the study discount levels in a different order at the two retailers.

Table6: Proposed Discount Level Schedule

Month	Standard LED		Specialty LED	
	Retailer A	Retailer B	Retailer A	Retailer B
September 2016	Lowest			
October 2016	Low	Highest		
November 2016	Low	High		
December 2016	High	High	Highest	Lowest
January 2017	Highest	Low	High	Low
February 2017		Lowest	Low	High
March 2017			Lowest	Highest

The proposed schedule was ultimately adjusted based on product availability and other retailer commitments related to the holiday season. Table 7 shows the pricing schedule by retailer and product as implemented. All dates shown represent the ending date of a given sales week. The trial was cut short before reaching the final pricing level of one of the reflector LEDs because the manufacturer discontinued the product. The Retailer A reflector also changed MSRP in February which led to a departure from the planned discount levels of 80%, 60%, 35% and 15%.

Table7: Pricing Schedule as Implemented

Retailer	Product	Rebate as % of MSRP	First Week	Last Week
Retailer B	Reflector	15%	3-Dec-16	24-Dec-16
Retailer B	Reflector	35%	31-Dec-16	28-Jan-17
Retailer B	Reflector	60%	4-Feb-17	25-Feb-17
Retailer B	Reflector	80%	4-Mar-17	25-Mar-17
Retailer B	Standard	80%	8-Oct-16	29-Oct-16
Retailer B	Standard	60%	5-Nov-16	7-Jan-17
Retailer B	Standard	35%	14-Jan-17	4-Feb-17
Retailer B	Standard	15%	11-Feb-17	4-Mar-17
Retailer A	Reflector	80%	3-Dec-16	28-Jan-17
Retailer A	Reflector	60%	4-Feb-17	18-Feb-17
Retailer A	Reflector	71%	25-Feb-17	25-Feb-17
Retailer A	Reflector	41%	4-Mar-17	11-Mar-17
Retailer A	Standard	15%	10-Sep-16	1-Oct-16
Retailer A	Standard	35%	8-Oct-16	26-Nov-16
Retailer A	Standard	60%	3-Dec-16	21-Jan-17
Retailer A	Standard	80%	28-Jan-17	11-Mar-17

In addition to the deliberately manipulated pricing levels, the research team leveraged weeks of sales data for the study products during the weeks prior to and after the conclusion of the pricing trial.

Table 8 provides a similar table for the two short-life LEDs included in the analysis. This pricing variation was not by design (e.g., it did not follow the discount levels presented in Table 3), but did allow the research team to estimate price elasticity of demand for this product category.

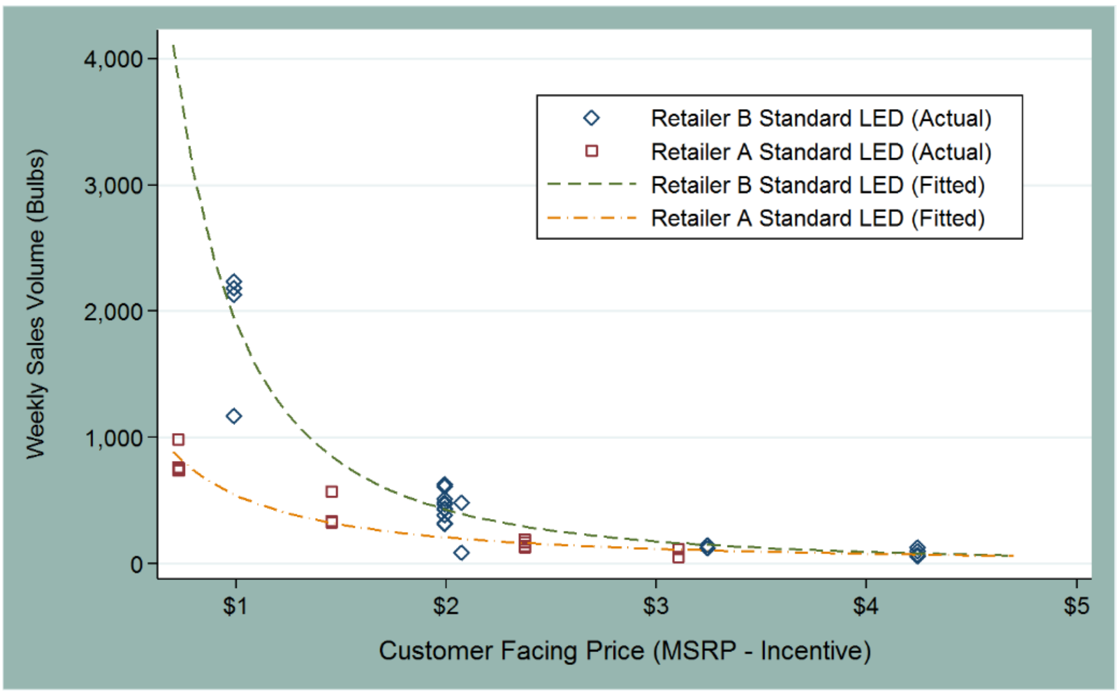
Table8: Pricing Schedule for Short-Life Standard LED Products

Product	Rebate as % of MSRP	First Week	Last Week
Short Life Standard - Daylight	67%	12-Mar-16	11-Jun-16
Short Life Standard - Daylight	39%	1-Oct-16	12-Nov-16
Short Life Standard - Daylight	36%	19-Nov-16	11-Feb-17
Short Life Standard - Daylight	42%	18-Feb-17	11-Mar-17
Short Life Standard - Soft White	67%	12-Mar-16	11-Jun-16
Short Life Standard - Soft White	35%	15-Oct-16	12-Nov-16
Short Life Standard - Soft White	31%	19-Nov-16	11-Feb-17
Short Life Standard - Soft White	36%	18-Feb-17	11-Mar-17

4 DATA AND MODELING

Sales volume of each product was captured on a weekly basis by the program delivery team and shared with the research team for analysis. Sales of trial products was stored as a bulb count (e.g., number of packages sold multiplied by package size). Weekly sales of each product were reported at the retailer level rather than by storefront. Figure 5 is a scatter plot of weekly sales volume versus customer-facing price for the two standard long-life LEDs.

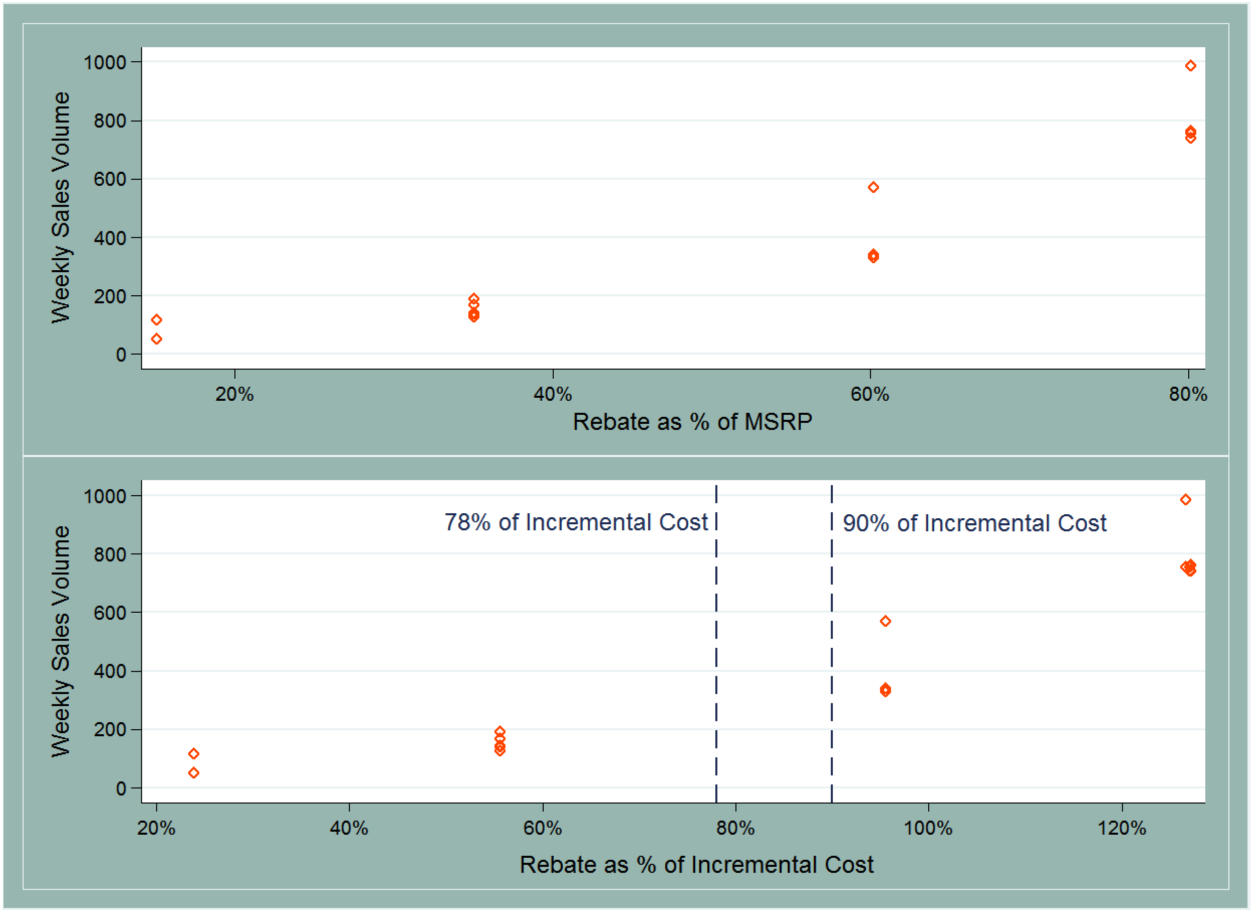
Figure5: Weekly Sales Volume vs. Price



The data in Figure 5 shows the expected relationship between price and sales volume. As the price goes down, demand for the product increases. While both products show increased sales volume as program discount levels increase, the price response is more dramatic for the standard LED at Retailer B. Figure 5 also includes trend lines fitted to each product's sales data. It is important to note the relationship between sales volume and price is non-linear. Capturing the relationship requires the data to be transformed prior to modeling. Each of the products examined exhibited a clear price response.

The sales data from the trial can also be visualized as a function of the program discount. Figure 6 shows the weekly sales volume of the Retailer A standard LED plotted against the rebate amount. The top portion of the figure expresses the discount as a percentage of MSRP and the bottom half of the figure expresses the discount as a percentage of the incremental cost. The vertical lines in the lower plot represent the two discount levels the Retail Lighting initiative utilized in FY2017. From July to February, the program offered LED discounts of 78% of incremental cost. In February 2017, Efficiency Maine increased the discount level to 90% of incremental cost.

Figure 6: Weekly Sales Volume vs. Discount Level–Retailer A Standard LED



After data visualization confirmed the assumed relationship between price and demand for each product, the research team used statistical analysis to determine a mathematical relationship between the change in price and change in sales volume. The analysis was conducted separately for each product at first. The Appendix of this report presents the technical details of the modeling effort. In Section 5, the research team proposes several ways study findings can be aggregated for use in program planning.

4.1 ELASTICITY COEFFICIENTS

Individual-product Poisson regression models produced highly significant elasticity of demand coefficients for each of the six products examined. The elasticity coefficient is the expected change in percent sales given a 1% change in customer-facing price.

Table 9 shows the elasticity coefficient of each product along with its 95% confidence interval. The sign of each coefficient is negative because the quantity demanded decreases as the price increases. The reflector bulbs showed very similar elasticity coefficients at the two participating retailers. Both long-life standard LEDs showed a strong price response, but there was a statistically significant difference between the elasticity coefficients, with the standard LED product at Retailer B showing a larger price response (E=-2.15) than the long-life standard LED at Retailer A (-1.37).

Table 9: Price Elasticity of Demand Coefficients by Product with 95% Confidence Interval

Product	Elasticity Coefficient (ΔQ / ΔP)	Upper Bound of 95% Confidence Interval	Lower Bound of 95% Confidence Interval
Retailer B Reflector LED	-0.73	-0.49	-0.98
Retailer B Standard LED	-2.15	-1.86	-2.45
Retailer A Reflector LED	-0.81	-0.46	-1.17
Retailer A Standard LED	-1.37	-1.23	-1.51
Retailer C Short Life Standard - Daylight	-0.78	-0.56	-1.01
Retailer C Short Life Standard - Soft White	-2.21	-1.92	-2.50

One of the more interesting findings of the study was the difference between the elasticity coefficients of the two short-life standard LEDs. Recall that these were both private label (store brand) LEDs offered at the same stores during the same period at almost identical prices. One potential explanation is that the difference in price response is a function of customer preference for the warmer feel of a 'soft-white' color spectrum (2700K) over a lamp that produces a cooler 'daylight' appearance at other end of the color spectrum (5000K).

The research team also estimated panel models where sales and price data for more than one product were analyzed together to produce an average elasticity coefficient across products. Table 10 provides pooled estimates for the product types considered in the study.

Table 10: Panel Model Estimates by Product Type

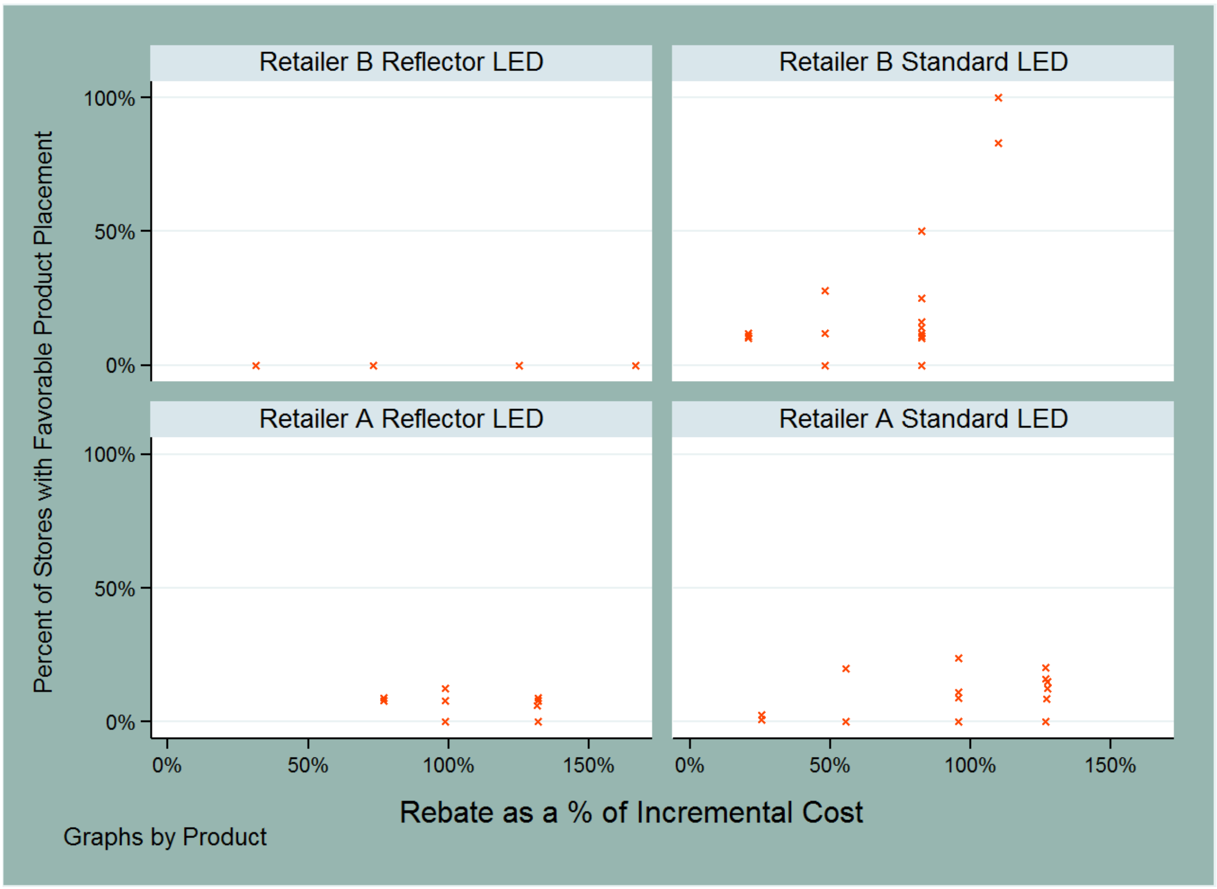
Product Type	Number of Products Analyzed	Elasticity Coefficient
Standard – Long Life	2	-1.78
Standard – Short Life	2	-1.47
Reflector	2	-0.76

Standard Long Life bulbs showed the largest elasticity coefficients and reflectors showed the smallest average coefficients. The difference in observed elasticity coefficients between standard LEDs and reflectors may have to do with the number of available sockets in homes. Reflectors provide a directional light that is typically only suitable for recessed can lighting. Standard LED bulbs are suitable for a broader number of applications within the average Maine home. These housing characteristics can affect purchase behavior. Consider a Maine shopper whose home has 40 sockets suitable for standard LED bulbs and six sockets suitable for reflectors. If that shopper sees a great deal on LED lighting, they are more likely to purchase a large quantity of the type of bulb that has more potential applications within the home.

4.2 LIKELIHOOD MODEL OF FAVORABLE STORE PLACEMENT

To model the likelihood of favorable store placement as a function of program discount levels, the research team first computed the percentage of participating retailers (with inventory) that had favorable product placement in each week using the field observations of the implementation team. This resulted in a weekly ratio between zero and one for each product. A scatter plot of the raw data is shown Figure 7.

Figure7: Percent of Stores with Off-Shelf Placement vs. Program Discount



The relationship between product placement and price varied by product and retailer. The research team noted the following observations by product:

¶ The reflector bulb at Retailer B (top left) did not receive off-shelf placement at any discount level. Perhaps not coincidentally, this was the LED product with the lowest price elasticity estimate in the trial.

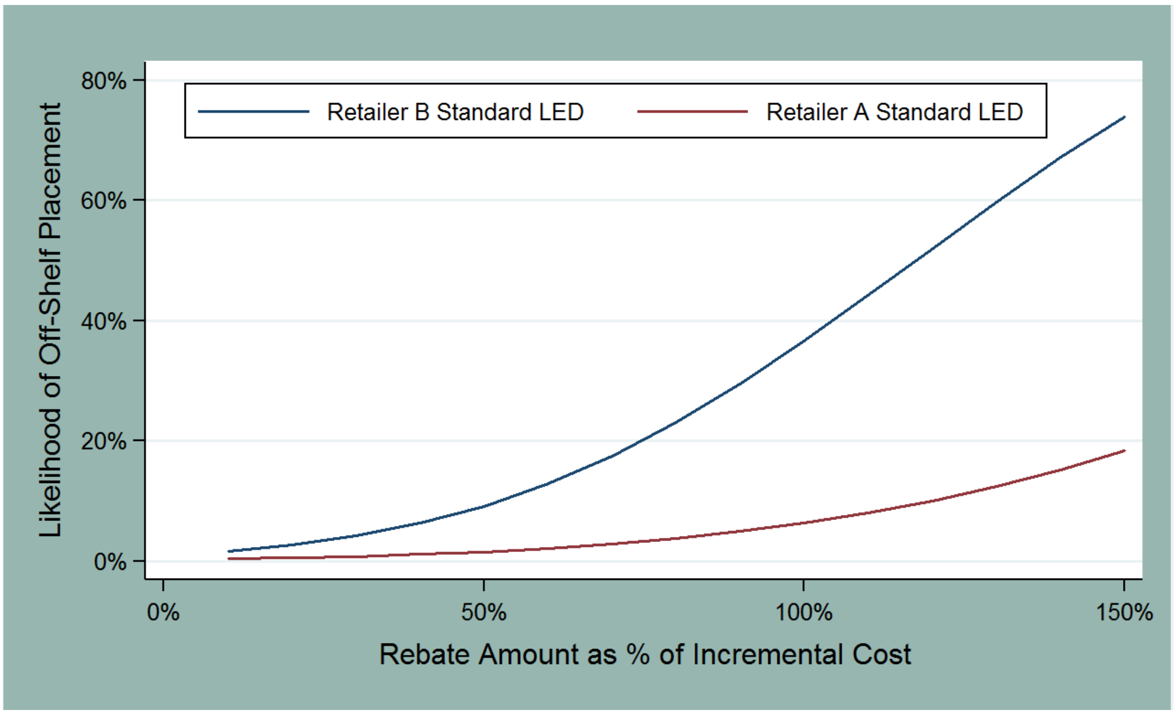
¶ A handful of Retailer A stores placed the reflector LED (bottom left) on end-cap or pallet displays after the holidays (and at the end of the 'Highest' discount level). The relationship is somewhat muddied for this product though, because of the change in MSRP and then discontinuation of the product.

¶ The standard LED at Retailer B (top right) showed the clearest response in product placement – and also the largest price elasticity coefficient. For two weeks at the 'Highest' discount level, each of the stores visited had the product on either a pallet display or wingstack. At the same time, the manufacturer of the LED also printed flyers for all participating stores highlighting the deal for shoppers.

- The standard LED at Retailer A (bottom right) saw some off-shelf placement at each discount level except for the 'Lowest' phase of the study.

The research team fit a fractional probit regression model using the observed product placement data to estimate the likelihood of off-shelf placement as a function of discount amount. Figure 8 compares the fitted values for the two standard long-life LED products.

Figure8: Standard LED Likelihood Model



Although the data are noisy, the expected relationship between program incentives and favorable product placement is present: as the rebate amount increases the probability of off-shelf placement increases.

5 PROGRAM DESIGN AND DELIVERY IMPLICATIONS

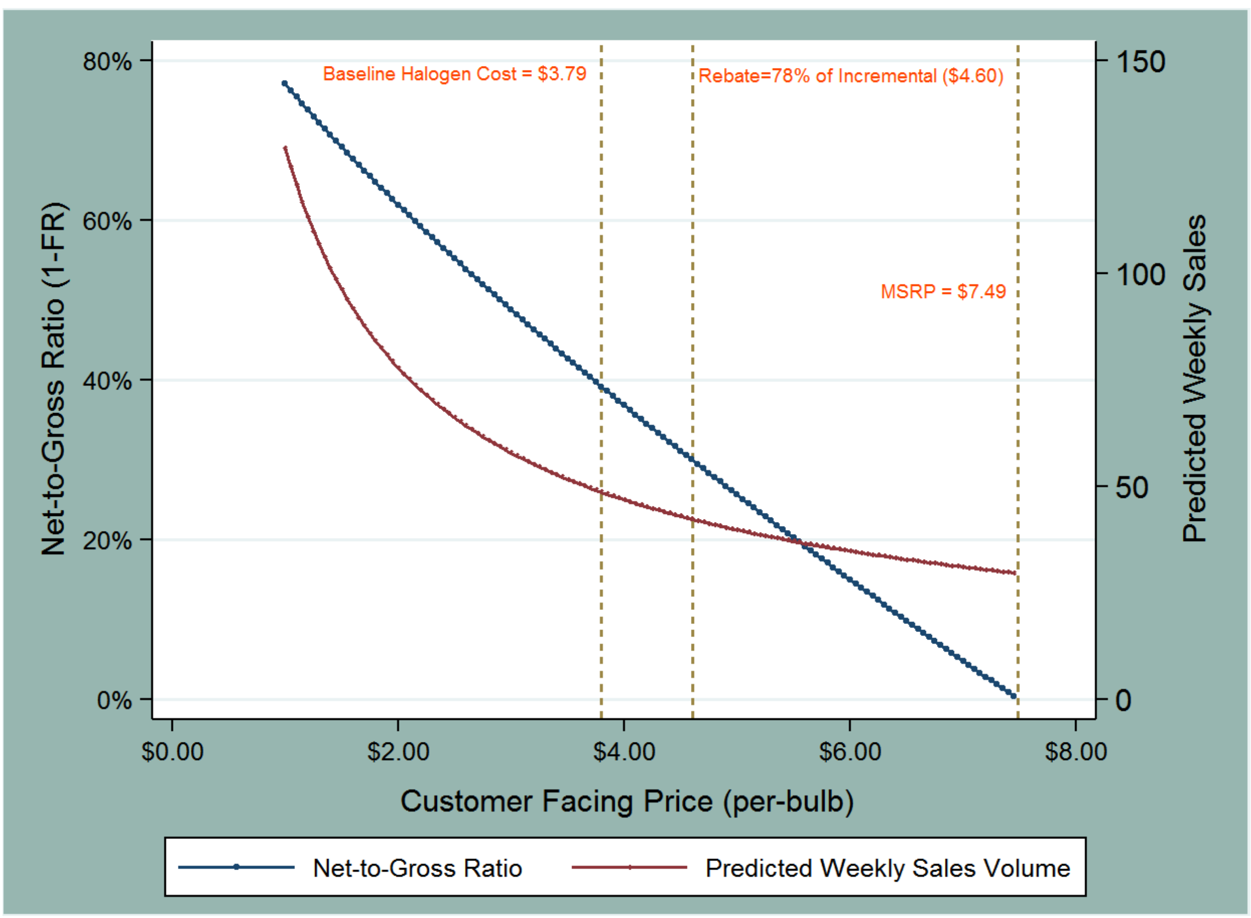
The LED price elasticity of demand estimates presented in this report can be leveraged for program planning in several different ways.

5.1 ESTIMATING FREERIDERSHIP AND NET-TO-GROSS RATIOS

The price elasticity of demand coefficients presented in Section 4 can be used to estimate sales volume at prices that were not observed during the pricing trial. Perhaps the most meaningful of these counterfactual estimates is what the expected sales volume would be if the LEDs were offered at MSRP, which equates to an Efficiency Maine discount amount of $0. Consider the BR30 reflector LED offered at Retailer B which had an MSRP of $7.49 per bulb. Absent any program discount, the product is expected to sell approximately 30 bulbs per week.

This estimate of natural sales volume is important because it implies non-program baseline sales, and thus it can be used to estimate the program freeridership. The difference between the observed sales volume at the discounted price and this estimate of natural sales volume is an estimate of the program "lift", or net impact. If the weekly sales volume at program discounts were 40 bulbs per week, the freeridership rate would be 30/40 = 75%. If program discounts were more aggressive and the product sold 200 bulbs per week, the freeridership rate would be 30/200 = 15%. Figure 9 plots the modeled relationship for the BR30 product between customer-facing price (determined by the Efficiency Maine discount), weekly sales volume and net-to-gross ratio. In this example, the net-to-gross ratio is equal to 1 minus the freeridership rate. In practice, there could be spillover or market effects that would make the net-to-gross ratio higher than 1 - FR.

Figure 9: Estimated Sales Volume and NTGR by Customer-Facing Price—Low Elasticity



The BR30 reflector lamp at Retailer B was the least elastic product in the pricing trial, so the sales volume and estimated NTG ratio are sluggish to increase as we move right-to-left across the pricing spectrum from MSRP to $1 per bulb.

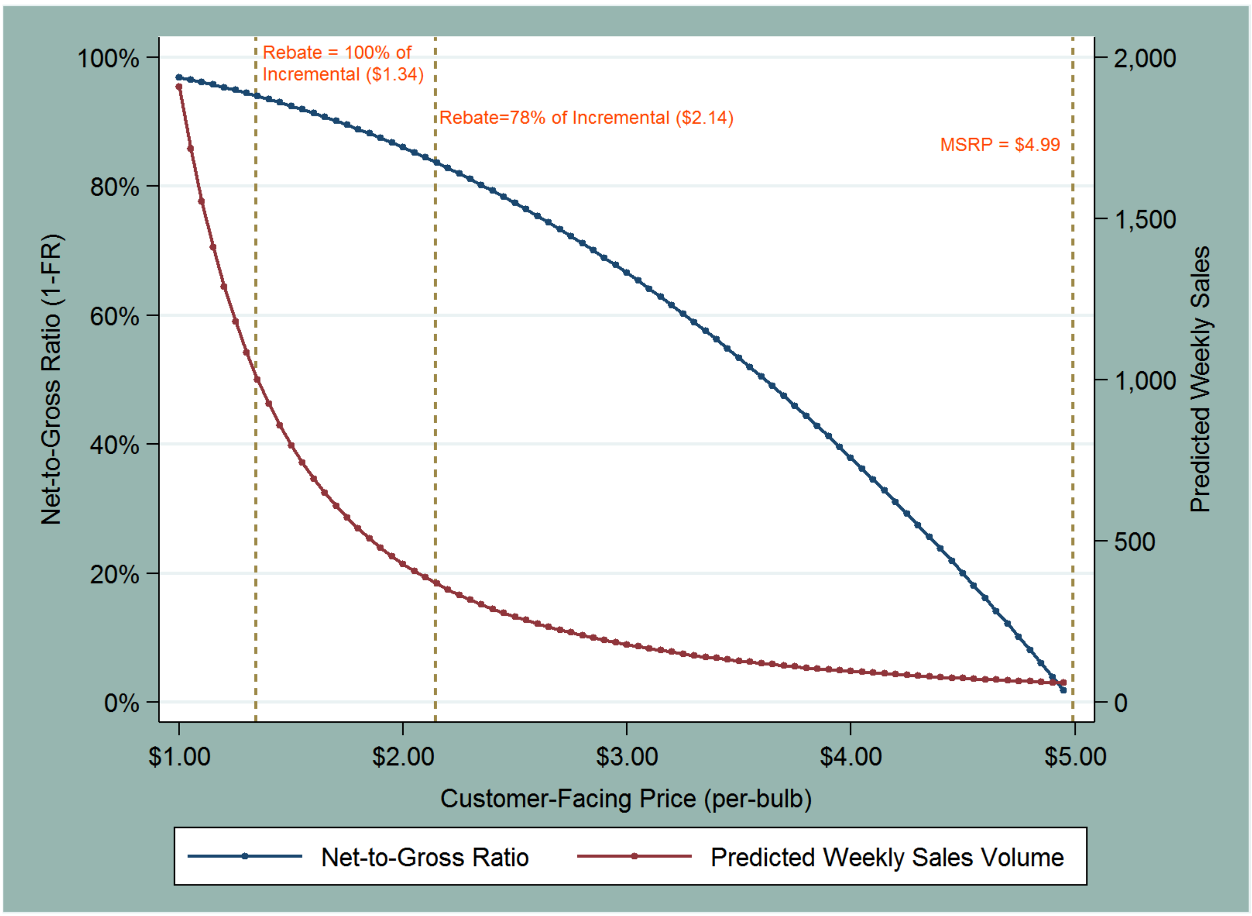
For this somewhat inelastic product:

¶ At a discount level of 78% of incremental cost, the expected freeridership rate is 70%

- At a discount level of 100% of incremental cost, the expected freeridership rate is 60%
- At a discount level of 150% of incremental cost, the expected freeridership rate is 37%

Figure 10 plots the same relationship for the standard long-life product at Retailer B, which was the most elastic product in the pricing trial. The counterfactual for this product is estimated at 60 bulbs per week. As customer-facing price drops, sales volume increases and free ridership decreases.

Figure 10: Estimated Sales Volume and NTGR by Customer-Facing Price—High Elasticity



For this extremely elastic product:

- At a discount level of 78% of incremental cost, the expected freeridership rate is 16%
- At a discount level of 100% of incremental cost, the expected freeridership rate is 6%
- At a discount level of 110% of incremental cost, the expected freeridership rate is 3%

5.2 OTHER PROGRAM DESIGN CONSIDERATIONS

The analysis of product placement as a function of program incentive levels also produced some valuable insights for program delivery. The LED that received off-shelf placement in most participating retail locations showed a much larger elasticity coefficient (E = -2.15) than the standard long-life LED that only received favorable placement in a handful of storefronts (E = -1.37). Of course, these are different products at different retailers, so there are several alternate explanations for the observed difference in price response, but it seems likely that the off-shelf displays and in-store promotions were a contributing factor to the high elasticity of the standard long-life LED at Retailer B. If the program planners can afford the implementation team flexibility on discount levels when negotiating MOUs with retailers and manufacturers, it could help secure off-shelf placement for program LEDs.

Given the focus on customer incentives in this report, it is worth specifically addressing how incentives are treated in the cost-effectiveness tests considered by Efficiency Maine. On a gross savings basis:

- **Total Resource Cost (TRC) Test**: In the TRC test, participant incentives are included in the incremental cost. This means that unless the incentive exceeds the incremental cost it has no bearing on the cost-effectiveness ratio of the measure. Stated another way, an LED with an incremental cost of $5 offered with a $1 incentive is no more or less cost-effective than that LED offered with a $5 incentive. The TRC test simply compares the avoided costs of the energy savings and reduced operation and maintenance costs to the incremental cost of the measure.
- **Program Administrator Cost (PAC) Test**: The PAC test examines cost-effectiveness from the perspective of the program administrator. From this perspective, the incentive is a cost. The incremental cost of the equipment borne by the participant is not included in the PAC test. The higher the incentive amount, the lower the PAC ratio for the measure will be.

The calculation of cost-effectiveness becomes more complex on a net basis due to the accounting for freeridership. Net cost-effectiveness is based on the difference between what occurred with the program and what would have occurred anyway without the program. The energy savings from free riders are not included in the calculation of avoided costs for the benefit component of the ratio. There is also no assumed participant cost for free riders because they would have incurred the incremental cost of the efficient purchase anyway. The treatment of incentives paid to free riders is a topic of discussion in the industry. The initial 2002 California Standard Practice Manual for Economic Analysis of Demand-Side Programs and Projects was ambiguous on the treatment of incentives paid to free riders. The inclusion of costs for incentives to free riders in the calculation of a TRC test was later addressed by the California Public Utilities Commission in a 2007 Clarification Memo. The 2007 Clarification Memo posited that incentives paid to free riders should be treated as cost in a TRC test to avoid creation of a free rider cost advantage to rebate programs relative to direct install programs. This is how Efficiency Maine has computed cost-effectiveness in program evaluations and Triennial Plan filings historically. The recently released National Standard Practice Manual[5] excludes incentives paid to free riders from cost effectiveness screening that includes participant impacts: "the net cost of free riders is zero under any test that includes participant impacts[6]."

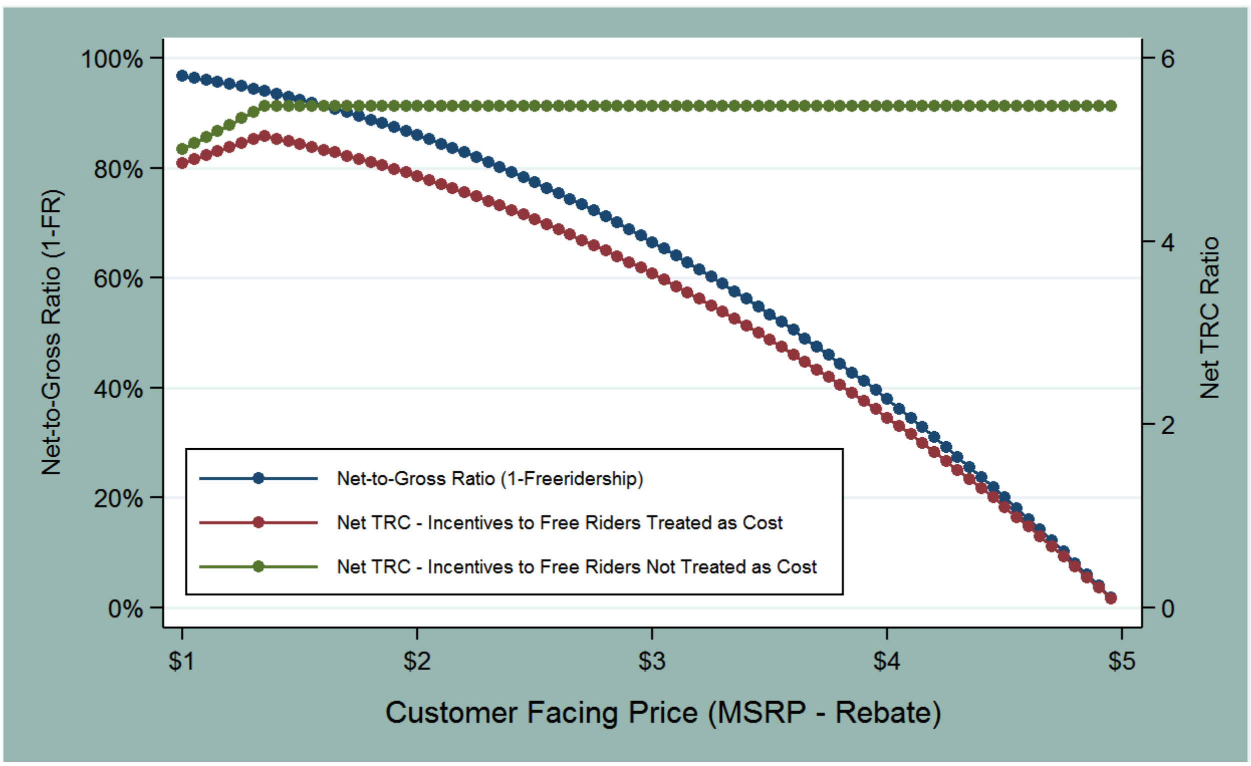
Figure 11 illustrates the difference between the two treatments of incentives to free riders using long-life standard LED bulb studied at Retailer B. When incentives paid to free riders are included as costs in the

[5] National Standard Practice Manual for Assessing Cost-Effectiveness of Energy Efficiency Resources, The National Efficiency Screening Project, EDITION 1 Spring 2017

[6] Ibid, pg 118.

TRC test (against zero benefit), the net TRC ratio follows the net-to-gross ratio closely. When the incentives paid to free riders are not included as costs, the net TRC matches the gross TRC ratio and is independent of the rate of free-ridership at the measure level. This simplified example at the measure level does not include program administrative costs. In practice, if the program administrative costs are spread across fewer net kWh savings, the net TRC will go also down as the freeridership rate increases. This creates a difference between gross TRC and net TRC even when incentives to free riders are not treated as cost. The downward slope in TRC in the upper left portion of Figure 11 occurs when the modeled incentive is larger than the incremental cost because the TRC formula compares the incentive and the incremental cost and uses the larger of the two as cost.

Figure 11: Treatment of Incentives to Free Riders Example-Standard Long-Life LED



5.3 CONCLUSION

The analysis of the LED pricing trial conducted in FY2017 provided some valuable insights into the retail lighting opportunity in Maine. It's clear that program discount (incentive level), in-store placement, and sales volume are connected. The following list summarizes some key takeaways from the study.

- There is a clear relationship between incentive levels and customer demand for LEDs. Sales volume increased for all products as the incentive level increased and the customer-facing price dropped.
- Increased incentive levels lead to lower levels of freeridership.
- The likelihood of favorable product placement increased with program incentive levels and securing "off-shelf" placement has a positive impact on sales.

¶ Lower freeridership improves the cost-effectiveness of the Retail Lighting initiative according to the TRC test because a reduced share of program funds is used to provide discounts to shoppers who would have purchased LED bulbs anyway.

The research team also found a significant difference in the price response of standard and specialty LEDs. The higher upfront cost, reduced separation between baseline and efficient cost, and limited number of available sockets are all potentially contributing factors to the observed difference in price response. The very different elasticity coefficients for the standard short-life products analyzed also seems to indicate a preference for soft/warm light compared to cool/daylight products.

APPENDIX A: POISSON REGRESSION

In selecting an analysis method, two important considerations should be the *type* of data being studied and how the data is distributed. In this case, the dependent variable being studied (weekly bulb sales) is a count variable because it represents a count of the number of bulbs sold in a week. Another way to think about it is that the number of bulbs sold in a week will always be a nonnegative whole number (no decimals).

One common approach to analyzing count data is Poisson regression. Poisson regression is appropriate if (1) the response variable is a count variable and (2) the response variable follows a Poisson distribution. The distinguishing feature of the Poisson distribution is that the mean of the distribution is assumed to be equal to the variance (variance = squared standard deviation) of the distribution. This is quite unlike the Normal distribution, where there is no relationship between the mean and the variance (or between the mean and the standard deviation). Note that explanatory variables used in the Poisson regression model do not have to follow the Poisson distribution, nor do they have to be counts.

A simple Poisson regression model with one predictor variable will take the form[7]:

$$\log(Y_i) = \beta_0 + \beta_1 X_i$$

Note that the Poisson regression model shown above models the log of the response variable rather than model the response variable directly. Thus, the focus shifts from the absolute change in weekly bulb sales to the relative change in weekly bulb sales. This framework lends itself nicely to the estimation of price elasticity of demand coefficients. Recall from Section 1 that the price elasticity of demand formula is:

$$\text{Price Elasticity} = \frac{\%\ \text{change in quantity demanded}}{\%\ \text{change in price}}$$

By including the logarithm of customer-facing bulb price as an explanatory variable in the Poisson regression model (rather than just customer-facing bulb price), the model will examine how *relative* changes in price affect *relative* changes in bulb sales (e.g., price elasticity). When dealing with logarithms and exponential functions, interpreting regression coefficients is not as straightforward as it is in ordinary least squares (OLS) regression. That said, the sign of the slope estimate(s) gives directional information about the relationship between the response and explanatory variable(s). If β_1 is negative, then Y tends to decrease as X increases. If β_1 is positive, then Y tends to increase as X increases.

If the Poisson distribution is not deemed a good fit for the response variable, analysts will typically pursue a negative binomial regression (NBR) model. Like with a Poisson regression model, an NBR model assumes that the response variable is a count variable, and the response variable will undergo a log

---

[7] Note that this model is mathematically equivalent to: $Y_i = e^{\beta_0 + \beta_1 X_i}$

transformation when estimating model parameters. However, in NBR, the assumption that the mean and variance of the response variable are equal is not necessary.

A third option is to pursue a log-log OLS model. In this model, OLS regression (rather than Poisson regression or NB regression) is used to estimate the linear relationship between the log of the response variable and the log of the explanatory variable. Again, the goal is to examine how relative changes in price affect relative changes in the number of bulbs sold.

For each of the six products considered, the research team estimated (1) a Poisson regression model, (2) a negative binomial regression model, and (3) a log-log OLS model. The reason the research team examined results under different modeling frameworks is not to be vague about our approach, but to see if different techniques provide similar answers – are the results robust? Table 11 shows the price elasticity of demand estimates for each product under each regression technique.

Table11: Price Elasticity of Demand Estimates

Product	Poisson Regression	NB Regression	Log-Log OLS
Short Life Standard - Daylight	-0.78	-0.78	-0.75
Short Life Standard - Soft White	-2.21	-2.20	-2.16
Retailer B Reflector LED	-0.73	-0.75	-0.76
Retailer B Standard LED	-2.15	-2.15	-2.14
Retailer A Reflector LED	-0.81	-0.78	-0.79
Retailer A Standard LED	-1.37	-1.47	-1.51

The research team concluded that the coefficients of interest (price elasticities) were robust to model specification given the consistency observed in Table 11. Subsequent estimates of price elasticity, freeridership, and net-to-gross ratios were based on Poisson regression models – which was the original analysis method proposed in the study scope of work.