MEMORANDUM

To: Massachusetts Electric Program Administrators

From: Jason Christensen, Doug Bruchs, and Bryan Ward, Residential Evaluation Team

Subject: Preliminary Lighting Demand Elasticity Findings

Date: March 16, 2015

To determine the net-to-gross ratio for the upstream lighting program, the Evaluation Team employed multiple approaches. These approaches included supplier interviews with lighting product manufacturers and retailers, Point-of-Sale data modeling, saturation and comparison area analysis, and demand elasticity modeling. This memo focuses on the demand elasticity analysis and presents preliminary net-of-freeridership findings. It is important to note that net-of-freeridership is not equivalent to net-to-gross because it only considers freeridership and none of the other factors (participant spillover, nonparticipant spillover, or market effects) sometimes considered when assessing net savings.

In addition, this memo describes the limitations of the available data and opportunities to improve the data for subsequent analyses.

The Evaluation Team (the Team) anticipated lighting products would incur price changes and promotion over the program period and would provide valuable information regarding the correlation between sales and prices. This would be used to develop a demand elasticity model to estimate freeridership for the upstream markdown channel in program year 2013. The robustness of the model depends greatly on the quality of the data available. This memorandum describes the limitations of the available data in detail and provides the preliminary results of our analysis.

A substantial portion of sales were not available for the analysis due to lack of variation in prices, difficulties in matching prices to sales periods, and potential reporting discrepancies. The various issues with the data are described in detail below.

However, there were sufficient variation in price and sales data to estimate price elasticities and predict freeridership for standard and specialty CFLs. The preliminary net-of-freeridership CFL results are shown in Table 2, overall and by bulb style.

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Table 1. Estimated CFL Freeridership

CFL Type	Percent of Sales	Net-of-Freeridership
Specialty	24.7%	44%
Standard	75.3%	61%
Overall	**100%**	**57%**

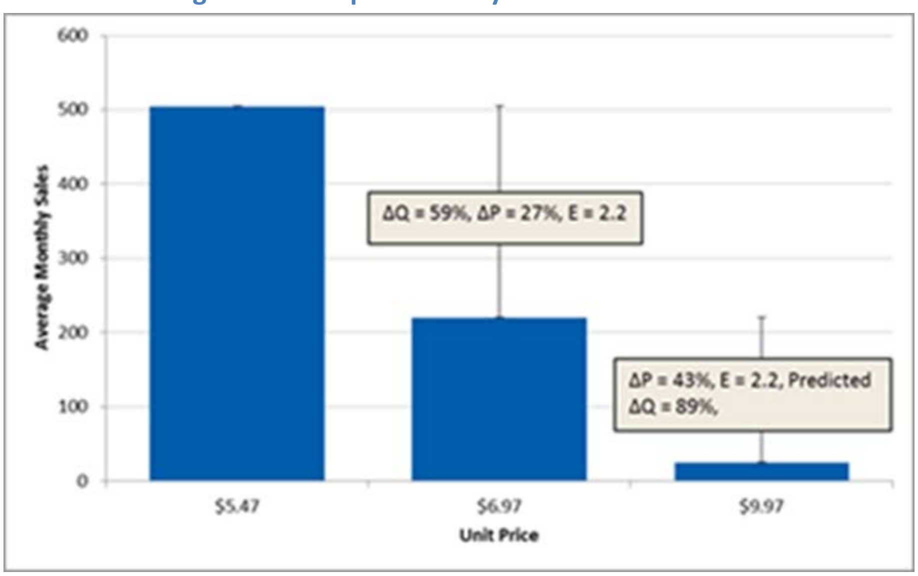
Methodology

Demand elasticity modeling draws upon the same economic principle driving program design: that changes in price and promotion generate changes in quantities sold (i.e., the upstream buy-down approach). Demand elasticity modeling uses sales and promotion information to achieve the following:

- Quantify the relationship of price and promotion to sales;
- Determine likely sales without program intervention (baseline sales); and
- Estimate freeridership by comparing modeled baseline sales with actual sales.

Figure 1 shows an example of sales observed at two price points ($5.47 and $6.97) observed in program sales data and the estimated elasticity of 2.2. Using the elasticity estimate and the price of $9.97, which is what the product would have sold for absent the program incentive, we predict the baseline sales, or freeridership.

Figure 1. Example Elasticity and Predicted Sales



The Team developed the model using program data on prices, the number of lamps purchased, and lamp and retailer characteristics. Unfortunately, for this analysis, store-level promotional and merchandising data were not available. Therefore, the model could not estimate separate effects for promotional activity.

We estimated freeridership using the following equation:

$$FR\ Ratio = \frac{\sum_i^n \left(E\left[bulbs_{NOPROG\,i}\right] * Gross\ kWh_i\right)}{\sum_i^n \left(E\left[bulbs_{PROG\,i}\right] * Gross\ kWh_i\right)}$$

Where:

$E[bulbs_{NOPROGi}]$	=	The expected number of lamps of type 'i' that would be purchased in absence of the program (as predicted by setting the model price to original retail levels)
$Gross\ kWh_i$	=	The gross energy savings for lamp type 'i.'
$E[bulbs_{PROGi}]$	=	The expected number of lamps of type 'i' purchased with program pricing (as predicted by the model)

The Team modeled the data as a panel, modeling a cross-section of program package quantities over time. Available pricing data for all lamp types—with and without program incentives—allowed us to use price and sales variations within the program period as the basis for the model.

Input Data

As the demand elasticity approach relies exclusively on program data, the model's robustness and explanatory power depends on data quality. Unfortunately, our team encountered issues with the data that limited our ability to produce net of freeridership estimates for LEDs, as well as separate estimates for retail channels for CFLs. These issues included:

- Difficulty in mapping prices to effective dates;
- Potential stocking issues and inconsistent reporting;
- Negative sales that appear to be corrections of prior invoices; and
- Months with missing sales.

Price Mapping

The analysis attempts to explain variation in sales over time using variation in price as the primary explanatory factor. As a result, it is crucial that our team accurately map effective prices to the appropriate sales period.

Lockheed Martin, the program implementer, provided three data sets to aid our mapping process. The first data set was program sales as reported by participating manufacturers or retailers. This data set contained the sales within each given time period, which ranged from weeks to months, as well as the product descriptions, pack size, and rebate amounts.

The second data set was the summary of all Memorandum of Understanding (MOU) documents for program year 2013. The MOUs detail which products the program supported and the agreed-upon target price and incentive levels for those products.

The MOUs are often updated during the program year, and our team found that many were updated in 2013. The updates can include changes to either the incentive level provided by the program, changes to the manufacturer or retailer price, or both. Lockheed Martin tracked these updates under different version numbers for each MOU. The MOU summary data contained up to 16 versions for a particular product.

The third data set Lockheed Martin provided was the Product Funding file, which contained each product and rebate amount as well as the effective dates for each rebate amount. The program fulfilment contractor, Parago (now Blackhawk Engagement Solutions), indicated that these were meant to reflect the different versions of the MOUs contained in the MOU summary data.

However, the Product Funding data did not contain the MOU version number, and the MOU summary did not contain effective dates for the various MOU versions, which prevented our team from easily and accurately creating a single file with price and sales over time.

The Team brought this to the attention of the PAs and implementers during the evaluation and Parago suggested that, if the effective dates were sorted and numbered for each bulb model supported by the program, they should correspond to the version numbers in the MOU summary data.

For some products, this was the case. For others, the version numbers did not line up and there were discrepancies that made matching the prices to the effective dates and sales periods more complicated in many cases and impossible in others.

In cases where there were discrepancies in the MOU version and the numbered effective date ranges, the Team employed a two-step approach:

1. Matched by retailer and model number for products with no variation in either the rebate amount or the prices; and
2. Matched by rebate amount for products where the number of changes to the rebate was equal to the number of changes to the target price

The second step assumes the target price changed only because of changes to the rebate amount.

If there were more changes to the target price than the number of changes to the rebate, which suggests there were changes to the original price set by the manufacturer or retailer that cannot be accounted for by changes to the rebate. For these products, without explicit dates when the prices were in effect, there was no accurate way to map the prices to the sales periods and include them in our team’s analysis sample.

Using these methods, the Team was ultimately able to accurately map prices for 72% of total 2013 program sales.

For products we were able to successfully map prices to, variation was measured within unique part number/retailer location combinations (i.e., a given bulb model within a unique retail location). Because of the difficulty in mapping prices for many of the products with price variation, the products with variation in prices represented a relatively small portion of sales.

Table 2 details the attrition of sales used in the analysis and which issue with the data led to the decision to remove the sales.

Table 2. Bulb Sales Attrition

Bulb Style	Total Sales	Sales With Missing Prices	Sales With No Variation	Removed for Negative Sales	Remaining Sales for Modeling
LED	449,118	240,073	74,098	134,947	0
Specialty	803,834	157,506	526,893	7,365	112,070
Standard	1,986,227	501,124	1,095,386	47,366	342,350

In total, model estimates were based on 14% of specialty CFL sales and 17% of standard CFL sales that the team was able to match prices, had variation in price, and had no apparent issues with data quality.

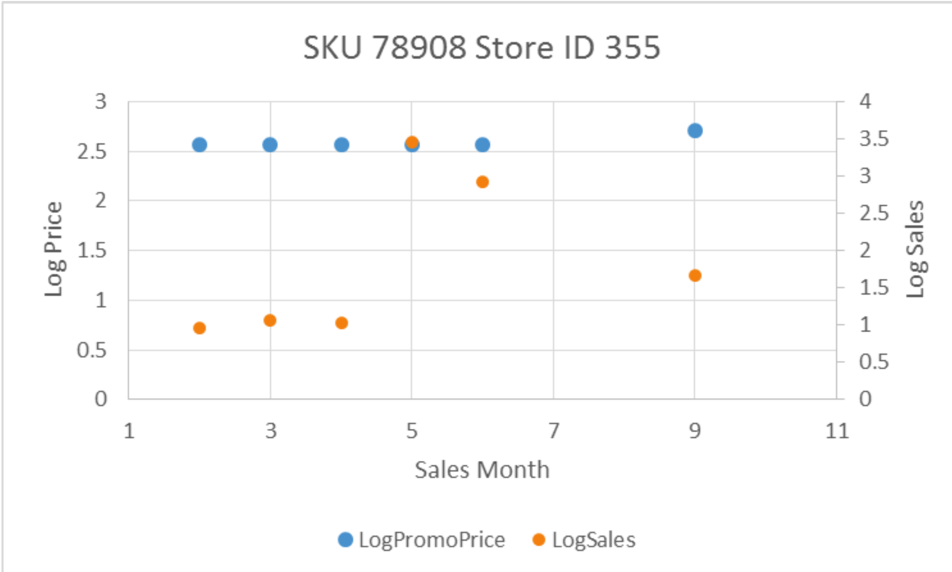
Stocking Issues

One of the fundamental assumptions of the elasticity model is that supply is always sufficient to meet demand at the given price. To ensure this important assumption was not violated, our team screened the data for any instances where this did not appear to be the case—for instance, when sales dropped sharply for similar products within the same time period across the same retailer. The team closely reviewed any products for which potential issues were identified.

When these products were reviewed more closely, the Team noticed inexplicable drops in sales, some of which were preceded or were followed by months where no sales were reported.

To illustrate, we provide an example in Figure 2.

Figure 2. Example of Potential Stocking Issue



In Figure 2, we see there was an uptick in sales in months 5 and 6 (orange dots), compared to months 2 through 4. The uptick was followed by missing sales in months 7 and 8 and then, when sales were reported again in month 9, they were considerably lower than the months prior to the missing sales.

Additionally, for some of these products, including the example above, the first reported sales covered a period of over three months. In order to standardize the time periods, the Team took the average daily amount for each time period and then summarized by calendar month. This assumes that the sales are relatively constant over the reporting period, which is reasonable when the reporting periods are close to a month in length. However, the assumption becomes more tenuous when the reporting periods cover many months, as in the example above. If all of the sales occurred only in month 4, the average monthly sales would have been greater at the lower price point than at the higher price and the correlation between sales and price would have been negative rather than positive.

Considering the length of the reporting period, the erratic nature of the sales in the figure above stands out even more. The first reporting period for the example SKU depicted in Figure 2 captured sales between January 27, 2013, and May 4, 2013. Average daily sales over that period are 0.09 bulbs per day. Beginning May 5, 2013, the sales are reported in more regular monthly intervals and average daily sales increase to 1.02 bulbs per day in May (an increase of 1004%) and 0.61 bulbs per day in June. Then there are the two missing months and, when data are reported again, sales are 0.18 bulbs per day in September, a decrease of 71% from June.

The dramatic difference in average daily sales between the first reporting period and the spike in May suggest that there is a reasonable possibility that the bulbs were not actually being sold as far back as January 27 of that year, though it is possible. The missing months also suggest the possibility that the products were not available over the entire program period.

The length of the reporting period, the associated volatility of sales due to the reporting periods, and months where sales were not reported were all criteria for screening the data used in the model.

Months with Missing Sales

There were a considerable number of LED products that were missing months of sales data in the 2013 summary sales reports. Most of these were associated with the retailer that accounted for the second largest number of LEDs that varied in price during the year. Unlike the example in Figure 2, not all of the missing months were followed or preceded by a large change in sales.

Negative Sales

Three manufacturers reported a significant number of negative bulb sales. Unfortunately, these were concentrated primarily in LED sales at two of the retailers where most of the LEDs with price variation were observed. There was also one retailer that sold standard and specialty CFLs that had negative sales.

In our experience, negative sales are corrections to prior invoices or reflect returned or unsold products. Table 3 provides an example for an LED product with negative sales.

Table 3. Example of LED Product with Negative Sales

POS Start Date	POS End Date	Quantity Sold	Promotional Price per Pack
12/31/2012	2/3/2013	105	$11.97
2/4/2013	3/3/2013	12	$11.97
3/4/2013	3/31/2013	15	$11.97
4/1/2013	5/5/2013	22	$11.97
5/6/2013	6/2/2013	227	$11.97
6/2/2013	6/30/2013	14	$11.97
7/1/2013	8/4/2013	27	$11.97
8/5/2013	9/1/2013	10	$9.97
9/2/2013	9/29/2013	24	$9.97
9/23/2013	9/29/2013	-96	$9.97
9/30/2013	10/27/2013	17	$9.97
10/28/2013	12/1/2013	-94	-

In this example, there are two negative sales reports, both of which are considerably larger than the positive sales reported for the current or immediately preceding period. As a result, when the Team summarized by calendar month, the overall reported sales in September and November were negative.

In this example, the fact that the manufacturer reported the negative sales only at the lower price point means that the sales at the lower price point are very likely understated and that the sales at the higher price point are inflated. This creates serious concerns about the validity of the LED elasticity estimates (which would be positive) if they relied on these data.

Sales data for one CFL manufacturer also included negative sales and were removed from the analysis along with the LED manufacturers.

Results

Given the potential stocking issues, the missing months, the negative sales, and the long, irregular reporting periods that occurred primarily among the two retailers that accounted for the majority of LED sales with varied prices, our team was unable to develop reliable LED elasticity estimates from a representative sample of products.

While some of these issues also existed for CFLs to a smaller degree, our team was able to rely on higher-quality data from other retailers and manufactures to generate a greater number of issue-free cross-sections that could mitigate the potential effects. Despite the fact that these represented a relatively low proportion of sales, the CFL cross sections did represent a variety of both products as well as retailers. Additionally, the CFL estimates are relatively stable and are comparable to estimates from other recent evaluations. Standard CFLs had a net-of-freeridership ratio of 61% and specialty CFLs a ratio of 44%.

Table 4. Estimated CFL Freeridership

CFL Type	Percent of Sales	Net-of-Freeridership
Specialty	24.7%	44%
Standard	75.3%	61%
Overall	**100%**	**57%**

It is important to reiterate the limitations of the available data given the representativeness of the sample (small proportion of sales with price variation) and the issues outlined above. These results should not be considered definitive. However, considering these results are only one piece of a larger analysis to inform the net-to-gross ratio, and the results are consistent with other recent evaluations in which data quality was not an issue, we feel relatively confident presenting these results with the appropriate caveats.

Benchmarking

Table 5 compares net-of-freeridership estimates from several recent evaluations using the elasticity modeling approach. The table also shows the average, sales-weighted original retail price of program bulbs and the incentive as a share of the original price. As mentioned above, the CFL net-of-freeridership ratio falls within the range of values observed in other recent evaluations.

Specialty CFLs are not included in the benchmarking table because the product diversity for specialty bulbs is much greater than for standard bulbs. For example, a program with a high proportion of three-way CFLs or globe bulbs might have a considerably different freeridership ratio than a program that incents primarily reflectors and flood lamps.

In general, as in the findings for this program, specialty CFLs are less price sensitive than standards, likely because of the limited applications of many specialty products. For example, in a recent evaluation for a Midwestern utility, freeridership for specialty products was 18 percentage points higher than for standard bulbs.

Table 5. Benchmarking Net-to-Freeridership and Incentive Levels

Utility	Bulb Type	Markdown per Bulb	Regular per Bulb	Incentive Share	Net of Freeridership
Massachusetts Utility	**Standard**	**$1.18**	**$2.00**	**59%**	**61%**
Northeast Utility 1	Standard	$0.96	$2.72	35%	53%
Northeast Utility 2	Standard	$0.94	$2.46	38%	50%
Southwest Utility 1	Standard	$0.74	$1.81	41%	55%
Midwest Utility	Standard	$1.13	$1.82	62%	57%
Southwest Utility 2	Standard	$1.37	$2.18	63%	83%
Mid-Atlantic Utility 1	Standard	$1.41	$1.97	72%	73%
Mid-Atlantic Utility 2	Standard	$1.43	$2.14	67%	65%
Southeast Utility	Standard	$1.09	$2.15	51%	52%
Mid-Atlantic Utility 3	Standard	$1.59	$2.10	76%	73%
Mid-Atlantic Utility 4	Standard	$1.46	$2.22	66%	65%
New England Utility	Standard	$1.00	$2.11	47%	68%

Recommendations for Future Evaluations

We anticipated data tracking and quality issues since this was our team's first demand elasticity analysis with Lockheed Martin data, and we propose the following strategies for generating future program datasets that support accurate and cost-effective demand elasticity modeling. We have employed these strategies over a number of years with other prominent upstream lighting program implementers and observed meaningful improvements in both data quality and evaluation results. Specifically, we suggest:

- Requesting audited/reconciled sales records at the end of the program year with negative sales resolved;
- Include effective dates for prices in the MOU versions data or MOU versions in the sales data to enable accurate mapping of prices;
- Work with manufacturers and retailers at the smaller retail venues to improve regularity in reporting frequencies;
- Actively track any known instances of products being unavailable within the program period; and
- Work with Lockheed Martin to vary incentive levels (and therefore customer prices) for a greater percentage of program participating bulbs and for a representative cross-section of retailers.