B O N N E V I L L E   P O W E R   A D M I N I S T R A T I O N

Residential Lighting Market Characterization Study

APRIL 2017

EXECUTIVE SUMMARY

Introduction

This report contains the detailed findings from the Bonneville Power Administration's (BPA) characterization of the Pacific Northwest residential lighting market. BPA's research challenge was threefold: first, understand how the rapidly changing lighting market will affect lighting efficiency programs; second, track shifts in consumer purchasing behavior; and third, model changes in regional lighting energy consumption and estimate Momentum Savings.

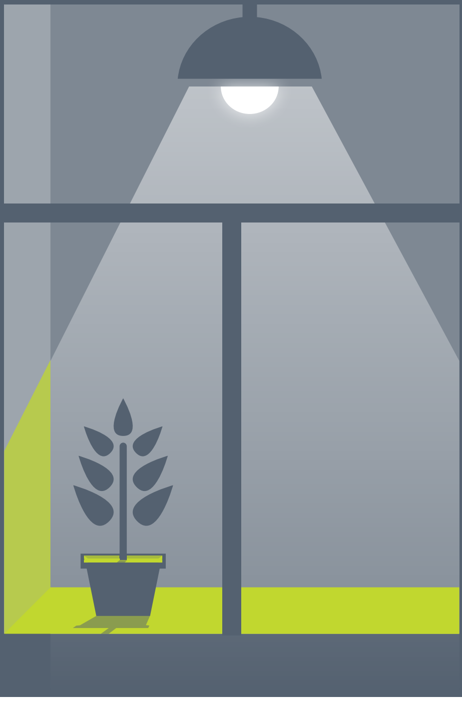
To meet these challenges and gather the market intelligence necessary to characterize the residential lighting market, the research team completed the following research activities.

Sales and Shelf Data Analysis
The team analyzed several sources of quantitative, regionally specific retail lighting market data. These sources included annual sales for a subset of regional retailers procured by the Northwest Energy Efficiency Alliance (NEEA), shelf stocking data gathered by NEEA through its long-term monitoring and tracking of the retail lighting market, and sales data provided by a prominent online-only lighting retailer.

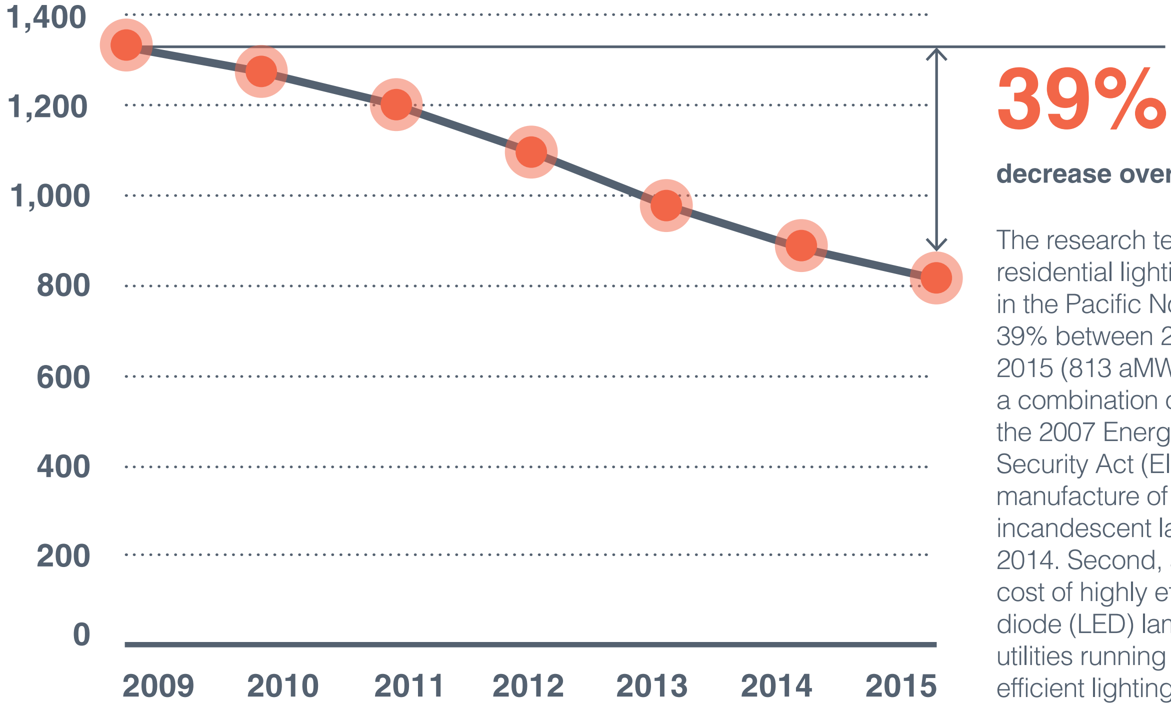
Market Actor Interviews
The team completed more than two dozen in-person interviews with national retailers and manufacturers at the 2015 ENERGY STAR® Partner Meeting and the 2015 Lightfair trade show. The team also completed telephone interviews with regional lighting showroom staff (n=14), residential new construction builders active in the Pacific Northwest (n=10), and online lighting retailers (n=3).

Literature Review
The team supplemented its primary data collection efforts by reviewing over 30 regional and national lighting studies, evaluations, and datasets.

Regional Model Development
The team combined the information from these research tasks, as well as from NEEA's Residential Building Stock Assessment, to model changes in regional lighting energy consumption over time.



Residential Consumption Decreased Between 2009 and 2015



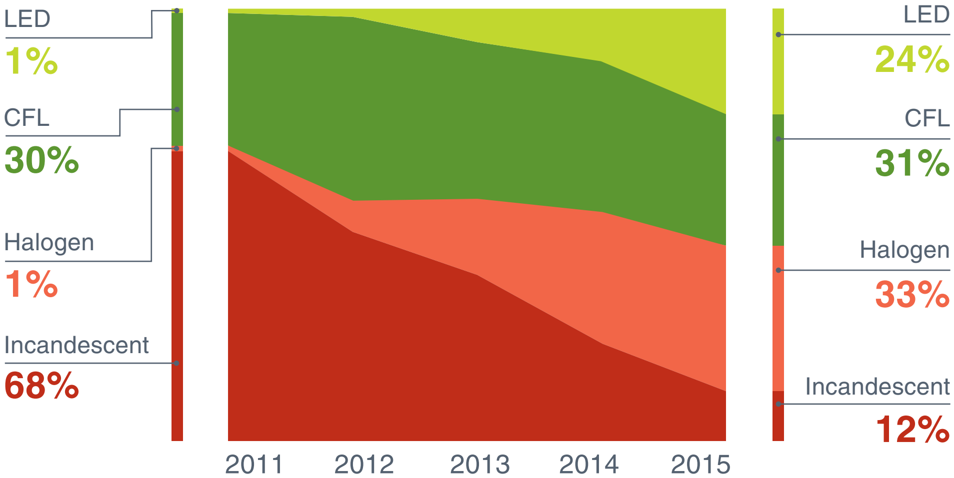
39%

decrease over the last seven years

The research team estimates that total residential lighting energy consumption in the Pacific Northwest dropped by 39% between 2009 (1,338 aMW) and 2015 (813 aMW). This reduction is a combination of three factors. First, the 2007 Energy Independence and Security Act (EISA) prohibiting the manufacture of the most common incandescent lamps between 2012 and 2014. Second, a rapid decline in the cost of highly efficacious light-emitting diode (LED) lamps. Third, regional utilities running programs that promote efficient lighting technologies.

SALES TRENDS

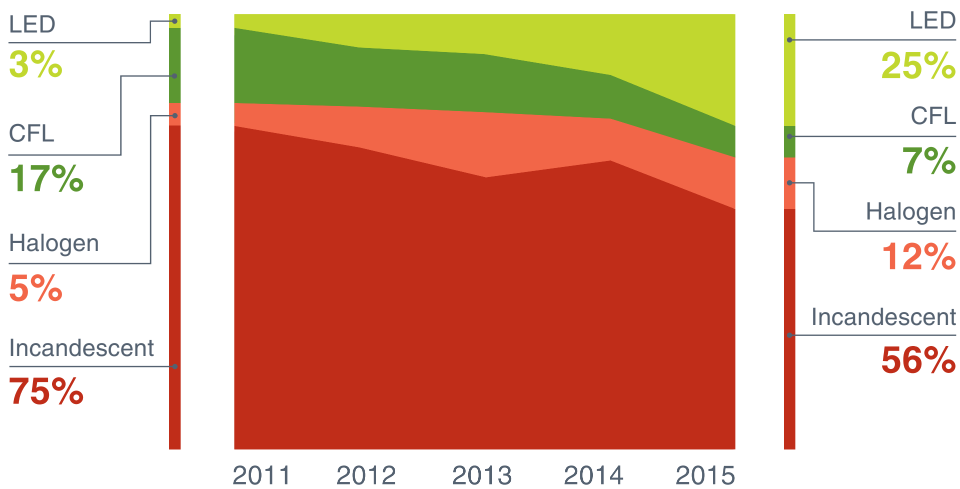
General Purpose Lamps



In 2011, residential customers looking to replace a general purpose lamp had two choices: a less expensive and inefficient incandescent lamp or a more expensive and efficient compact fluorescent lamp (CFL). By 2015, customers primarily chose between two different technologies: halogen and LED. Due to EISA's significant impact, halogens have replaced incandescent lamps as the consumer's low cost and low efficiency option. At the same time, LEDs—now widely available and more cost-competitive with CFLs—are increasingly becoming the preferred efficient option. The result is a markedly more efficient residential lighting market.

Specialty Lamps

While LEDs have also become a more popular option for specialty applications (e.g., reflector, globe, decorative and mini-base, and 3-way lamps), incandescent lamps have retained most of their specialty lamp market share over the past five years. This is because EISA focused on general purpose lighting and exempted many specialty lamps. For example, the 65W bulge reflector (BR) lamp so common in residential recessed fixtures, is exempt from EISA.



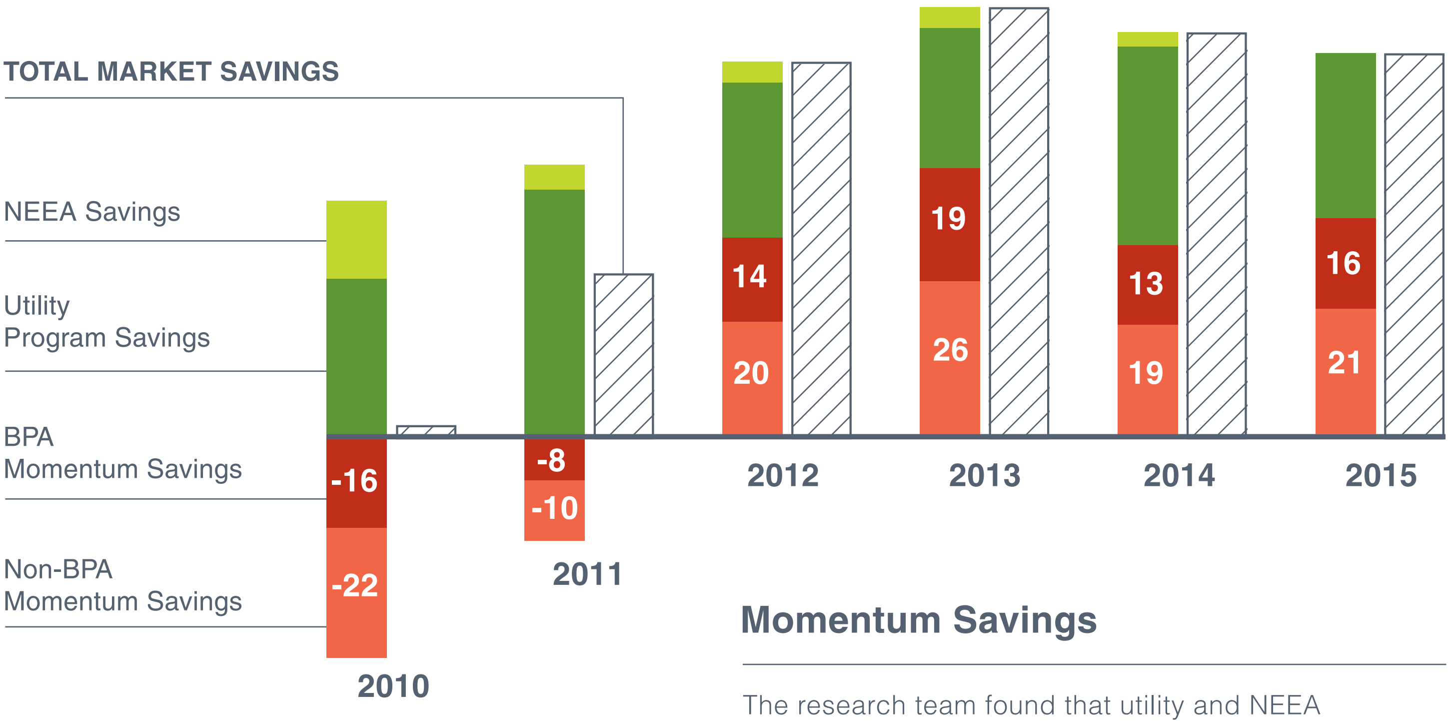
A Shifting Profile

The increasing market share of LEDs and the replacement of incandescent lamps with halogens has substantially changed the characteristics of the average lamp. This is because LEDs are highly efficacious and can last upwards of 20 years. In addition, halogens, while far less efficacious than LEDs, are still a more efficient option relative to incandescent lamps. Because of these technological shifts, the average lamp sold in 2015 is 41% more efficacious, draws 32% fewer watts, and consumes 31% less energy annually than the average lamp in 2011. The longer rated life of LEDs also means the average lamp in 2015 will last almost twice as long as it did in 2011. Together, lower energy consumption and longer lifetimes means persistent energy savings for residential lighting.

	EFFICACY (lumens/watt)	RATED LIFE (years/lamp)	WATTAGE (watts/lamp)	CONSUMPTION (kWh/year)
2011	16	3.6	49.7	38
	+41%	+67%	-32%	-31%
2015	22.5	6.1	33.8	27

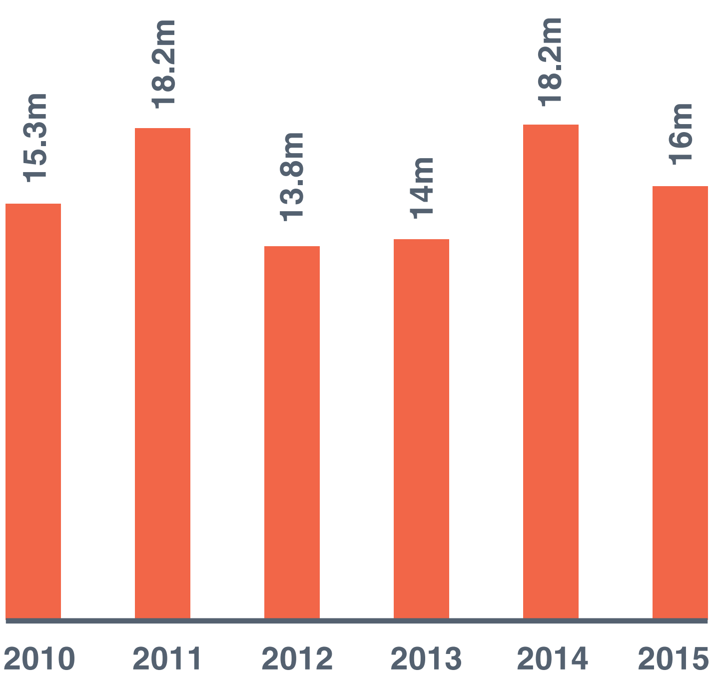
SAVINGS

Energy Savings (aMW)



Program Activity

Between 2010 and 2015, regional utilities and NEEA incentivized more than 95 million screw-in lamps. BPA estimates there were approximately 492 million total lamp sales during this timeframe, which means programs touched almost one in five lamps sold in the region.



Momentum Savings

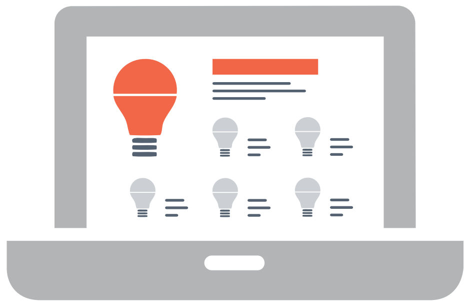
The research team found that utility and NEEA savings outpaced total market savings in 2010 and 2011 relative to the 2009 frozen baseline. As market efficiency increased, Momentum Savings accumulated, resulting in 92 aMW of total Momentum Savings between 2010 and 2015. The negative savings in the early years reflected that all of the efficient market share present in 2009 was, by definition, part of the frozen baseline—only incremental gains in efficient technologies after 2009 produced savings in each year. For example, even though overall 2010 sales were 21% CFL, the CFL sales share only increased by 0.01% between 2009 and 2010. However, as the CFL and LED sales shares grew relative to the frozen baseline and these technologies accumulated in the stock, savings increased throughout the Sixth Power Plan period.

The rapid change in the residential market—yielding 302 aMW of market savings in six years—was driven by increased sales shares of efficient CFLs and LEDs and enabled by the short lifetimes of incandescent and halogen lamps. As these technologies decreased in the stock, natural lamp burnout—and, therefore, new purchases—declined by one-third between 2010 and 2015. Unless consumers begin replacing lamps before the end of their natural lifetime, the market size and associated opportunity to drive further efficiency gains will continue to diminish in coming years.

MARKET CHANGES

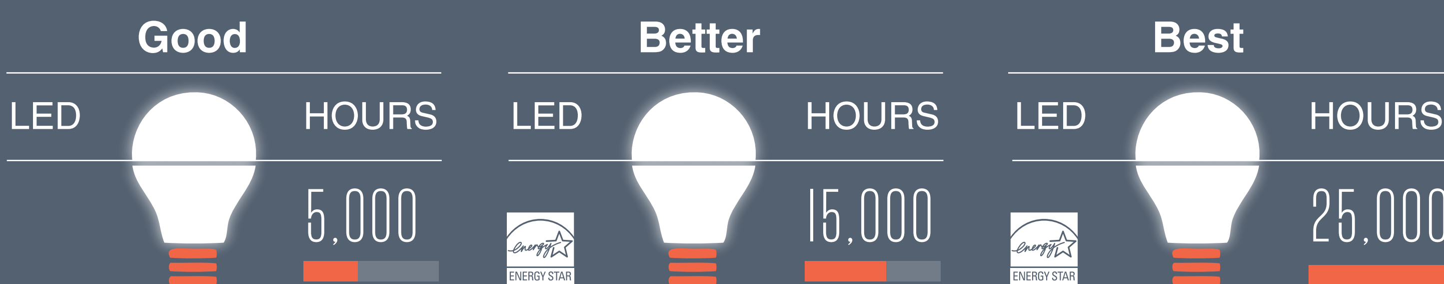
The Online Market Is Growing

As of late 2016, there were already as many as 30 lighting-focused retailers active online. One market actor said their company has averaged double-digit year-over-year growth in its online sales over the last six years. The research team anticipates that even more online retailers will emerge and that an increasing percentage of residential lighting sales will happen online. Market actors offered two theories for the rise in online sales: macro changes in consumer behavior, and convenient access to a larger variety of lamps. While consumers are buying more of everything (including lamps) online, they are also using the online search functionality to purchase hard-to-find lamps with less hassle.



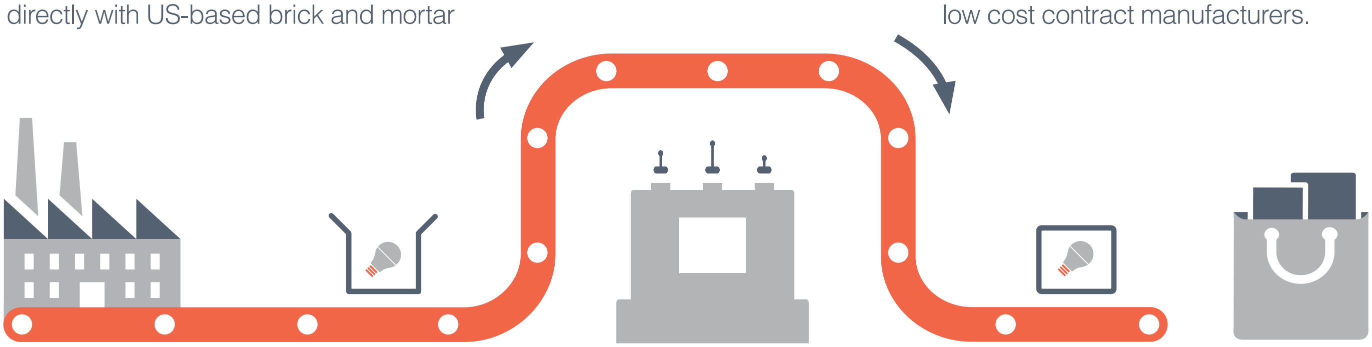
ENERGY STAR vs. Non-ENERGY STAR

In December 2015, the Environmental Protection Agency finalized a new lighting specification to capture greater energy savings through increased efficacy requirements. At the same time, high consumer demand for LEDs at lower price points has caused many lighting manufacturers to produce more non-ENERGY STAR LED bulbs as a cheaper option than their ENERGY STAR-certified counterparts. To minimize price, these manufacturers have relaxed certain ENERGY STAR LED requirements such as omnidirectionality, dimmability, and expected useful life—features consumers may not fully understand or are unwilling to pay a premium for. As a result, many retailers now offer an all-LED "Good, Better, Best" model that consists of variations of the same technology with varying levels of sophistication. ENERGY STAR 2.0 for lamps took effect in January 2017.



An Evolving Supply Chain

Technological shifts have also meant shifts in the residential supply chain. Overseas contract manufacturers are increasingly bypassing traditional intermediaries to work directly with US-based brick and mortar and online retailers. Supply chain actors are adapting to evolving market dynamics by expanding their specialty lighting products to differentiate themselves from high volume, low cost contract manufacturers.



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Introduction

Bonneville Power Administration (BPA) contracted with Navigant Consulting, Inc. and Cadeo (the research team) to characterize the residential lighting market in the Pacific Northwest. To this end, the research team interviewed a wide-range of lighting industry market actors, analyzed retail lighting sales and shelf data, and developed a regional model to estimate changes in lighting-related energy consumption over time. This report summarizes the results of these efforts.

How to Use This Document

Before reviewing the research findings, it is important to understand the structure of this document as well as the activities completed to investigate the residential lighting market. This document consists of two parts: a **Research Summary** and a **Research Portfolio**.

The **Research Summary** distills the findings from the wide-ranging activities the research team completed as part of the residential lighting market characterization. In this section, the team highlights key findings, identifies important connections across research activities, and discusses the implications of this market intelligence for regional lighting programs. It also includes the research team's estimation of Momentum Savings generated between 2010 and 2015.

The second part of this report is the **Research Portfolio**. It contains the nine memos that the research team submitted to Bonneville Power Administration (BPA) between May 2015 and February 2017 following the completion of each research activity. These memos detail each activity's methodology and findings. Readers should refer to the Research Portfolio for an in-depth discussion of each activity.

Brief Description of Research Activities

The research team completed four research activities with the goal of understanding the rapidly changing lighting market, tracking shifts in consumer purchasing behavior, modeling changes in regional lighting energy consumption, and estimating Momentum Savings.

Literature review. To keep pace with the dynamic lighting market, stakeholders in the Pacific Northwest have undertaken an increasing number of market and consumer tracking studies in recent years. In an effort to leverage, complement, and build upon these efforts, the research team began its own market characterization by reviewing numerous lighting-related studies and datasets. In total, the research team reviewed over 30 different resources. The team used the information obtained through this review to develop inputs to a regional lighting model and to develop market actor interview guides.

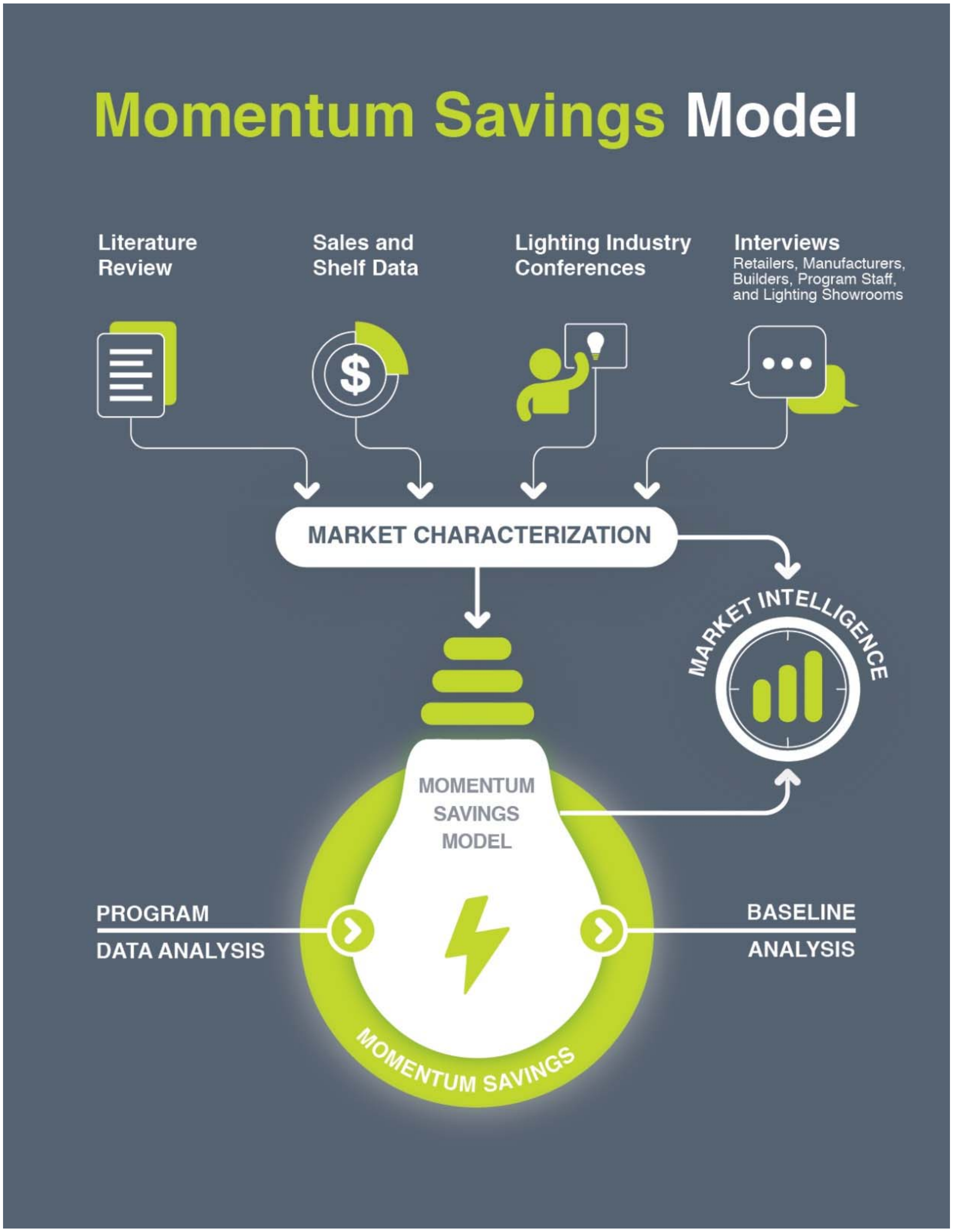
Market actor interviews. Identifying and interviewing the right market actors is critical to the success of any market characterization. To find the market actors most knowledgeable about lighting, research team members attended the 2015 Lightfair® trade show and the 2015 ENERGY STAR® Partner Meeting, where they completed more than two dozen in-person interviews with national retailers and manufacturers. To complement the perspectives gained at these industry events, the research team also completed telephone interviews with regional lighting showroom staff (n=14), residential new construction builders active in the Pacific Northwest (n=10), and online lighting retailers (n=3).

Sales and shelf data analysis. The research team complemented the qualitative insights of these market actor interviews with the quantitative objectivity of regional and national market data. The research team has access to several sources of quantitative regional retail market data, including full category, annual sales for a subset of regional retailers collected by Nielsen and procured by the Northwest Energy Efficiency Alliance (NEEA), shelf stocking data gathered by NEEA through its long-term monitoring and tracking of the retail lighting market, and sales data provided directly from a prominent online-only lighting retailer. Collectively, this data—once integrated into a market framework—offered the research team a clear picture of the Pacific Northwest market.

Regional model development. Using the market data described above as well as building and lighting stock data from NEEA's Residential Building Stock Assessment (RBSA) and the Northwest Power and Conservation Council's (the Council's) Sixth and Seventh Power Plans (Sixth Plan, Seventh Plan), the research team constructed a regional lighting stock turnover model. First, the model calculates the failure of existing lights based on their age, technology, and expected useful life. Next, the model replaces all failed lamps with a mixture of technologies (incandescent, halogen, CFL, and LED lamps) on an annual basis. The replacement technologies mirror the distribution of technologies sold by regional retailers in each year. The model's stock turnover approach allowed the research team to estimate a number of regional lighting metrics, including total residential lighting energy consumption, total market savings (relative to specified baselines), and regional Momentum Savings—the market savings that remain after accounting for previously claimed local utility program and NEEA lighting savings. Perhaps most importantly, the model offers the region its most robust and dynamic lighting-related planning and reporting tool to date.

Figure 1 summarizes the interrelationships of these tasks and how the research team used each to characterize the residential lighting market.

Figure 1: Research Activities and their Applications



Research Summary

This section summarizes the research team's key findings related to Momentum Savings and regional lighting trends.

Momentum Savings

The research team developed a model that depicts Pacific Northwest residential lighting-related energy consumption between 2009 (the model's base year) and 2015 (the last year of the Council's Sixth Plan period).

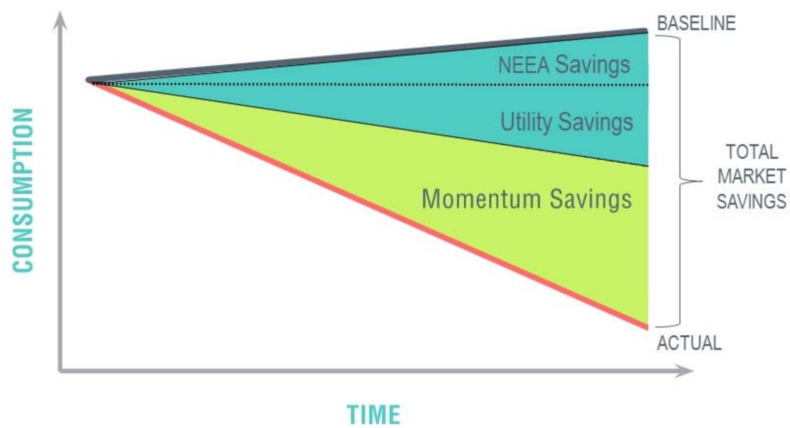
The model considers the impact that approximately 60 million annual lamp sales have on the more than 300 million residential lighting sockets in Pacific Northwest homes. It allowed the research team to compare actual energy use to predicted energy usage levels by converting the technology sales trends into regional lighting energy use.

Before discussing the model or its results in more detail, it is important to first define several key Momentum Savings terms:

- **Baseline consumption**: The anticipated annual energy consumption for a given market—in this case, residential lighting
- **Market consumption:** The actual annual energy consumption for that market, determined retrospectively using market data
- **Total market savings:** The difference between baseline energy consumption and actual energy consumption
- **Utility savings:** All programmatic savings within the market claimed by regional utilities
- **NEEA savings:** Any net market effects claimed by NEEA for initiatives within the market
- **Momentum Savings:** Any savings that occur above the baseline and that are not directly incented by programs or claimed as part of NEEA's net market effects

Figure 2 highlights the interdependent relationships between these terms.

Figure 2: Elements of Momentum Savings



The remainder of this section details the scope and structure of the regional lighting model and the research team's estimations of total market and Momentum Savings. The team also offers some critiques of the model and explains how the residential lighting Momentum Savings methodology differs from previous Momentum Savings analyses conducted by BPA.

For more information about each of the topics covered below, please see the Momentum Savings Methodology Memo provided in the Research Portfolio.

Analysis Scope and Model Details

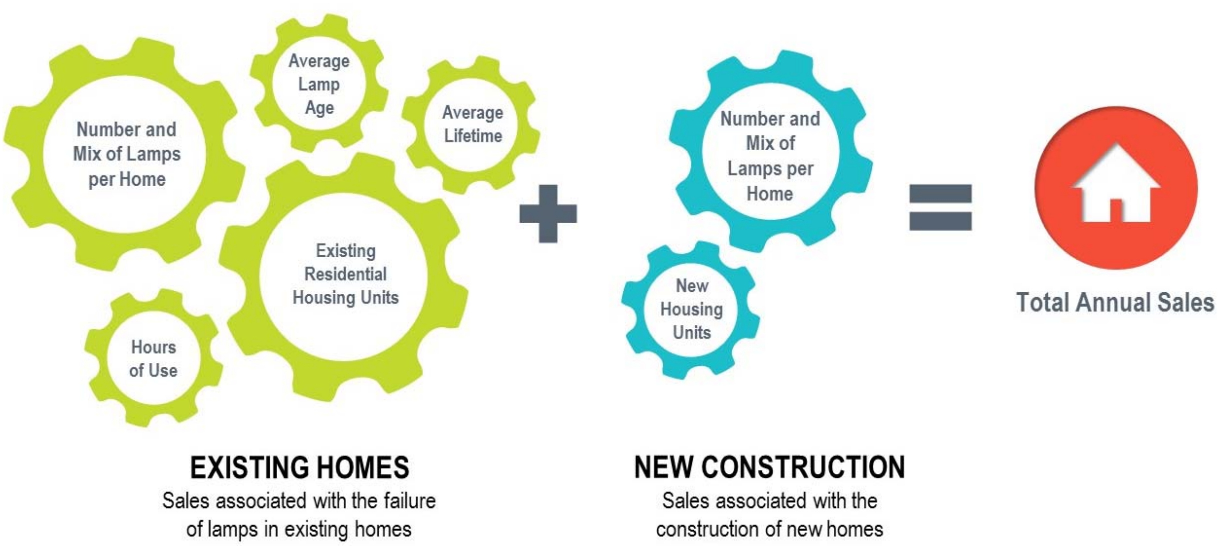
To understand the Momentum Savings results, it is important to understand the research study's scope and model structure. The research team defined and modeled the region's residential lighting market as described in Table 1.

Table 1: Research and Model Scope

Dimension	Definition	Notes
Product Scope	Screw-in lamps, linear lamps	Includes all Regional Technical Forum (RTF) categories
Unit of Account	Installed stock of lamps	Departure from typical Momentum Savings approach, which focused on sales
Sector and Housing Type	All residential housing types (single family, multifamily, and manufactured homes)	Includes multifamily units but excludes common areas in multifamily buildings
Geographic Scope	Oregon, Washington, Idaho, and Western Montana	Consistent with the Council's Power Plans
Purchase Triggers	All purchase types	Model turnover is driven by lamp failure (e.g., replace-on-burnout); the team did not identify reliable information to also include an early retirement turnover trigger

The underlying premise of stock turnover models is that lamp sales are triggered when lamps in the existing housing stock fail and require replacement. The model calculates failures in the existing stock based on the age and average life (in years) of each lamp in the stock. For example, if a specific lamp has a three-year life, then lamps of that type installed in 2009 should, on average, fail and be replaced in 2012. Figure 3 illustrates the key components of the model's calculation of installed lighting stock turnover in existing homes (replacement sales) and growth in lighting stock (newly constructed homes).

Figure 3: Stock Turnover Method for Estimating Turnover and Growth



Differences from Previous Momentum Savings Models

Previous Momentum Savings analyses defined the market in terms of sales, whereas this analysis defines the residential lighting market in terms of the installed stock. The research team deviated from the typical approach in order to account for differences in the number of sales in each year. For example, as the residential lighting market moves toward longer-lived lamps, the rate of lamp turnover decreases and retailers sell fewer lamps each year. However, simply selling less of something is not the same thing as saving energy.

In order to control for the differences in market size over the analysis period and to accurately reflect total market and Momentum Savings, the research team needed to make this subtle but critical shift in its approach. Regardless of the calculation method, any resulting market savings are solely the result of differences in the efficiency mix of sales between the actual and baseline cases.

Model Baseline

Momentum Savings analyses have historically used the Council's Sixth Plan forecasts for a given end-use as the baseline. The research team did not follow this precedent for this specific analysis because the residential lighting market changed more dramatically than anticipated by the Council's Sixth Plan. Instead, the research team developed two alternative baseline efficiency scenarios: a frozen efficiency baseline and a RTF baseline. Each baseline offers a different perspective on the changes in regional lighting-related energy consumption between 2010 and 2015. The team explains each below.

- **Frozen efficiency baseline.** For this baseline, the research team froze the technology mix of sales in 2009, shown in Table 2, and held it constant for the entire analysis period. The frozen baseline offers a straightforward estimate of total market change since 2009, when nearly three-quarters of the region's lamps were incandescent. It is important to note that the team did not have access to reliable market data for 2009. Therefore, the research team estimated the 2009 frozen efficiency scenario by backcasting the 2011-2015 efficiency mix, which it calculated using more complete sales and shelf stocking data.

Table 2: Frozen Efficiency Baseline Mix (General Purpose Bulbs)

Year	Incandescent	Halogen	CFL	LED
2009	71%	0%	29%	0%

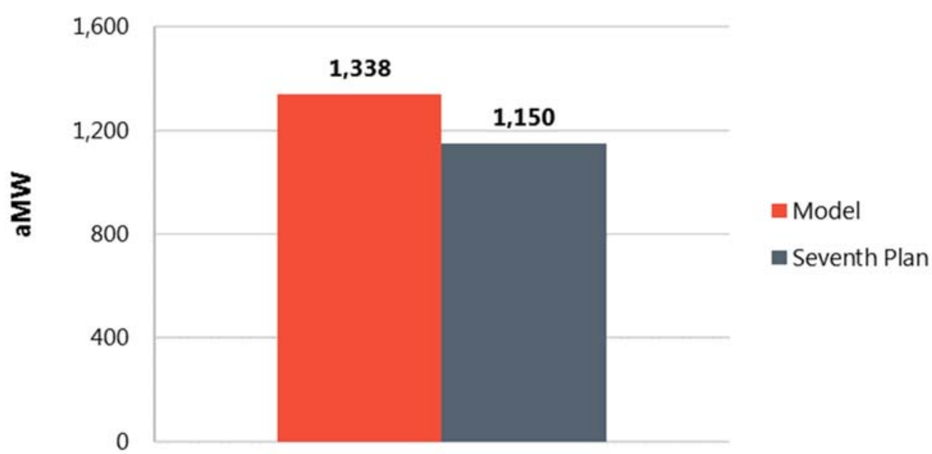
- **RTF baseline.** The RTF baseline provides a measure of total market and Momentum Savings against the efficiency baseline that most regional utilities use to claim savings for their lighting programs. For the RTF baseline, the research team adjusted the baseline efficiency mix in each year to match the baseline assumed by the RTF for both general purpose (Table 3) and specialty lamps. Since the RTF updated its lighting baselines in response to the Energy Independence and Security Act of 2007 (EISA), the efficiency of the RTF baseline increases over time.

Table 3: RTF Baseline Mix (General Purpose Lamps)

Year	Incandescent	Halogen	CFL	LED
2010	100%	0%	0%	0%
2011	100%	0%	0%	0%
2012	92%	8%	0%	0%
2013	81%	19%	0%	0%
2014	0%	61%	39%	0.6%
2015	0%	61%	39%	0.6%

While the research team did not use the Sixth Plan as its model baseline, it did validate the reasonableness of the model's estimate of total lighting energy consumption in its base year (2009) by comparing it to a similar estimate from the Council's Seventh Plan.[1] As shown in Figure 4, the team's model (1,338 aMW) and Seventh Plan (1,150 aMW) estimates were within 16% of each other.

Figure 4: Comparison of Model and Seventh Plan 2009 Total Lighting Energy Consumption



Note: Does not include HVAC interaction effects.

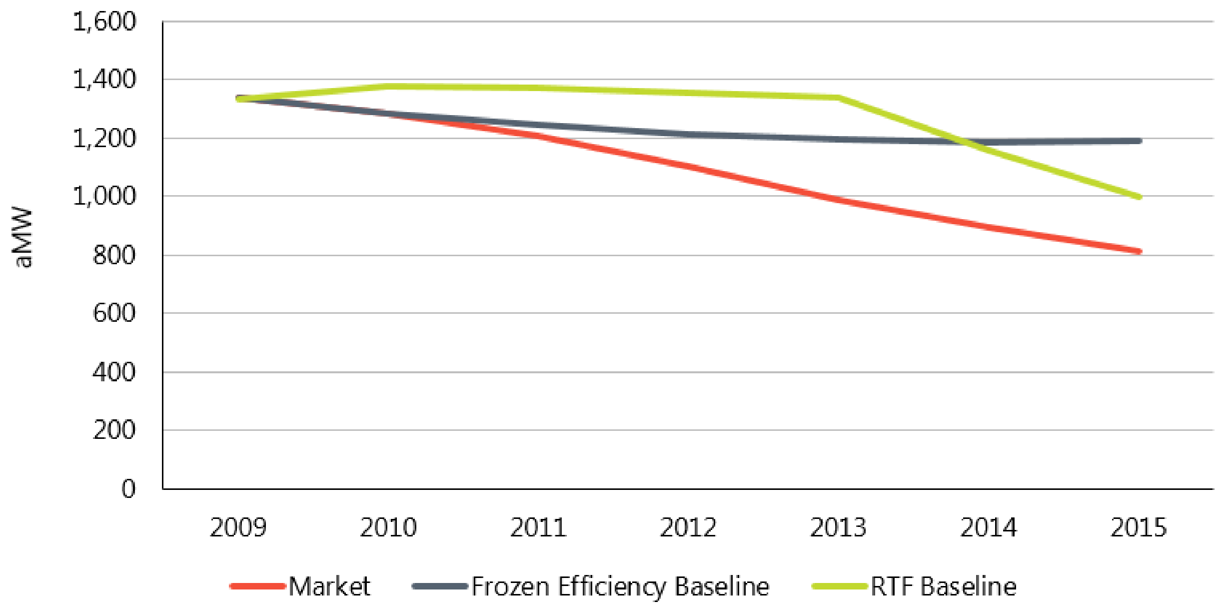
Source: Residential Momentum Savings Model, Seventh Power Plan end-use load data

Regional Lighting Consumption

Figure 5 compares the research team's estimate of the changes in total residential lighting energy consumption between 2009 and 2015. Specifically, the figure compares all three modeled scenarios: the actual—or market—scenario, the frozen efficiency baseline scenario, and the RTF baseline scenario.

[1] The research team used the Seventh Plan—not the Sixth Plan—for this comparison since the Seventh Plan included retrospective estimates of usage. The Sixth Plan only included prospective forecasts.

Figure 5: Model Estimates of Total Lighting Energy Consumption: 2009-2015



Source: Residential Momentum Savings Model

Differences in sales mix and stock turnover drive the differences between these scenarios as described below:

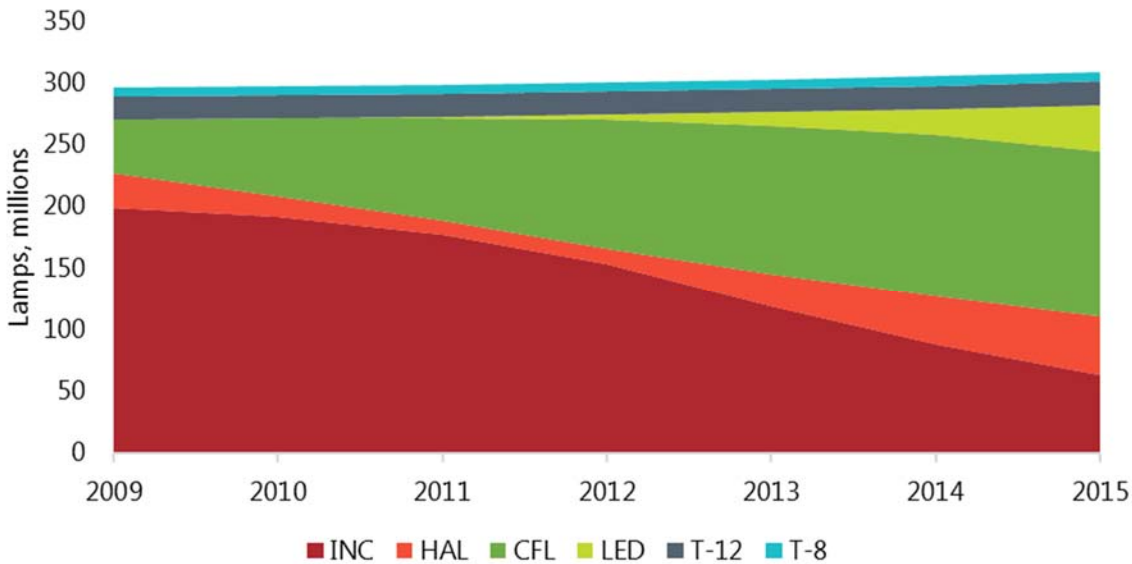
- **Actual Market.** The total lighting-related energy consumption in the region dropped by 39% between 2009 (1,338 aMW) and 2015 (813 aMW) in the market scenario. This reduction is a combination of EISA largely eliminating incandescent lamps from the market, LED lamps quickly gaining market share, and regional utilities running effective lighting programs. This market shift means that in 2015 lighting accounted for 11% of total residential load as opposed to 15% forecasted in the Council's Seventh Plan.

- **Frozen Baseline.** In the frozen baseline scenario consumption also declined over time, though not as quickly as the actual consumption (only 11% by 2015). Since the majority of stock turnover was from incandescent lamp failures (due to their shorter lifetime) and the 2009 sales mix was about 20% CFL, CFL saturation initially increased, which resulted in decreased total consumption, even in the frozen baseline. Once CFL saturation plateaued in 2014, total consumption began to grow along with the building stock (due to new construction).

- **RTF Baseline.** The RTF baseline stock consumption increased initially because the sales mix for 2010 and 2011 was 100% incandescent. With incandescent lamps replacing all failures during this period—and most failures in 2012 and 2013—the incandescent share of the stock increased until the RTF baseline sales mix became nearly all halogen and CFL in 2014. At this point, the efficiency of the stock technology mix improved rapidly and stock consumption dropped accordingly, leading to a 25% reduction relative to 2009 by 2015.

Figure 6 shows the total number of lamps installed in the residential sector in the region between 2009 and 2015, as well as the mix of technologies present in the lamp stock. As evident below, the growth of CFL and LED lamps—both efficient technologies—in the stock drives the decrease in total lighting-related energy consumption shown Figure 5. Overall, the total stock grew slightly due to new construction but not enough to counteract the decline in consumption driven by the adoption of efficient technologies. CFLs and LEDs, which combined made up less than 20% of total screw-in lamp stock in 2009, represented over 60% by 2015.

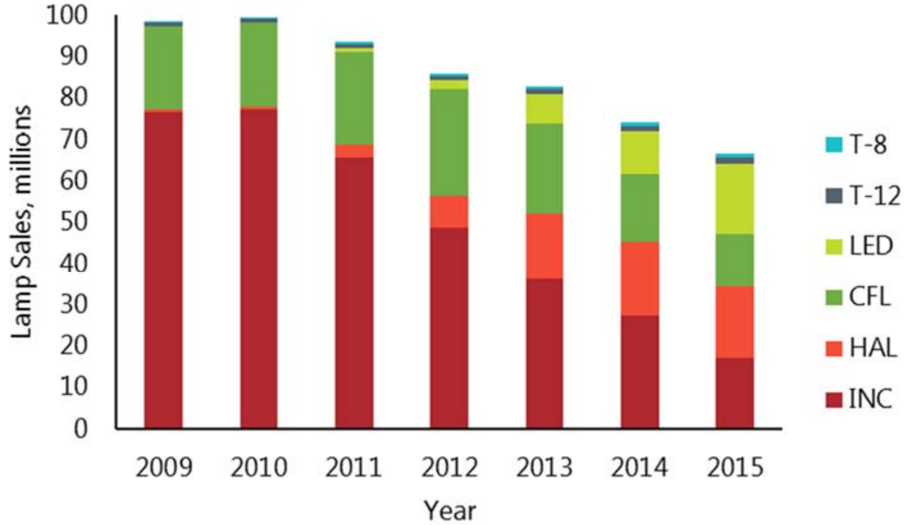
Figure 6: Lamp Stock by Technology, Market Scenario



Source: Residential Momentum Savings Model

One result of the increase in CFL and LED stock saturation was a year-over-year reduction in total regional lamp sales. As more of the sockets in the region filled with longer-lived lamps, new lamp sales declined as shown in Figure 7. The entire residential lamp market shrank by 33% between 2009 and 2015. This decline could slow or plateau in the upcoming years if consumers replace longer-lived lamps before they burn out. The current residential model does not include a retrofit rate to account for early replacement.

Figure 7: Total Lamp Sales by Technology, Market Scenario



Source: Residential Momentum Savings Model

Accounting for Utility and NEEA Savings

The difference between the modeled market and two baseline scenario consumption estimates shown above in Figure 5 reflect the total market savings for each year and baseline scenario. To avoid double counting any previously claimed program savings, the research team subtracted all lighting-related utility and NEEA savings from the total market savings. The remaining market savings, as illustrated by Figure 2, are Momentum Savings.

The team relied on the following data sources when gathering data on all local lighting program activity and NEEA net market savings.

- **Utility savings.** The research team relied upon three data sources to determine total utility lighting program activity in the region between 2010 and 2015:
  - BPA's IS2.0 database, which captures public utility lighting program activity including both CFLs and LEDs
  - NEEA's annual survey of local utilities, through which NEEA collected the total number of CFLs (2010-2015) and LEDs (2015 only) incentivized by regional investor-owned utilities (IOUs)
  - Publically available program evaluations and annual reports, which the team used to determine the number of LEDs incentivized by IOUs prior to 2015. For certain IOUs, the team was unable to find reliable information online. In these instances, the team contacted the IOU, or the organization administrating the program, directly.
- **NEEA savings.** NEEA uses information gathered through its annual survey of local utilities to estimate the net market effects that result from its long-term support of CFLs in the Pacific Northwest. NEEA provided their net market effects savings claims by year and lamp type to the research team.

The research team added the utility-incented and NEEA-claimed lamps by year and lamp type together, as shown in Table 4. The team calculated the regional energy impact of these lamps by multiplying the regional totals by the per-unit energy savings used by the RTF in each year and then subtracted the result from the model's estimate of total market savings in each year to determine Momentum Savings.

As detailed below, regional utilities and NEEA incentivized more than 95 million screw-in lamps between 2010 and 2015. For context, the research team's model estimated total residential lamp sales in the region during the same timeframe was approximately 500 million lamps. This means that almost one out of every five lamps sold between 2010 and 2015 went through a regional lighting program.

Table 4: Summary of Utility and NEEA Savings: 2010-2015

Year	General Purpose (Millions of Lamps)				Specialty (Millions of Lamps)			
	Public Utilities and IOUs	NEEA	Total Units	Total Savings (aMW)	Public Utilities and IOUs	NEEA	Total Units	Total Savings (aMW)
2010	7.1	3.0	10.1	**20**	3.3	1.9	5.2	**7**
2011	10.8	0.7	11.5	**30**	5.8	0.9	6.7	**12**
2012	8.3	0.4	8.7	**18**	3.8	1.3	5.1	**8**
2013	8.3	0.0	8.3	**15**	4.1	1.6	5.7	**9**
2014	11.1	0.0	11.1	**20**	5.9	1.1	7.0	**13**
2015	12.4	0.0	12.4	**20**	3.7	0.0	3.7	**9**
Total	**58.1**	**4.0**	**62.1**	**123**	**26.5**	**6.9**	**33.3**	**59**

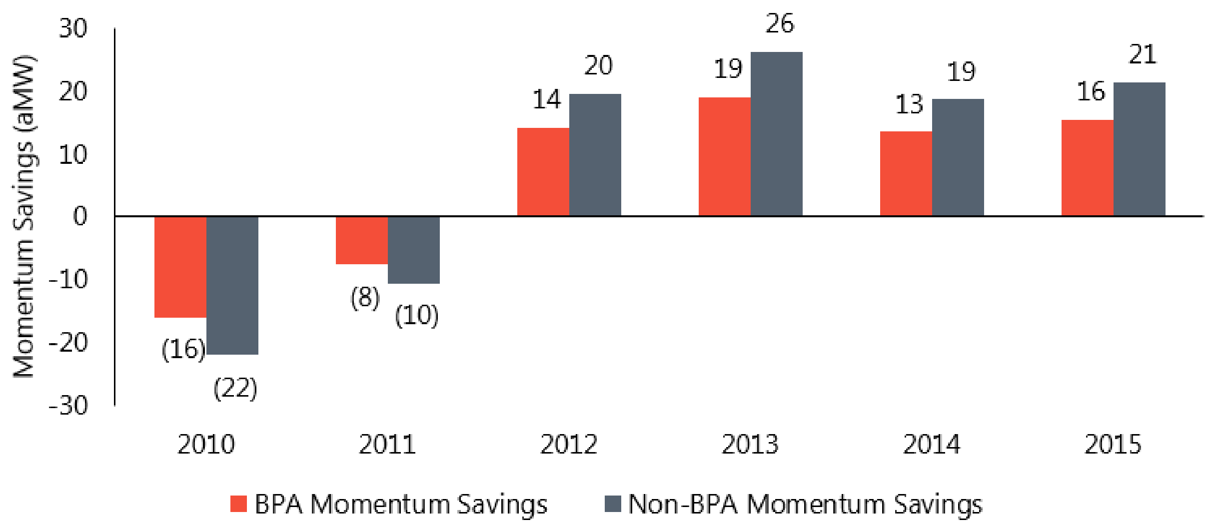
Momentum Savings Results

Figure 8 and Figure 9 subtract utility and NEEA savings from the frozen efficiency and RTF baselines, respectively, to reveal any remaining regional Momentum Savings. Both figures include estimates of BPA and non-BPA Momentum Savings. BPA Momentum Savings are 42% of total regional Momentum Savings; the balance are non-BPA Momentum Savings.[2]

The research team found that utility and NEEA savings outpaced total market savings in 2010 and 2011, relative to the frozen baseline. As market efficiency increased in 2012 through 2015, Momentum Savings accumulated, resulting in 92 aMW of regional Momentum Savings during that period. The negative savings in the early years reflected that the frozen efficiency scenario effectively assumes that the market will be at least as efficient as the baseline year (2009). Thus, only incremental gains in market share for efficient technologies contributed to market savings. For example, even though overall 2010 sales were 21% CFL, the CFL sales share only increased by 0.01% between 2009 and 2010. However, as the CFL and LED sales shares grew relative to the frozen baseline and these technologies grew in the stock, savings increased throughout the Sixth Plan period.

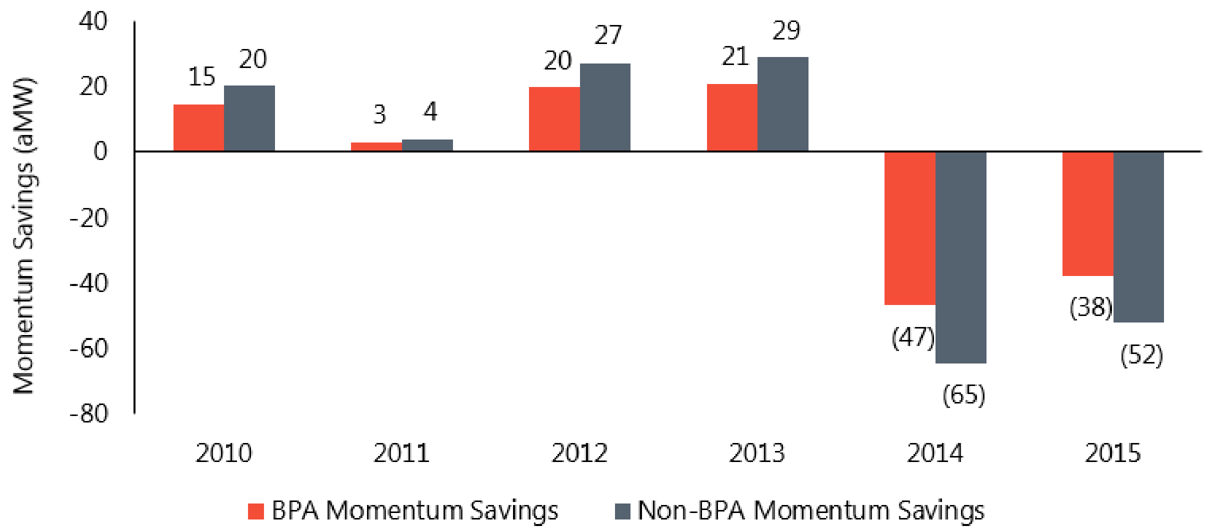
[2] BPA's 42% allocation of regional Momentum Savings was established in its Energy Efficiency Action Plan (https://www.bpa.gov/EE/Policy/EEPlan/Documents/BPA_Action_Plan_FINAL_20120301.pdf). The plan states: "BPA has taken responsibility for achieving the public power share of approximately 42% of savings."

Figure 8: Momentum Savings, Frozen Efficiency Baseline



In contrast, programs claimed savings relative to the RTF baseline in all years, which led to negative Momentum Savings until the incremental market gains increased in later years (Figure 9). This is because the RTF baseline was much less efficient than the market until 2014 and much more efficient than the market in 2014 and 2015. The large number of shorter lifetime incandescent lamps in the RTF scenario stock gave the sudden change in sales mix an immediate effect on the stock consumption. Under this baseline scenario, the negative Momentum Savings (-201 aMW) generated between 2014 and 2015 were greater than the positive Momentum Savings (138 aMW) found between 2010 and 2013, leading to negative Momentum Savings totals of -64 aMW for 2010-2015.

Figure 9: Momentum Savings, RTF Baseline



The frozen baseline results suggest that while program savings exceeded market potential relative to a frozen baseline in early years, the market changed quickly enough in later years to generate substantial

Momentum Savings over the Sixth Plan period. The RTF baseline results show that the current RTF baseline was more efficient than the actual market in 2014 and 2015.

Model Reliability

The regional lighting model has both strengths and weaknesses, which the research team highlights in Table 5.

At a high level, the model represents the team's best effort to leverage the data available for both stock and sales despite some disconnects between these data sources. For example, the relatively high sales shares of CFLs in the 2011-2015 regional sales data, the known CFL stock saturation in 2011, and the widely accepted hours of use and lamp lifetime data yield model results that show CFL stock saturation in the Pacific Northwest continuing to increase through 2015. However, Massachusetts—another state with historically strong program activity—has seen stagnant CFL saturation in recent years. It is difficult to pinpoint the reason for this difference: it could be regional variation, unknown customer behavior such as removing or stockpiling lamps,[3] or uncertainty in the model's inputs. Future data—such as the next RBSA study—will provide a valuable check for these results and will inform whether the next iteration of this model will need to adjust turnover, stock, or sales inputs.

[3] The research team did apply a 5% uninstall rate to CFLs to account for early removal and/or higher storage rates for this technology. This factor reduces the CFL sales installed in the stock by 5%. The RBSA indicated that CFLs are about 11% more likely to be in storage than other technologies relative to their presence in the stock. The team performed sensitivity analysis on this input to inform the final reduction value. This is described in more detail in the Momentum Savings Methodology Memo.

Table 5: Regional Lighting Model Strengths and Weaknesses

Strengths	Weaknesses
Built bottom-up with Pacific Northwest-specific data. The building stock forecasts come from the Council's Seventh Plan, the lighting stock information comes from the RBSA, and all the market data is all from regional retailers. The research team also leveraged the RTF's hours-of-use assumptions.	**Backcast the base year.** The lack of reliable market data before 2011 required the research team to backcast technology trends to determine the technology mix for both 2009 and 2010. This means that the stock and sales technology mixes in these years are more uncertain than in 2011-2015. If this model is used to estimate Momentum Savings in the Seventh Plan period, this weakness will be resolved as the data leading up to 2015 is robust for both stock and sales.
Versatility. The richness of the available regional data allowed the research team to segment the model by year, application, technology, and lumen bin. As a result, the model can answer a wide variety of research and program planning questions.	**Result validity declines for very granular results.** The research team focused on calibrating the model sales and stock estimates for the largest lumen bins and applications that drive overall results. The results for smaller lumen bins and applications are more uncertain.
Easily updatable. The research team designed the model as a long-term regional resource. The incremental effort to update the model with more recent data and further explore the lighting market is relatively low.	**Does not account for early retirement.** Due to the lack of dependable information, the research team did not include an early retirement purchase trigger to account for residential customers proactively replacing functioning lamps prior to failure. The research team knows, anecdotally, that early retirement exists. However, it was unable to quantify early retirement rates or identify the most common replacement scenarios.
Forecasting capability. The model can estimate sales and stock dynamics into the future, giving researchers the opportunity to explore the effects of changing sales and stock mixes on market size and remaining efficiency potential.	**Statistical uncertainty.** Analytica, the model's platform, allows users to assess how sensitive the model results are to variations in a specific input. However, the research team did not conduct statistical uncertainty analysis due to the large number of inputs and the complexity of the modeling process.

Regional Lighting Trends

In addition to modeling regional lighting consumption and estimating Momentum Savings, the research team analyzed annual sales and shelf data from regional retailers to identify market trends and potential programmatic opportunities. The team combined these analytical findings with the qualitative market assessments provided by a wide range of interviewed market actors. These market actors included lighting manufacturers, several types of lighting retailers (traditional brick and mortar retailers, online retailers, and lighting showrooms), as well as residential remodelers and new home builders.

A (Different) Two-Technology Market

In 2011, residential customers looking to replace a general purpose lamp[4] had two choices: a less expensive and inefficient incandescent lamp or a more expensive but efficient CFL. Five years later, the market has dramatically shifted toward two different lighting technologies.

The research team found that the implementation of EISA, which increased its coverage annually between 2012 and 2014, was largely successful in its goal of eliminating the sale of the market's least efficient lighting technology: incandescent lamps. In just five years, incandescent lamps went from more than two-thirds of regional sales to just over 10%. This represents a technology change in more than half (56%) of the general purpose retail market. As shown in Figure 10, halogen lamps—the technology most commonly used for track lighting and torchieres prior to EISA—were redesigned for general purpose applications and quickly took over as the most popular low-cost, EISA-compliant lamp choice for regional residential customers.

CFLs have maintained their market share over the same period and boasted the second largest market share in 2015. In this market, however, remaining stationary means falling behind. At the same time that EISA addressed inefficiency at the bottom of the lighting market (regulating incandescent lamps), advancements in LED technology—and the corresponding drops in retail price—pushed efficiency at the top of the market, expediting the shift from CFLs to LEDs. The faster-than-anticipated evolution of LEDs coupled with increasing customer demand for the technology resulted in LED market share increasing from almost nothing (1% in 2011) to nearly one-quarter of the market (24%) in 2015. LED market share gains occurred largely at the expense of CFLs, which failed to compete with halogens as an EISA-compliant alternative to regulated incandescent lamps.

All signs point to LEDs overtaking CFLs as the leading efficient technology, perhaps even as early as 2017. In fact, GE announced in February 2016 that it would discontinue making CFLs altogether.[5] During the market actor interviews all manufacturers and retailers the research team spoke to were clear that they would shift away from CFLs and focus their resources exclusively on LEDs.

It remains to be seen how consumers will react to the removal of CFLs from the retail lighting market. Some market actors speculated that efficiency motivated CFL purchases so the majority of these customers would shift their purchases to LEDs instead. Others believed that halogens and LEDs will more equally absorb CFLs' vacated market share. Utility programs should keep a close eye on how consumers respond and in what proportions historical CFL purchasers transition to less (halogens) and more (LEDs) efficient lighting alternatives.

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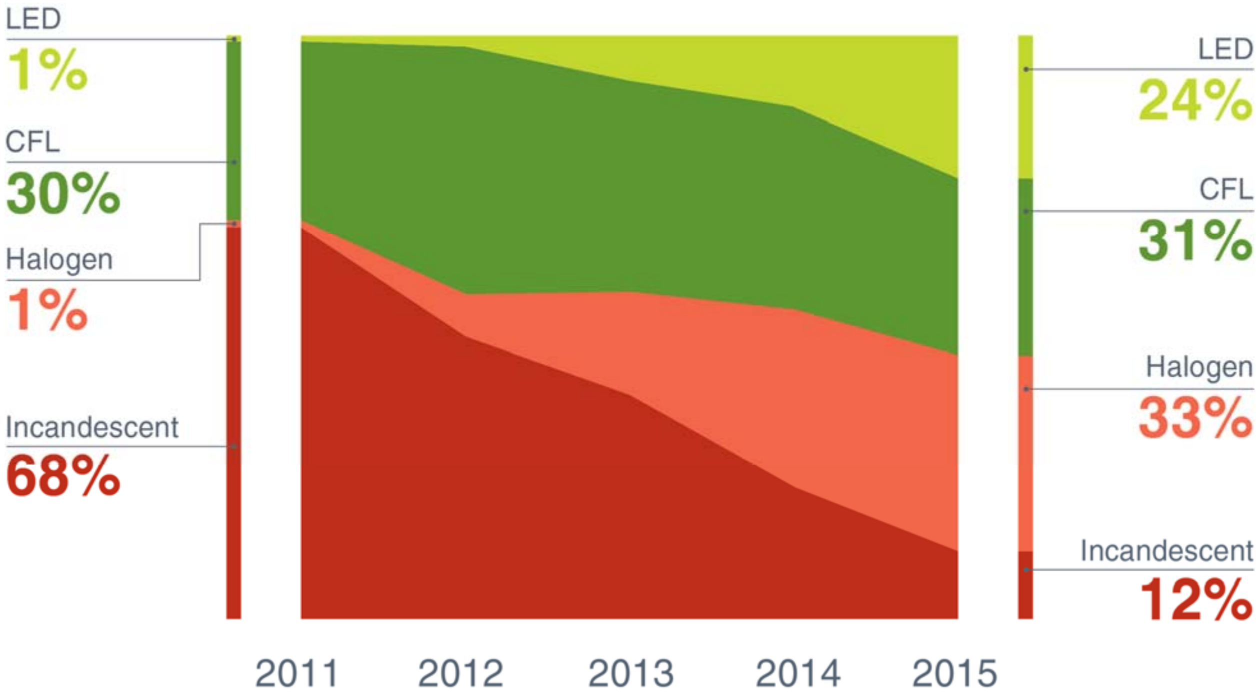
[4] i.e., A-line, medium screw-base lamps

[5] http://www.gereports.com/say-goodbye-say-hello-ge-stops-making-cfls-says-go-go-go-to-leds/

Figure 10: Regional Technology Trends in General Purpose Lighting: 2011-2015



Specialty Lamps: A Market of Their Own

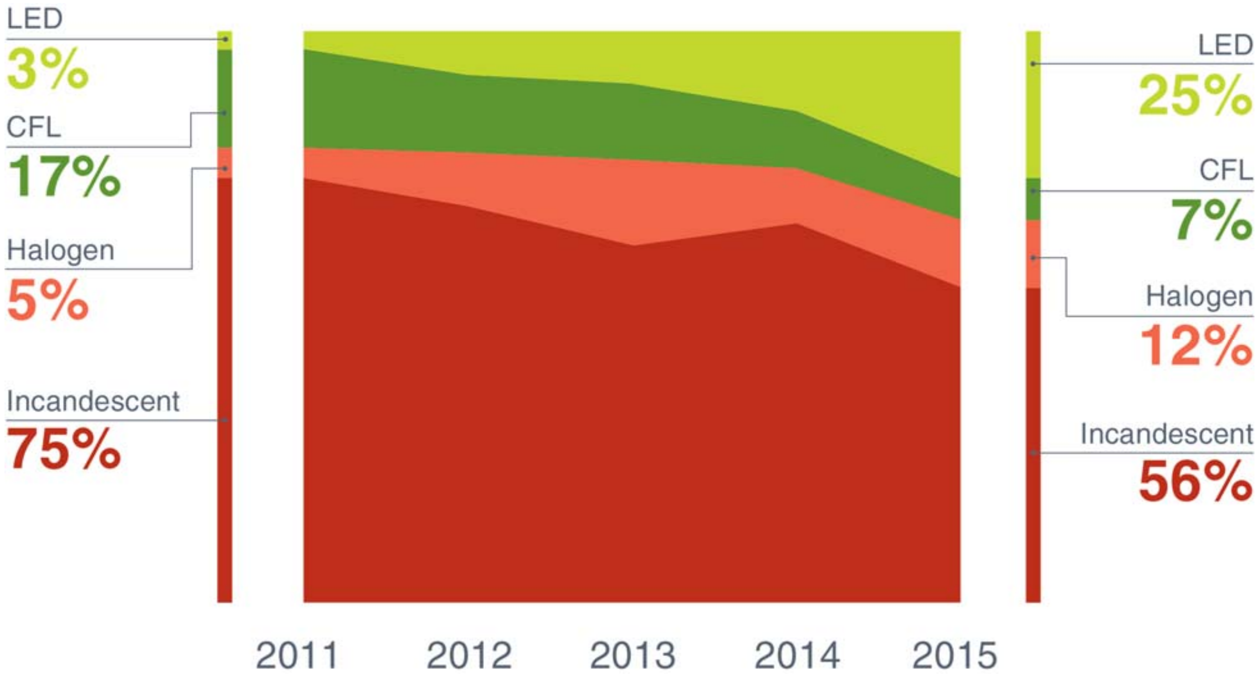
Specialty applications include reflector, decorative and mini-base, globe, and 3-way lamps. During its 2011 RBSA, NEEA found that nearly one-third of the region's residential sockets were home to a specialty lamp.

CFLs' departure from the market is on an expedited timeline when it comes to specialty lamps. As evident in Figure 11, LEDs have almost entirely cannibalized CFLs' share of efficient specialty sales over the past five years. LEDs, a more compact and inherently directional light source, are far better suited for most specialty applications. Consumers appear to agree as CFL's specialty lighting market share is down to 7% in 2015.

Incandescent lamps remain the dominant technology for specialty lamps due to EISA's various exemptions and out of scope designations. For example, incandescent reflector and bulged reflector lamps, which are outside EISA's scope, are two of the highest selling specialty lamps in the Pacific Northwest. Customers commonly install these reflectors in exterior fixtures, which have longer operating hours than interior fixtures. Indoors customers often install reflectors in recessed cans, a type of fixture that builders in the region are increasingly installing as part of residential remodels or in new construction. Whether outside and benefiting from longer operating hours or inside as part of a fixture growing in popularity, unregulated reflector lamps offer an opportunity for program savings.

In general, the high penetration of specialty lamps coupled with the perseverance of incandescent technology means specialty LEDs remain an opportunity for regional lighting programs—at least in the short term.

Figure 11: Regional Technology Trends in Specialty Lighting: 2011-2015



Market Forecast: More Change

The 2007 EISA legislation included a requirement that the US Department of Energy (DOE) revisit general service lamp (GSL) efficiency standards and finalize new efficiency requirements by January 2017. Since the updated standard will not become effective until January 1, 2020, industry stakeholders commonly refer to the impending standard as EISA 2020.

The DOE issued a Notice of Proposed Rulemaking (NOPR) for GSL in February 2016. The NOPR proposed efficacy requirements ranging from 70 to 105 lumens per watt (lm/W), depending on the lumen output of the lamp. The proposed efficacy range would have effectively prohibited the manufacturer of incandescent, halogen, and compact fluorescent lamps and established a requirement that only the most efficient LEDs currently on the market would meet.

Ultimately, the DOE decided not to adopt these, or any new efficacy requirements. As a result, a backstop requirement of 45 lm/W, which was included in the original 2007 legislation, will go into effect on January 1, 2020. However, the new administration and Congress will still have the opportunity to change or eliminate the backstop requirement before it goes into effect.

The 45 lm/W backstop, assuming it takes effect, would effectively eliminate halogens from the retail lighting market, while allowing manufacturers to continue producing CFLs. However, most interviewed manufacturers said they planned to transition away from CFLs, regardless of EISA 2020, and would focus their research and development and marketing resources on LEDs. As a result, it is unlikely the backstop provision, which would allow CFL production, will derail—or even meaningfully slow—the residential lighting market's inevitable movement toward LEDs.

Although the DOE did not propose new efficacy requirements as part of this rulemaking process, the DOE did expand the legislation's scope to include most of the lamps exempt from the current legislation. The expansion in scope will result in significant energy savings since previously exempted lamps, such as reflector and decorative and mini-base lamps, collectively represent nearly 30% of retail sales in the Pacific Northwest. The new scope also removes existing loopholes for rough service, shatter-resistant, vibration service, and 3-way lamps. In total, the new scope will cover 96% of the currently exempt lamps. Only a small number of low volume specialty categories like appliance lamps, black lights, bug lights, and infrared lights will continue to be exempt.

In addition to federal lighting standard changes, the DOE and Environmental Protection Agency (EPA) established a new ENERGY STAR lighting specification that became effective at the start of 2017. The new lighting specification, known as ENERGY STAR 2.0, increased efficacy requirements to reflect recent improvements in LED technology and capture greater energy savings. The new specification also increased the range of ENERGY STAR-eligible products to include connected and color-tunable lamps. While efficacy requirements increased for all lamp types, lifetime requirements actually decreased for omnidirectional (general purpose) lamps—from 25,000 to 15,000 hours. Also, the EPA is not grandfathering in any lamps from the previous specification, which means all lamps need to be reevaluated in order to maintain their ENERGY STAR qualification. Perhaps most notably, CFLs do not meet the new efficacy standard, which will hasten the technology's departure from efficiency programs and the retail lighting market in general.

Time to Get Creative

With the changes to federal lighting standards and ENERGY STAR specifications, it is clear that utility programs will need to continue to evolve. Programs will need to assess their current approach and consider a wide range of potential changes. These changes could include segmenting the retail lighting market more finely to focus on specific retailer type, lamp application, and customer combinations. Changes could also include approaching incentives differently. Alternative methods (e.g., gift cards or product bundling) and amounts may be necessary to encourage retailers to stock, and customers to purchase, the lighting products that still yield cost-effective savings.

One way to combat declining cost-effectiveness is to set program incentives with retailers in a manner that maintains their comparative pricing advantages and encourages lower pre-program prices for efficient lighting. An interviewed lighting retailer explained that because it has low, relatively fixed margins, it takes less program support (i.e., a smaller incentive) to get a lamp to a program's desired price point. The retailer felt that offering greater incentives to other retailers with higher margins (in order to reach the same price point) discouraged those retailers from offering their lowest price. Lighting programs should carefully consider differences in retailers pricing strategies when setting incentives and seek a balance between maximizing program expenditure and reaching the targeted customer segments.

Retailers also indicated that they are updating their lighting planograms—the schematic that depicts which products they will sell and where on the shelves those products will reside—more frequently to keep pace with changes in technology and consumer preferences. Several major retailers said they now update their planograms quarterly rather than annually or biannually. These retailers felt that utility programs should work more closely with them during these updates to focus program incentive funding on efficient lighting products that retailers planned for the most prominent shelf locations.

Online: The Emergence of a Viable Lighting Channel

The research team's interviews with market actors revealed that an increasing number of residential customers are purchasing their lights online. Estimates of the total percentage of retail lighting sales happening online differ, but market actors speculated the value is no less than 4% and no greater than 10%. To support this contention, one online market actor cited six consecutive years of double-digit year-over-year sales growth, while another pointed to a network of more than 30 lighting-focused online retail sites. All interviewees agreed growth will continue, both in terms of sales volume and the number of online lighting retailers. As a result, utility programs should also look to the online channel as a source of lighting savings.

From a program opportunity perspective, the research team found—based on the limited data available—that online retailers tend to sell more incandescent lamps than their traditional brick and mortar retail competitors. While the cause of the disparity is unknown, higher instances of incandescent sales may mean a less efficient base case and higher per-unit savings for programmatic sales online.

A robust online lighting channel also means that regional programs could work with these retailers to reach rural customers historically underserved by traditional in-store buy-down program models. Nearly universal access to the Internet means customers in rural communities could access the full gamut of incentivized efficient lighting products available in urban centers.

Going Direct

Large manufacturers such as GE, Philips, and OSRAM have always worked directly with major retailers. On the other hand, small and midsized manufacturers—those without vertically integrated production—have historically shepherded lamp components made by Chinese contract manufacturers to the US market. These small and midsized manufacturers, sometimes referred to as re-labelers, served as the intermediaries between the less-connected overseas contract manufacturers and traditional lighting retailers, leveraging well-known brand names and an established distribution network. Small and midsized manufacturers also have well-established relationships with utilities, regional organizations, and energy efficiency program administrators that offer lighting efficiency programs.

The research team learned that Chinese contract manufacturers are starting to take their products directly to both traditional and online US-based retailers. The good news is that consumers will see lower LED prices because of this supply chain streamlining. However, interviewed market actors, including those that work for the displaced small and midsized manufacturers, expressed concern that these new relationships may introduce lower quality products into the market since contract manufacturers, allegedly, do not have the same standards and quality control procedures. The validity of this argument remains to be seen as retailers reported they have their own quality standards and expectations. Regardless, consumers may not be overly concerned about an incremental drop in quality as long as the price is right.

Since utility programs have long worked with small and midsized manufacturers to administer their lighting programs, program managers may need to forge new relationships with market newcomers or increasingly rely on retailers. Program managers will also face new decisions, such as whether to promote LEDs that are not ENERGY STAR-qualified.

Research Portfolio

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RTF Baseline Methodology Memos

Market Actor Interview Findings Memos

[6] The research team provided this memo to BPA, and subsequently to the RTF, in May 2015. While developing the regional residential lighting model in 2016, the research team made a number of enhancements to the Chain Logic Method (which aggregates retailer-specific sales data and market shares to reflect regional averages) detailed in this memo. As a result, the 2014 market averages shown in this memo differ from the 2014 market averages used in the residential model and those used to calculate the Momentum Savings contained in this report. The research team has included the May 2015 memo in its original form, since the RTF used it for a measure update, but recommends readers refer to the final model, and associated export tables, for all market information for 2009 through 2015.

[7] Similar to the screw-in baseline memo, the 2014 market averages contained in the linear fluorescent lamp baseline memo (dated August 2015) differ from the 2014 market averages that the team used in the residential model and those used to calculate Momentum Savings. Again, the research team recommends that readers refer to the final model for all market information.

[8] The research team anonymized this memo for publication. The team previously provided BPA with a more detailed, but confidential, version of this memo for market research and program planning purposes.

[9] As with the Lightfair Findings memo, the team anonymized the ENERGY STAR Partner Findings memo for publication but provided a confidential version to BPA.

Appendix A – Residential Lighting Momentum Savings Methodology Memo

To: Jessica Aiona and Carrie Cobb, Bonneville Power Administration (BPA)

From: Navigant and Cadeo Residential Lighting Team

Date: March 13, 2017

Subject: Residential Lighting Momentum Savings Methodology

This memo documents the Navigant and Cadeo team's (the research team's) methodology for estimating residential lighting Momentum Savings for the Northwest Power and Conservation Council's (the Council's) Sixth Power Plan (Sixth Plan) period (2010-2015). The methodology follows Bonneville Power Administration's (BPA's) Four Question Framework, which is BPA's standard analytical framework for estimating Momentum Savings.

The first section of this memo summarizes how BPA typically uses the Four Question Framework. The next four sections detail the methodology the research team used to answer each of the Four Questions for the residential lighting market and describe the key data sources, technical decisions, and assumptions underpinning the results.

Momentum Savings Analysis Framework

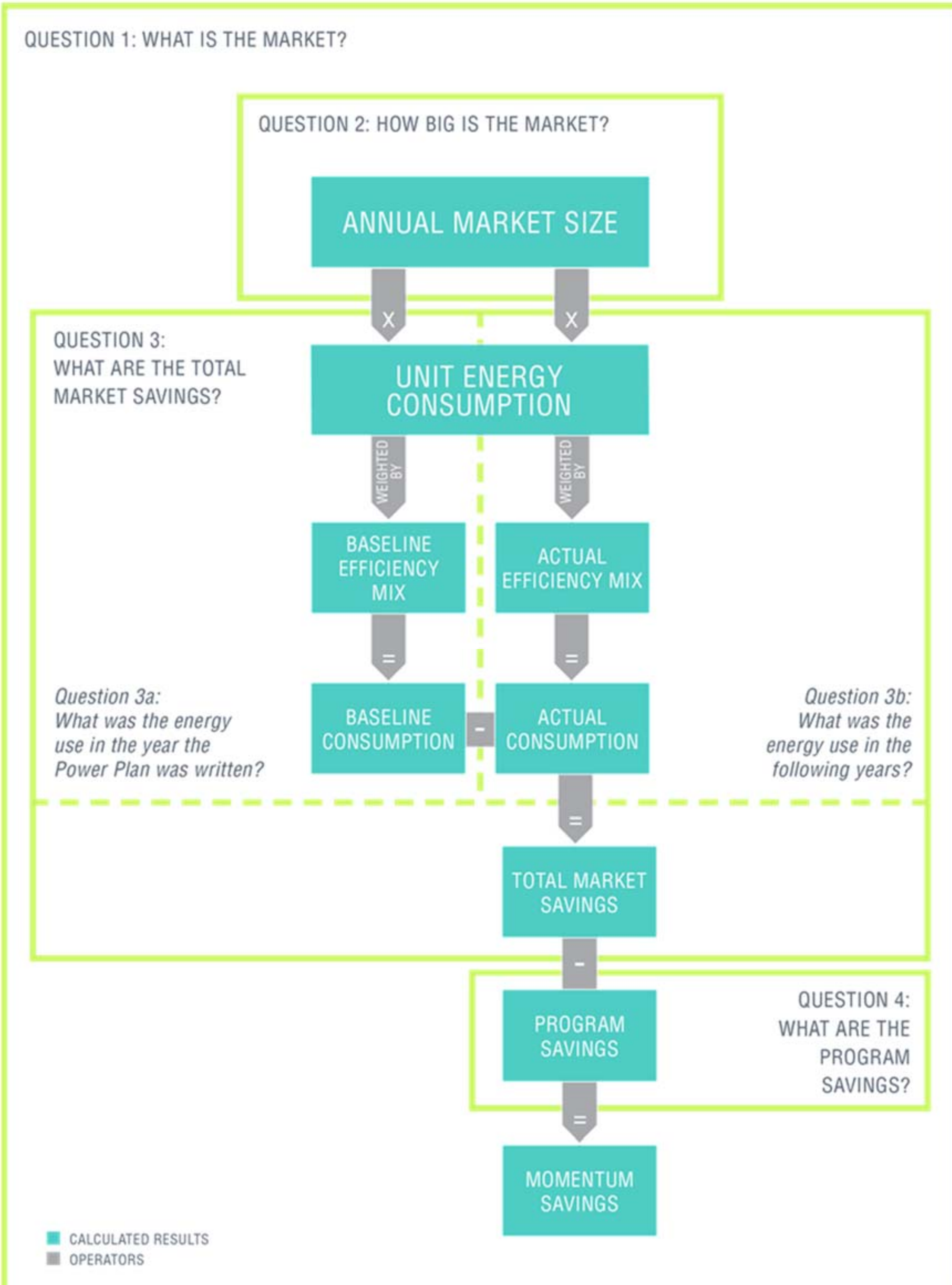
The research team organized its methodology, as well as this memo, around the following Four Questions:

1. What is the market?
2. How big is the market?
3. What are the total market savings?
4. What are the program savings?

Answers to these questions provide the data necessary to estimate Momentum Savings—the energy savings that occur above the Council's Sixth Plan frozen baseline and that are not directly incented by programs or claimed as part of Northwest Energy Efficiency Alliance's (NEEA's) net market effects. Figure A-1 summarizes how the questions fit together to estimate Momentum Savings.

While Momentum Savings analyses typically define the market in terms of sales, the research team defines the residential lighting market in terms of installed stock. As explained in more detail in the following sections, this change in approach was necessary because of the difference in the average lifetime (and, therefore, the turnover rate) of lamps between the baseline and actual cases. Regardless of the method of calculation, any resulting savings are solely the result of differences in the efficiency mix of sales between the actual and baseline cases.

Figure A-1: Overview of the Momentum Savings Analysis Framework



In the following sections, the research team answers each of the Four Questions for residential lighting.

Question 1: What is the market?

A complete and precise market definition clarifies the scope of the analysis. The research team defines the residential lighting market in the Pacific Northwest using the elements summarized in Table A-1 and discussed in detail in the remainder or this section.

Table A-1: Market Definition

Element	Definition	Notes
Product Scope	Screw-in lamps, linear lamps	Includes all Regional Technical Forum (RTF) categories
Unit of Account	Installed stock of lamps	Departure from typical Momentum Savings approach, which focused on sales
Sector and Housing Type	All residential housing types (single family, multifamily, and manufactured homes)	Includes multifamily units but excludes common areas in multifamily buildings
Geographic Scope	BPA service territory (Oregon, Washington, Idaho, and Western Montana)	Consistent with the Council's Power Plans
Purchase Triggers	Lamp failure and new construction	Model turnover is driven by lamp failure (e.g., replace-on-burnout); the research team did not identify reliable information to also include an early retirement purchase trigger

Product scope. At the highest level, the market definition—and, therefore, this Momentum Savings analysis—focuses on two residential lighting product categories: **screw-in lamps and linear lamps**. The research team further divided each of these product categories into their constituent applications and lumen bins (or, in the case of linear lamps, lamp length bins), as shown in Table A-2.

Not every lamp currently installed in the region falls into one of the lighting application and lumen bin/lamp length combinations found in Table A-2. However, the overwhelming majority do. According to the team's analysis of NEEA's Residential Building Stock Assessment (RBSA), 93% and 91% of the Northwest residential lighting stock by sockets and watts, respectively, fall into one of the model's application and lumen bin/length categories.[1]

[1] The majority of the lamps the research team excluded from the stock were defined in the RBSA in a way that precluded valid categorization for this analysis. For example, the RBSA lamp type data field held values of N/A or #N/A for some excluded lamps.

Table A-2: Market Definition by Lumen Bin or Lamp Length for Applications Included in the Analysis

Application	Lumen Bin/Lamp Length		
General Purpose	250-1049 lumens	1050-1489 lumens	1490-2600 lumens
Reflector	250-1049 lumens	1050-1489 lumens	1490-2600 lumens
Decorative and Mini-Base	250-1049 lumens	1050-1489 lumens	1490-2600 lumens
Globe	250-1049 lumens	1050-1489 lumens	1490-2600 lumens
3-Way*			250-2600 lumens
Outdoor General Purpose	250-1049 lumens	1050-1489 lumens	1490-2600 lumens
Outdoor Reflector	250-1049 lumens	1050-1489 lumens	1490-2600 lumens
Linear	2-foot**	4-foot	

**The research team assigned 3-way lamps to a single lumen bin (250-2600) due to the small number of 3-way lamps in the lighting stock as well as the lamp's ability to produce varying light outputs. **The analysis includes 2-foot linear lamps in the 4-foot length bin (e.g. one 4-foot lamp represents two 2-foot lamps).*

Three primary aims drove the research team's decisions regarding which applications to include and how to divide them:

1. Maximize the value of the available sales data by creating definitions to which the sales data, with its varying quality and granularity, could be mapped with integrity
2. Align the applications and lumen bins with regional definitions established by the Regional Technical Forum (RTF) and Council, where possible
3. Align definitions with the scope of federal regulations, where possible

Appendix 1d provides a more detailed description of the research team's rationale for defining applications and lumen bins.

Unit of account. This specifies the metric by which the research team quantifies the market. In this analysis, the team defined the unit of account as the installed lamp **stock**. That is, the research team defines the market by the number of lamps operating in residential homes in each year of the analysis period.[2] While the stock changes over time based on the **flow** of new lamps (i.e., annual sales[3]), the market's unit of measure for savings is the installed **stock**.

Sector and housing type. The market for this analysis includes the lamps listed in Table A-2 that are sold and installed in residential single family homes, manufactured homes, or multifamily units. The research team excluded common areas of multifamily buildings and all other non-residential applications from the analysis.

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[2] In contrast to other Momentum Savings analyses, this analysis arrives at its first-year savings estimate through an examination of the stock's energy consumption—not the flow.

[3] To simplify the terminology throughout this memo, the research team uses the term "sales" to describe the volume of new units flowing into the stock, although the term "new installations" would be more precise. The team recognizes that customers may not always purchase and install a lamp in the same calendar year.

Geographic scope. For this analysis, the market includes all lamps purchased and installed in Oregon, Washington, Idaho, and Western Montana.[4]

Purchase triggers. Purchase triggers—newly constructed homes, product failure, and early retirement—drive the purchase and installation of new lamps. The market definition for this analysis includes all identified residential lamps regardless of whether they were installed for new construction, replace-on-burnout, or early retirement. The research team considered tracking early retirement and replace-on-burnout purchase triggers separately. However, a lack of reliable information regarding the frequency and prevalence of early retirements prevented the team from creating a separate trigger. Instead, the team treated all non-new construction sales as replacement sales.

Question 2: How big is the market?

For this analysis, the market size is the number of in-scope lamps (as defined in Question 1) installed in residential homes in Oregon, Washington, Idaho, and Western Montana in a given year. In this section, the research team describes its methodology for estimating the market size.

Estimating Market Size

The market size—or the installed stock—is the product of the number homes in the region and the number of lamps per home in any given year. During the analysis period (2009-2015), the market size grew annually due to two factors: growth in the housing stock (new construction) and a higher number of lamps per home in new construction relative to the existing stock.

Housing stock. The research team used housing stock estimates from the Seventh Power Plan (Seventh Plan)[5] for each of the three housing types over the 2009-2015 analysis period. To align with the Seventh Plan, the team excluded housing stock in Eastern Montana from its analysis. The overall housing stock grew each year due to new construction.

Number of lamps per home. The research team used data from the 2011 RBSA to calculate the average number of lamps per home by application and housing type in 2011. By multiplying this number by the number of homes in the stock, the team calculated the total installed lamp stock for 2011.

To determine the number of lamps in each new construction home, the research team accounted for changes in home size (square feet per home) and lighting density (lamps per square foot). To calculate this, the team used the RBSA to develop a time series of lamps per square foot by year of construction. As shown in Equation A-1, the team multiplied the number of lamps per square foot in each year by the average square footage of newly constructed homes in that year to calculate the number of lamps per home in new construction.

[4] Because some of the data sources used for this analysis reflect all of Montana, the research team had to make adjustments to reflect only Western Montana. The team notes throughout this memo where it adjusted (or did not adjust) input data sources to exclude Eastern Montana.

[5] While the Sixth Plan is contemporary to the analysis, the housing counts it contains are a forecast rather than the actuals found in the Seventh Plan.

Equation A-1: Lamps per New Construction Home

$$\text{Lamps per Home in New Construction} = \text{Average Lamps per Square Foot} \times \text{Average New Construction Home Size}$$

The research team then calculated the number of lamps per home in existing homes in each year of the analysis by examining how new construction shaped the overall stock over time. Starting with the number of lamps per home in 2011 as estimated by the RBSA, this approach assumes that the existing stock of homes in any year is comprised of new construction homes from years prior and accounts for annual demolitions. Equation A-2 illustrates how the team calculated the time series of lamps per home in the existing stock starting in 2012, the year after the RBSA.

Equation A-2: Lamps per Home in All Stock

$$\text{Lamps per Home in All Stock}_{2012} = ((\text{Average Lamps per Home in New Construction}_{2012} \times \text{New Construction Homes}_{2012}) + (\text{Average Lamps per Home in Existing Stock}_{2011} \times (\text{Existing Stock Homes}_{2011} - \text{Demolitions}_{2012})) / \text{All Stock Homes}_{2012}$$

The total lamp stock in any given year is the product of the number of homes and the number of lamps per home in the stock. The research team developed a time series of total installed lamps in each year of the analysis period using Equation A-3, which is shown below.

Equation A-3: Installed Stock of Lamps

$$\text{Installed Stock of Lamps} = \text{Average Lamps per Home in All Stock} \times \text{Number of Homes in All Stock}$$

Table A-3 shows the resulting residential lighting market size for each year.

Table A-3: Total Installed Lamp Stock by Year

Year	Installed Lamps
2009	296,388,304
2010	297,555,570
2011	298,722,829
2012	300,504,309
2013	302,622,528
2014	305,336,907
2015	309,129,638

Source: Residential Momentum Savings Model

Question 3: What are the total market savings?

Total market savings are the difference between baseline energy consumption and actual energy consumption in average megawatts (aMW). If the actual market energy consumption modeled by the research team is lower than the baseline energy consumption in any given year, the difference is the total market savings. In this analysis the team compares the actual market consumption to two distinct baseline cases, each of which yields different estimates of total market savings.

Below the research team discusses the four key inputs that drive energy consumption in both the baseline and actual cases and then describes how and why the inputs vary in each case.

Calculating Annual Energy Consumption

Comparing the energy consumption of the baseline case to that of the actual case results in the savings for each year of the analysis period. By energy consumption, the research team means the annual energy usage of the total market as defined by Questions 1 and 2 (i.e., all installed lamps in the Northwest).

As shown in Equation A-4, the team calculates energy consumption based on installed lamp stock and the unit energy consumption (UEC) of each lamp type and age cohort. The team's model determines the number of installed lamps by simulating stock turnover, whereas the UEC comes directly from input assumptions.

Equation A-4: Energy Consumption

$$\text{Annual Energy Consumption}_{y} = \sum_{a,b,h,i,t} \left(\text{Installed Lamps}_{a,b,h,i,t,y} \times \text{Unit Energy Consumption}_{a,b,t,y=i}\right)$$

Where:

- a = application
- b = lumen bin
- h = housing type
- i = installation year
- t = technology
- y = year in the study period

The following sections describe the components that influence the energy consumption calculations. The first step is determining UEC estimates for each lamp type. The second step is determining how the energy consumption of the installed lamp stock changes over time, for which the model relies on three key factors:

1. Market size
2. Application (and lumen bin) mix in the installed stock
3. Efficiency mix of the installed stock

Unit Energy Consumption of Each Lamp Type

The first step in calculating the market's energy consumption is to determine the UEC associated with each lamp type. The UEC refers the amount of energy (kWh) a given lamp type consumes in one year. By "lamp type," the research team means each technology-application-lumen bin permutation. For example, one such permutation—or lamp type—is an incandescent, reflector lamp with a lumen output between 250 and 1049 lumens; another is a general purpose, LED lamp between 1050 and 1489 lumens. With up to four technologies and three lumen (or length) bins within each of the eight applications, there are 80 unique lamp types, each with its own UEC.[6] Each lamp type's UEC is a function of the average wattage and daily hours of use (HOU), as shown in Equation A-5.

Equation A-5: Unit Energy Consumption

$$UEC = \text{Average Wattage} \times \text{Hours of Use} \times 365.25$$

Each of these inputs is described below.

Average Wattage

The research team used the regional sales and shelf data, weighted using the Chain Logic Method (discussed in detail in The Chain Logic Method section below), to estimate the average wattage for each technology within each application and lumen bin. For example, Table A-4 shows the average wattage of general purpose lamps by lumen bin and technology in 2015. Since the efficacies of individual technologies have improved over time (most notably for LEDs), the research team computed a different average wattage for each year of the analysis period.

Table A-4: Average Wattage by Technology and Lumen Bin, General Purpose Lamps: 2015

Lumen Bin	Incandescent	Halogen	CFL	LED
250-1049	51	41	13	9
1050-1489	97	66	20	13
1490-2600	151	72	24	16

Source: Residential Momentum Savings Model

[6] There are 80 unique combinations (not 96) because the analysis uses a single lumen bin for three-way lamps, two length bins for linear lamps, and only two technologies (T8 and T12) for linear lamps.

Hours of Use

The research team used HOU data from the RTF's most recent baseline analysis.[7] The HOU inputs vary by application and lumen bin, but not by technology. Table A-5 shows the daily HOU for each application and lumen bin, which the team multiplied by 365.25 to estimate annual HOU.

Table A-5: Daily HOU by Application and Lumen Bin

Lumen Bin	General Purpose	Decorative and Mini-Base	Globe	Reflector	3-Way	Linear	Outdoor: General Purpose and Reflector
250-1049 (24 in)	1.77	1.92	1.33	2.40	1.85		
1050-1489 (48 in)	1.87	1.88	1.54	2.51	2.33	1.89	3.70
1490-2600 (96 in)	1.82	1.32	1.94	2.06	2.27		

Source: Regional Technical Forum

Using the above inputs, the research team calculated an average UEC for each application-lumen bin-technology permutation in each year of the analysis. Again, as an example, Table A-6 shows the results for general purpose lamps in 2015.

Table A-6: Annual UEC (kWh) by Technology and Lumen Bin, General Purpose Lamps: 2015

Lumen Bin	Incandescent	Halogen	CFL	LED
250-1049	33	26	8	6
1050-1489	67	45	13	9
1490-2600	100	48	16	11

Source: Residential Momentum Savings Model

Market Size: Number of Lamps in the Installed Stock

The market size is the total number of lamps installed in the Northwest in any given year. Because the research team defined the market as the total lighting stock (not lamp sales), the market size grew each year—due to new construction—between 2009 and 2015. However, it is important to note that the market size for any given year is the same in both the baseline and actual cases: what changes is the mix of technologies within each application.

Application (and Lumen Bin) Mix in the Installed Stock

The application mix reflects each lamp application's share of the total installed lamp stock. Because lamps of the same technology (e.g., incandescent) have different wattages across applications, the application mix must be taken into account to calculate the market's overall energy consumption.

[7] https://rtf.nwcouncil.org/measures/res/ResLighting_Bulbs_v4_2.xlsm

The research team derived the stock application mix using three steps. First, the team mapped each lamp type captured in the 2011 RBSA to one of the six lighting applications included in the market definition. Table A-7 shows how the team mapped RBSA lamp types to each modeled application, as well as which RBSA lamps types the team excluded from the analysis. As evident in the table, the RBSA lamp types the team excluded from the analysis are less common types that collectively represent approximately 9% of the total installed watts in the residential sector.

Table A-7: Model Applications Mapped to RBSA Lamp Types

Model Applications	RBSA Lamp Types	Count of Lamp Types	Share of Total Installed Residential Wattage
General Purpose (Indoor and Outdoor)	A-Shape Bulb, Circline (Screw Base), Clear, Colored, LED Exterior, LED Interior, Standard A-Lamp, Straight Tube, Twist	9	91%
Decorative and Mini-Base	Decorative, Mini-Base	2	
Globe	Globe	1	
Reflector (Indoor and Outdoor)	Flood, MR, PAR, Reflector	4	
3-Way	3-Way CFL, 3-Way Incandescent	2	
Linear	T-12, T-8	2	
Excluded	Fluorescent Other, Fluorescent Unknown, Heat Lamp, High Pressure Sodium, Low Pressure Sodium, Mercury Vapor, Metal Halide, Other, Pin base, Quartz Tube, T-4, T-5	12	9%

Source: Research team analysis of NEEA's 2011 RBSA

Second, the research team assigned each lamp in the RBSA to a lumen bin within each application. Because the RBSA does not collect the lumen output of each inventoried lamp, the team estimated lumen output by multiplying each lamp's wattage by the average efficacy (lumens per watt) for that specific technology in 2011. After estimating each lamp's lumen output, the research team calculated the share of lamps in each of the lumen bins in each application. The team excluded lamps with lumen outputs that fell outside of the lumen range given by the market definition (either <250 or >2600 lumens) from the analysis. Because the defining characteristic of the linear fluorescent lamp application is lamp length, not lumen output, the research team divided the linear application into the two most common residential lamp lengths: 2-foot and 4-foot. The team excluded all other lengths from the analysis.

The third step to develop the stock application mix was to create additional application mixes for exterior applications. The research team developed the same data cuts (application and lumen bin) for the RBSA's exterior lighting datasets. However, the team opted to include only exterior applications for general purpose lamps and reflectors in the analysis since these applications constituted 89% of all outdoor lamps. The research team allocated the lamps to each application and lumen bin based on the combined interior and exterior weighted lamp counts, with the sum of all applications and lumen bins totaling 100% in each housing sector and geography.

The team calculated these application and lumen bin mixes for each of the three housing types: single family, multifamily, and manufactured homes and assumed the application mix was constant throughout the analysis period for each housing type.

Efficiency Mix of the Installed Stock

The efficiency mix of the installed stock is the fourth key input to the calculation of total market energy consumption in each year. It is a function of several variables, the most important of which is the efficiency mix of *sales* in prior years. Conceptually, the stock is simply the accumulation of prior years' sales: the more efficient the sales mixes, the more efficient the resulting stock mix.

Momentum Savings analyses have typically focused on first-year consumption of the market's actual *sales* mix because that allows for a direct comparison to the efficiency mix implied by the current practice baselines assumed in the Council's Power Plans. However, as discussed in the introduction and in Question 1, this analysis defines the market *as the installed stock*. As such, total energy consumption in any given year is a function of the total number of lamps in the stock and the average UEC of *those lamps* (rather than the average UEC of the lamps sold in the market).

In this stock-focused approach, the comparison between the baseline sales mix and actual sales mix is still the driver of savings. The difference is that the savings occur by comparing two installed stock efficiency mixes: one that results from the assumed baseline sales mixes year after year and one that results from actual sales mixes year after year. Put differently, instead of comparing the baseline and actual sales mix to calculate savings, the research team compares how those respective sales mixes *change the installed stock*.

To estimate the installed stock efficiency mix in any given year, four primary inputs are required:

1. Characterization of the installed stock (size, mix, and age of the lamps in the stock)
2. Estimate of how fast the existing stock turns over each year
3. Estimate of how fast the stock grows due to new construction in each year
4. Efficiency mix of sales in each year of the analysis period

A stock turnover model, summarized in Figure A-2 and described immediately below, drives the first three of these inputs. A description of the team's method for estimating the efficiency mix of sales in each year, the fourth primary input, follows.

Stock Turnover Model

The underlying premise of the stock turnover model is that lamp sales are triggered when lamps in the existing housing stock fail and require replacement. The model calculates failures in the existing stock based on the age and average life (in years) of each lamp in the stock. For example, if a given lamp has a three-year life then lamps of that type installed in 2009 should, on average,[8] fail in 2012, triggering sales in that year.

Figure A-2 illustrates the key components of the stock turnover model in calculating the installed stock's turnover (replacement sales) and growth (new constructed homes). The following sections discuss each of these components.

Figure A-2: Stock Turnover Method for Estimating Turnover

Stock Turnover Logic

Three key inputs drive the calculation of how quickly the stock turns over (and, therefore, how quickly the stock efficiency mix can change) in the research team's stock turnover model.

1. **Mix and age distribution of lamps in the initial installed stock.** The number of lamps in the stock that will fail in a given year depends on the age distribution and the technology mix of the lamps in the stock. Accordingly, the research team developed an age and mix distribution of the installed stock in the initial year (2009) of the analysis period.[9] The team details its method of backcasting from the 2011 RBSA installed stock in Appendix 2d.
2. **Average lifetime of each of the lamp types that make up the installed stock.** The research team used lamp lifetimes that are consistent with the US Department of Energy's (DOE's) recent

[8] This is a simplified example meant to illustrate the replacement cycle conceptually. In reality, the model employs survival distributions such that the population of lamps (in this example) would fail, on average, after three years of use.

[9] In contrast to other stock turnover models, the research team did not assume the lamp stock turns over at a rate of 1/lifetime, as this common stock modeling assumption is inappropriate for the lighting market. When competing technologies in a market have different lifetimes (such as with lighting) and the mix of those technologies has not been stable in the stock (such as with lighting), one must estimate the age of each lamp in the stock to predict when it would fail (on average).

models of national LED adoption.[10] Table A-33 provided in Appendix 2a details these lifetimes by technology.

3. **HOU of the lamps.** Operating hours vary by application. As discussed in Table A-5, the research team used the operating hours determined through the 2011 RBSA metering study[11] and used by the RTF for its most recent residential lighting measure update (v4.2).[12] It is important to note that the team adjusted the RBSA HOU data to align RBSA application-specific HOU values with the set of applications in the model. Since HOUs vary by room type, the team weighted each of these values to account for the prevalence of each application and lumen bin in each RBSA-designated room type.

Taken together, the lifetime and operating hours of each unique lamp type (e.g., incandescent general purpose lamp, LED reflector lamp, etc.) in the stock determine the frequency with which it fails, on average. For example, if an incandescent general purpose lamp has a lifetime of 1,000 hours and the research team assumes lamps of this type operate (are turned on) for 500 hours per year, then the team can expect these bulbs to fail, on average, after they have been in the stock for two years. Using the count and age of each lamp type in the stock, the stock turnover model determines the number of failures by lamp type and the corresponding number of replacement lamps in any given year.

The model employs failure distributions for each technology; these prescribe the percentage of lamps of a certain age that will fail in any given year. The failure distribution is based on a Weibull distribution having a mean value equal to each lamp's expected lifetime (as described above), along with a shaping factor of five.[13] The Weibull distribution assumes that a greater portion of lamps fail before the expected lifetime as opposed to a normal distribution, which would assume equal numbers of lamps failing before and after the mean (expected) lifetime.

Replacement sales are calculated as shown in Equation A-6 through Equation A-8.

Equation A-6: Failure Distribution

$$\text{Failure Distribution}_{a,b,g,t,y} = \text{Weibull Distribution}\ (\text{Mean Lifetime}_{a,b,t,y=i}\ ,\ \text{Shaping Factor})$$

Where:

a = application

b = lumen bin

g = age

h = housing type

i = installation year

t = technology

y = year in study period

[10] http://energy.gov/sites/prod/files/2015/07/f24/led-adoption-report_2015.pdf

[11] https://neea.org/docs/default-source/reports/residential-building-stock-assessment--metering-study.pdf?sfvrsn=6

[12] http://rtf.nwcouncil.org/measures/res/ResLighting_Bulbs_v4_2.xlsm

[13] The value of the shaping factor is consistent with the US DOE lighting market model.

The model tracks the age of every installed lamp, which allows the research team to apply the appropriate failure percentage to each age cohort. For every year of the study period, the model predicts the quantity of lamps that fail from each age cohort using Equation A-7.

Equation A-7: Failures by Vintage

$$Failures_{a,b,h,i,t,y} = Lamp\ Stock_{a,b,h,i,t,y} \times Failure\ Distribution_{a,b,g,t,y=i}$$

Those failures are then subject to replacement. Upon replacement, a lamp may switch from one technology to another depending on the sales mix for that particular year. Though the technology can change, the lumen output (or length) of the lamp remains the same.

Equation A-8: Replacements

$$Replacements_{a,b,h,t,y} = \left(\sum\nolimits_{i,t} Failures_{a,b,h,i,t,y}\right) \times Sales\ Mix_{a,b,h,t,y}$$

Stock Growth

In addition to changes in the existing stock mix due to the stock turnover function described above, the installed stock of lamps grows over time due to new construction. If the overall sales mix is different than the existing stock mix (which is almost always the case), this stock growth impacts the stock's overall efficiency mix, albeit slightly. The research team described the method of calculating new construction stock in Question 2 above.

Sales Efficiency Mixes

The sales efficiency mix is the final critical input to determine how the overall stock efficiency mix changes. The sales efficiency mix is the market share of products sold in a given year at each different efficiency level. For the purposes of this analysis, efficiency levels correspond to four technologies: incandescent, halogen, compact fluorescent, and LED. While the stock turnover logic and stock growth inputs determine how many lamps flow into the installed stock each year, the sales efficiency mix determines *how* efficient those lamps are.

The analysis uses three different sets of efficiency mixes: two represent alternative baseline scenarios and one represents the actual market as observed by available retail sales and shelf-stocking data. Below the research team discusses the two baseline sales efficiency mixes and then describes how it estimated the actual sales mixes.

In each scenario, the model's total sales volume is driven by lamp failures and does not include any lamp purchases that might go into storage. Since the 2011 RBSA found that CFLs were overrepresented in storage relative to their share of the stock—CFLs in storage were 23% of the sum of all CFLs installed and in storage; this value was 12% for incandescents and other technologies. This implies that 11% more CFL sales go into storage than other technologies, either due to bulk purchasing or equipment removal. To account for this effect the research team applied a 5% uninstall rate to the CFL sales.[14] During the

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[14] The research team used 5% because this value could decrease over time as customers realize that CFLs do not burn out as often.

calibration process, the team performed sensitivity analysis on this parameter to gauge the effect on model results, specifically ensuring that the CFL stock saturation share aligned with the 2011 RBSA data.

Baseline Efficiency Mix

Unlike other Momentum Savings analyses, the research team developed two different baseline efficiency mixes for this model: a frozen efficiency baseline and an RTF baseline. These two baselines provided two different scenarios against which the team measured total market change. Each baseline scenario offers a different perspective on the change in regional residential lighting energy consumption between 2009 and 2015. The frozen baseline offers an estimate of total market change since 2009, while the RTF baseline estimates market savings relative to the baseline used by most regional utility lighting programs. The research team describes each baseline efficiency mix in detail below.

Frozen efficiency. The first baseline efficiency mix freezes the market efficiency mix of sales in the model's base year (2009) for the duration of the analysis (2010-2015). The research team determined and applied the 2009 average market efficiency mix for each application and lumen bin; Table A-8 shows the largest lumen bin in the general purpose application.[15] The method for calculating the efficiency mix in 2009 is the same as the method for estimating the actual efficiency mix, which is described below. These shares include the 5% CFL adjustment described above.

Table A-8: Frozen Efficiency Baseline Mix, General Purpose Bulbs (250-1049 Lumens)

Year	Incandescent	Halogen	CFL	LED
2009	71%	0%	29%	0%

Source: Residential Momentum Savings Model

RTF baseline. The second baseline case allows the baseline efficiency mix to change over the analysis period to be consistent with the RTF's baseline for that year. In the case of the RTF baseline, the overall baseline market efficiency of sales increases over time in contrast to the frozen baseline case, in which the baseline sales mix is constant.[16] Figure A-3 shows the timing of the RTF baseline updates.

[15] When viewing results, reviewers may notice that average technology mixes—and, therefore, efficacies and wattages—do vary slightly at the application level. This is due to the different technology mixes by lumen bin: since lifetime varies by technology, each lumen bin turns over at a different rate. This leads to variations in the sales mix over time at the application level.

[16] Note that while the sales mix remains constant, natural turnover results in changing stock consumption in the frozen baseline over time because the 2009 sales mix is more efficient than the 2009 stock.

Figure A-3: RTF Baseline Updates[17, 18]

<table>
<tr><th></th><th>LED</th><th>CFL</th><th>Specialty CFL</th></tr>
<tr><td>4/10/2010</td><td></td><td>Incandescent lamp (CFL 1.5)</td><td></td></tr>
<tr><td>6/1/2011</td><td></td><td rowspan="3">Incandescent lamp, capped at EISA (CFL 2.1)</td><td></td></tr>
<tr><td>12/11/2012</td><td></td><td rowspan="3">Incandescent lamp (Specialty CFL 1.3)</td></tr>
<tr><td>8/20/2013</td><td rowspan="2">RBSA, adjusted for EISA and IRL (LED 3.0)</td></tr>
<tr><td>10/15/2013</td><td>RBSA, adjusted for EISA and IRL (CFL 3.0)</td></tr>
<tr><td>4/23/2014</td><td colspan="3">RBSA, adjusted for EISA and IRL (3.3)</td></tr>
<tr><td>8/18/2015</td><td colspan="3">Shelf/Sales data, adjusted for EISA and IRL (4.1)</td></tr>
</table>

Source: Regional Technical Forum

With a time step of one year, the model cannot directly replicate the midyear timing of each RTF baseline change. Therefore, the research team rounded the RTF updates to the nearest year (considering the Energy Independence and Security Act of 2007's [EISA's] implementation schedule) and grouped the RTF's separate LED and CFL baselines into a combined general purpose application.

This process resulted in the research team converting Figure A-3 into Table A-9, which shows the baselines used in the model for the general purpose application and all specialty applications (reflectors, decorative and mini-base, globe, and 3-way). Table A-9 also cites the relevant RTF residential lighting measure workbook that the team used to develop the baseline. The research team extracted the baseline efficiency mix in terms of both the technology and average wattage from these RTF workbooks.

[17] EISA refers to The Energy Independence and Security Act of 2007; IRL refers to the Incandescent Reflector Lamp Standard that was finalized in 2009 and came into effect in 2012.

[18] The information in parentheses (e.g., CFL 1.5) indicates the relevant RTF residential lighting measure workbook version.

Table A-9: Adjusted RTF Baselines by Year and General Purpose/Specialty

Year	General Purpose	Specialty
2010	Incandescent (CFL v1.5)	Incandescent (Specialty CFL v1.3)
2011	Incandescent (CFL v2.1)	Incandescent (Specialty CFL v1.3)
2012	Incandescent lamp. Capped at EISA levels for 2012 (100 > 72W) (CFL v2.1)	Incandescent (Specialty CFL v1.3)
2013	Incandescent lamp. Capped at EISA levels for 2012 (100 > 72W) and 2013 (75W > 53W) (CFL v2.1)	Incandescent (Specialty CFL v1.3)
2014	RBSA (Called for EISA; all levels) (CFLandLEDLamps v3.3)	RBSA (Called for EISA; all levels) (CFLandLEDLamps v3.3)
2015	RBSA (Called for EISA; all levels) (CFLandLEDLamps v3.3)	RBSA (Called for EISA; all levels) (CFLandLEDLamps v3.3)

Source: Research team analysis of Regional Technical Forum data

Table A-10 shows the year by year efficiency mix assumed in the RTF baseline scenario. Again, the research team uses the general purpose lamp—the most prevalent application—as an example.

Table A-10: RTF Baseline Mix, General Purpose Lamps

Year	Incandescent	Halogen	CFL	LED
2010	100%	0%	0%	0%
2011	100%	0%	0%	0%
2012	92%	8%	0%	0%
2013	81%	19%	0%	0%
2014	0%	61%	39%	0.6%
2015	0%	61%	39%	0.6%

Source: Research team analysis of Regional Technical Forum data

Actual Sales Efficiency Mix

The actual sales efficiency mix in each year of the analysis is the primary driver of total market savings. The research team used a two-pronged approach to estimate the actual sales mixes in each year of the analysis period. First and foremost, the team relied on any and all available sales data and other market data to estimate the sales mix whenever possible. Second, the team calibrated the stock turnover model to those estimates and used the model's turnover logic (described above) to backcast sales mixes in years where no data was available. Specifically, the team had sufficient market data to estimate the market's efficiency mix from 2011 to 2015 using a methodology called the Chain Logic Method, which is described in the following section. The team backcast sales mixes for 2009 and 2010 using the stock turnover model.

The Chain Logic Method

The Chain Logic Method is an analytical framework for logically combining disparate data sources to estimate a given market's sales efficiency mix. Ultimately, it provides a means of weighting various data points into a market average—in this case, the market average efficiency mix in each year of the analysis.

The research team followed a six-step analytical process to estimate the efficiency mix:

- Step 1: Develop the efficiency mix for each retailer for which the team has data
- Step 2: Segment the market into distinct channels; assign a market share to each market channel
- Step 3: Assign each retailer to a market channel (i.e., market segments)
- Step 4: Determine the relative market share of each retailer within each channel
- Step 5: Compute each retailer's market share of the overall market
- Step 6: Compute the overall market efficiency mix

Step 1: Develop the Efficiency Mix for Each Retailer for Which the Team Has Data

For the purposes of this analysis, an efficiency mix reflects the market share of lamps sold in a given calendar year among four technologies: incandescent, halogen, compact fluorescent, and LED.

Data Sources

The research team used three primary data sources to characterize the efficiency mixes of individual retailers: NEEA shelf-stocking data, Nielsen sales data, and online retailer sales data. The following describes each of these data sources as well as others that the research team reviewed to corroborate the primary data analysis.

NEEA shelf-stocking data. Since 2005, NEEA has undertaken the Northwest Residential Lighting Long-term Market Tracking (LTMT) study. NEEA uses the study, repeated on an annual basis, to track regional lighting market metrics and to estimate the market transformation savings generated by its previous CFL program. NEEA completed the most recent report in 2015.[19] The LTMT study explores a wide variety of lighting topics including customer awareness, retailer/manufacturer perceptions of efficient products, and stocking practices. It is the latter resource—shelf-stocking data—that is of particular interest to the research team, as it provides insight into purchasing preferences for each year.

The research team is aware that stocking practices do not perfectly reflect consumer purchasing behavior, as merchandising strategies and other market factors greatly affect the product volume and placement on shelves. However, the team determined during interviews with major do-it-yourself (DIY) and mass merchandise retailers that these retailers develop their shelf planograms with the goal of achieving a 1:1 ratio between the number of products on the shelves and actual sales. These retailers explained that the goal of aligning shelf space and sales is mainly about restocking efficiencies: ideally these retailers want to restock everything at once each night. They shared that stocking the shelves to mirror sales levels enabled this process and avoided inefficient, ad hoc restocking throughout the day.

Nielsen sales data. To complement the shelf-stocking data collected through the LTMT study, NEEA purchased retailer sales data gathered by Nielsen, a consumer insights company. Unlike the shelf-stocking data, the Nielsen data reflects the actual sales that occurred annually from 2011 through 2015 for a subset

[19] https://neea.org/docs/default-source/reports/northwest-residential-lighting-long-term-market-tracking-study.pdf?sfvrsn=4

of contributing retailers. The Nielsen data is extremely detailed and provides insight into sales by technology, wattage, lumen bin, and pack size. However, the Nielsen data is not fully representative of the entire residential retail lighting market, as several high-volume lighting retailers do not provide sales data to Nielsen. The research team estimates that the retailers providing data to Nielsen represent approximately 23% of the total residential retail market.

Online retailer sales data. As part of its ongoing non-residential lighting distributor data collection efforts, BPA solicited 2015 sales data from a prominent online retailer. Based on customer information and shipping addresses, the online retailer estimated that 30% of its total sales (in terms of units) are to residential customers.

The research team also reviewed the following sources which were not directly incorporated into the analysis:

CLEAResult-tracked retailer data. The CLEAResult dataset is a mixture of program and non-program lamp data collected from Northwest retailers. However, the dataset is limited: it only includes CFLs and LEDs (i.e., no inefficient technologies); it does not include any stock keeping unit details; and it is a mixture of actual and estimated sales.

The research team compared the CLEAResult data with the Nielsen sales and NEEA shelf-stocking data above. The research team found that the CLEAResult data was generally similar with regard to technology and lamp type mixes to the Nielsen and NEEA data. This finding validated the team's decision to rely primarily on the Nielsen and NEEA data, which are more detailed and comprehensive (i.e., contain efficient and inefficient technologies) than the CLEAResult data. The research team was able to use the CLEAResult data, which reports sales by retailer, to develop the team's market share estimates for individual retailers.

National Electrical Manufacturers Association (NEMA) shipment data. The research team compared annual results for the Pacific Northwest to national sales data reported by NEMA. The team found the regional data generally mirrored national trends, which validated the reasonableness of its regional data sources. It is important to note that NEMA shipment data is limited to general purpose lights only.

Data Cleaning and Mapping

Each of the raw datasets uses different naming conventions for bulb shapes, bases, and technologies. The research team created standardized naming conventions in order to map the data to its model applications. The lamp types for the analysis and lamp styles from the data assigned to each are shown in Table A-11. To the extent possible, the research team matched the binning choices made by the RTF in the current measure workbook.

Table A-11: Summary of Lamp Styles and Base Types by Application

Application	Lamp Types Included	Base Types Included
General Purpose and Dimmable	A-Lamp, Spiral/Twister, Edison, Tube	Medium, Intermediate
Globe	Globe	Medium, Intermediate
Reflector	Downlight, PAR, Reflector, MR Type	Medium, Intermediate
Decorative and Mini-Base	C-Type, Chandelier, Decorative, Globe, T Type	Candelabra, European (E14), Mini Candelabra
3-Way	A-Type, Reflector, Globe, Tube	Medium, Intermediate
Linear	T12, T8, T5	Pin Base

Step 2: Segment the Market into Distinct Channels; Assign Market Share to Each Market Channel

There are many ways to segment a market. The research team elected to divide the residential brick and mortar retail market into three channels: DIY home stores (e.g., Home Depot, Lowe's), mass merchandise retailers and club stores (e.g., Walmart, Costco), and small hardware (e.g., ACE Hardware, True Value Hardware). The team chose these channels, first and foremost, because it had foundational data on the market share associated with these groupings, which a major retailer presented at the 2014 ENERGY STAR Partners Meeting. Additionally, these categories left little doubt as to what stores belonged to them, reducing any uncertainty in assigning retailers to the correct channel.

This channel share data did not include the online sales channel. The research team estimated the share of residential lighting sold through the online category based on a November 2015 interview with a prominent online retailer, as well as the team's subsequent analysis of that retailer's 2015 unit sales data by sector. Using this information, the research team estimated that approximately 4% of total residential lamp purchases are made online. The team reduced the market shares of the three brick and mortar channels proportionally, resulting in the channel shares shown in Table A-12.

Table A-12: Market Share by Retailer Channel, Including Online

Retailer Channel	Market Share
DIY	50%
Mass Merchandise and Club Stores	32%
Small Hardware	14%
Online	4%

Source: Research team analysis of sales and interview data

Step 3: Assign Each Retailer to a Market Channel (i.e., Market Segments)

The research team then assigned each retailer in the Nielsen data, NEEA's shelf-stocking data, and the online channel data to one of the market channels (Table A-13). Each retailer could belong to only one channel.

Table A-13: Retailers by Retail Channel

Retailer Channel	Retailer
DIY	The Home Depot
	Lowe's
Mass Merchandise and Club Stores	Walmart
	Target
	K-Mart
	Fred Meyer
	Costco
	Sam's Club
	Other Mass Merchandise and Club Store Retailers
Hardware	Ace Hardware, True Value Hardware
	Other Small Hardware
Online	Bulbs.com
	1000Bulbs.com
	Amazon

Source: Research team analysis

Step 4: Determine the Relative Market Share of Each Retailer within Each Channel

Next, the research team estimated the market share of each retailer within its market channel. For the DIY and hardware categories, the team used retailer store counts in the Pacific Northwest (obtained from retailer websites in 2016) as well as the average number of lamps stocked by each retailer (determined through NEEA's shelf studies) to estimate each retailer's relative market share within each retailer channel.

Since NEEA's lighting LTMT did not visit every retailer within a given channel, the research team created an "Other" category to reflect the market share held by these retailers. The team used professional judgment to assign channel market shares to the "Other" hardware and mass merchandisers retailer categories.[20] The research team assumed the efficiency mix of the retailers associated with the "Other" designation was the weighted average of the known retailers in that category. Table A-14 provides an illustrative example of this methodology.

[20] The research team worked with regional program staff to determine that insufficient DIY retailers existed—beyond those visited through the LTMT—to merit creating a similar "Other" category for the DIY channel.

Table A-14: Example of Retailer Share Calculation for Hardware Channel, Including Other

Retailer	Store Count (A)	Average Lamps/Store from Shelf Survey (B)	Total Regional Lamps Stocked (A*B)	Market Share
Hardware #1	30	500	15,000	23.75%
Hardware #2	60	750	45,000	71.25%
Other Hardware	N/A	N/A	N/A	5.0%

Note: Illustrative example, not actual data.

The research team followed this same approach for the DIY channel, the hardware channel, and—with one modification—the mass merchandise and club channel. The modification resulted from the research team having actual sales totals for one retailer in this latter category from CLEAResult and the sales total of all other retailers in the category from Nielsen. The team used these two sales totals to estimate the channel market share of the single retailer. The team then assigned the remaining market share to the other retailers in the channel using store counts and average lamps per store data, as described above for the hardware stores.

The team only had sales data from one retailer in the online channel, so it extrapolated that retailer's efficiency mix to the entire online channel because that retailer estimated its mix was consistent with the others in the channel.

Retailer market share over time. The retailer store counts, shelf data, Nielsen data, and CLEAResult data that informed the calculation of retailer market shares were based upon 2014 data. The research team held the retailer market shares constant across the analysis period due to lack of information about shifts in retailer market share between 2011 and 2015.

Step 5: Compute Each Retailer's Market Share of the Overall Market

The research team then converted each retailer's market share within each channel into a market share of the total market. To do this, the team multiplied each retailer's market share within each channel by the market share of the channel to which the retailer belonged. For example, as shown by the illustrative data in Table A-15, the DIY 1 retailer has a 55% share of the channel to which it belongs, while the channel itself constitutes 50% of the market. Taken together, that means the DIY 1 retailer has 27.5% of the overall market. The final share represents the weight applied to the efficiency mix calculated in this retailer's sales data.

Table A-15: Example of Combining Channel and Retailer Market Shares (Illustrative Only)

Channel	Market Share of Channel	Vendor	Vendor Market Share of Channel	Vendor Market of Overall Market
DIY	50%	DIY 1	55%	27.5%
		DIY 2	20%	10.0%
		DIY 3	25%	12.5%

Note: Illustrative example, not actual data.

Step 6: Compute Overall Market Efficiency Mix

After estimating each retailer's efficiency mix (Step 1) and overall market share (Step 5), computing the market's overall efficiency mix is done by taking the weighted average of those two results. Table A-16 shows the actual technology mixes the research team calculated using the Chain Logic Method as described.

Table A-16: Estimated Actual Efficiency Sales Mixes by Year, General Purpose Bulbs (250-1049 Lumens)

Year	Incandescent	Halogen	CFL	LED
2011	63%	0%	35%	1%
2012	49%	6%	42%	2%
2013	42%	18%	31%	10%
2014	23%	31%	30%	16%
2015	9%	34%	27%	30%

Source: Research team analysis of sales and shelf data

The research team made select adjustments to individual application and lumen bin efficiency mixes from this analysis when there was insufficient data.[21]

Model Calibration and Gap Filling

The stock turnover model must replicate the resulting efficiency mixes to represent the actual market sales mix and, ultimately, energy consumption. The research team also used the stock turnover model to backcast the efficiency distributions for 2010 and 2009, years for which the team had no sales data. This section describes the research team's approach to these tasks.

The research team developed an approach that utilizes both the available sales data and a set of structured economic and consumer choice assumptions to model market shares segmented by the aforementioned model dimensions. The goal of this approach is to ensure the most accurate results possible by using sales data and maintaining the ability to fill in data gaps and backcast market shares for 2009 and 2010 (due to lack of market data) with a consistent and transparent method. Backcasting both sales and stock simultaneously depends on many factors and is inherently uncertain. In order to improve confidence in the 2009 and 2010 sales and stock estimates, the research team sought to both align the 2011-2015 modeled sales with the actual sales data and ensure that the stock saturation in 2011 aligned with the RBSA.

[21] In the Decorative and Mini-Base 250-1049 lumen bin, the research team replaced 2011 shares with the 2012 shares, as the CFL share was unrealistically high (20% higher than 2012). The team believes this is because of small lumen bins and less detailed data in 2011 compared to later years. In the Decorative and Mini-Base 1050-1489 lumen bin, the team replaced 2014 and 2015 shares with 2013 shares to remove odd trends in the halogen shares. In the Globe 250-1049 lumen bin, the research team replaced 2011 shares with 2012 shares. The CFL share was unrealistically high, and the 2011 data was less detailed than in later years.

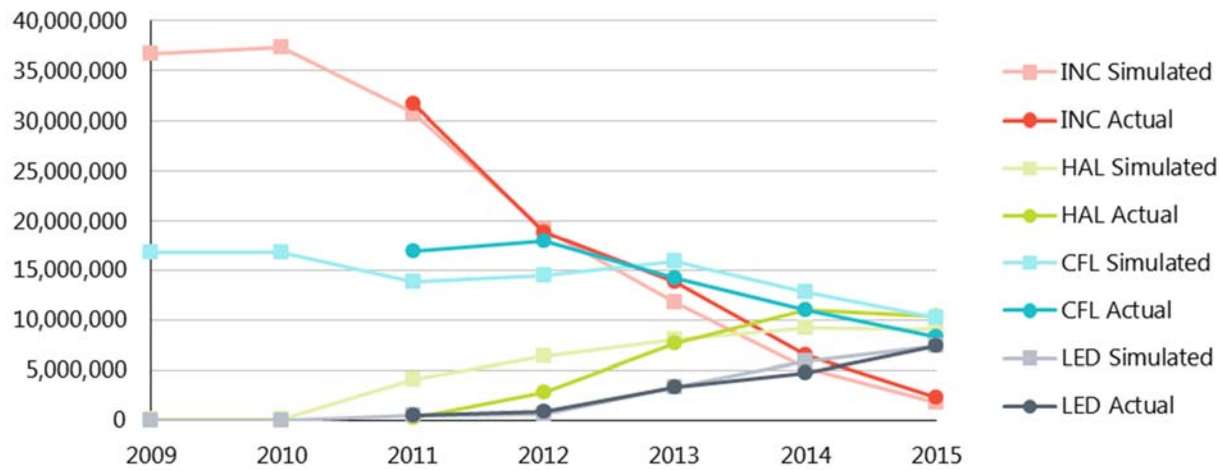
The team developed a Bass diffusion framework coupled with a logit model to estimate customer adoption decisions among different technologies. The logit model predicts rational consumer choice behavior using economic factors (first cost and operating cost), while the Bass diffusion helps capture non-economic factors that may cause adoption to differ from strictly economic predictions. The Bass and logit models provide a formulaic structure for determining the mix of sales among technologies whenever actual sales data does not exist or is incomplete. The research team calibrated the formulaic portion of the model to the actual sales data, ensuring that the calibrated Bass diffusion and logit structure would fill in data gaps with a logically consistent algorithmic approach while still using sales data directly where it existed. The team used the following process:

1. **Use stock model to estimate market size.** As described above, the research team leveraged data from the RBSA (historical lighting saturation) and Seventh Plan analysis (existing stock of homes and new construction rates).
2. **Perform initial calibration of model to sales data shares using goal-seeking logic.** The research team used non-linear optimization algorithms to solve for a modeled market that aligns with the available sales data for each application and lumen bin. This automated process set initial input parameters for the logit and provided a starting point for the more manual iteration steps, which helped refine the sales mixes.
3. **Compare results to sales and stock data.** The research team looked at the high-level and dimension-specific results and compared them to the sales data as well as the expected trends from the team's market research. With each iteration and sensitivity analysis, the team reviewed the results for the following:
    a. Do modeled sales follow the same overall trend as actual sales?
    b. Do the modeled sales diverge from the actual sales more at the beginning or end of the actual sales period?
    c. Does the resulting stock mix align with the RBSA? If not, are the backcast years contributing significantly to the error?
4. **Iterate results.** The research team iterated the results using both the optimization and manual adjustments until the model and sales aligned and the 2011 stock mix stayed within 4% of the RBSA CFL saturation across applications. At the application level, the team focused on the largest lumen bins to improve the overall results. Thus, results for smaller lumen bins (and, to a lesser extent, very small applications such as Globe and 3-Way) are not as tightly calibrated as the dominant lumen bin for each application. The research team limited manual adjustments to the following:
    a. In order to align the results with the RBSA CFL stock saturation, the team reduced CFL sales shares for 2011 for the decorative and mini-base, and reflector and outdoor reflector applications. For example, using the sales mix directly from the chain logic analysis yielded 2011 decorative and mini-base CFL sales that exceeded the number of CFLs in the 2011 end-of-year stock in that application as estimated from the RBSA data. This adjustment also caused the modeled CFL sales to decrease in 2009 and 2010.
    b. As described in the Sales Efficiency Mixes section, the team applied an uninstall/in-storage rate to CFLs to account for the RBSA finding that more CFLs end up in storage than other technologies relative to their stock saturation. The team performed a

sensitivity analysis on reducing CFL sales by 1% to 10% and selected a value of 5% because it yielded the best alignment with the 2011 CFL stock saturation in the RBSA.

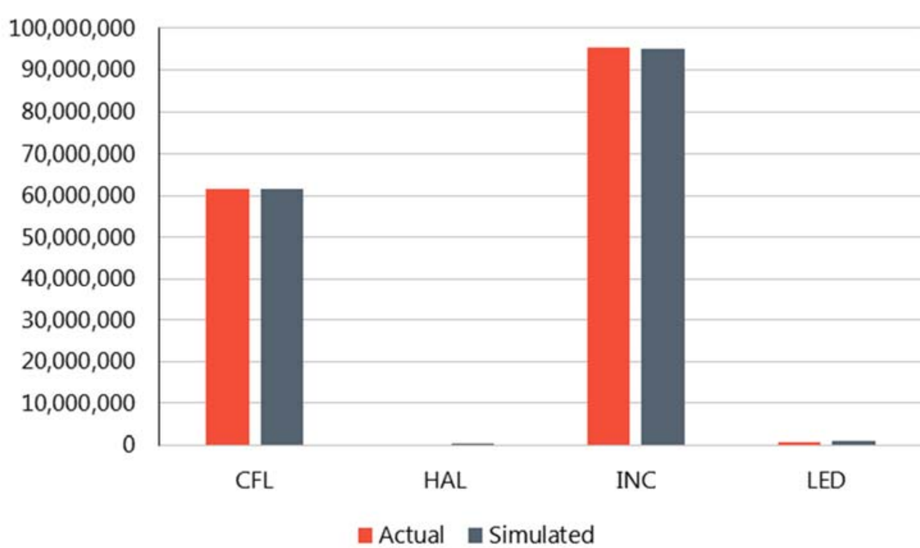
Figure A-4 shows the modeled sales for 2009-2015 as well as the actual sales for 2011-2015 to which the team calibrated. Figure A-5 shows the modeled stock for 2011 compared to the technology mix in the 2011 RBSA. The team performed this calibration for each unique application and lumen bin.

Figure A-4: Calibrated Model Outputs for General Purpose Application (All Lumen Bins)



Source: Residential Momentum Savings Model

Figure A-5: Calibrated 2011 Stock for the General Purpose Application (All Lumen Bins)



Source: Residential Momentum Savings Model

Table A-17 shows the efficiency mixes for general purpose bulbs.

Table A-17: Applied Efficiency Mixes by Year, General Purpose Bulbs

Year	Incandescent	Halogen	CFL	LED
2009	70%	0%	30%	0%
2010	70%	0%	30%	0%
2011	65%	0%	33%	1%
2012	48%	7%	43%	2%
2013	36%	20%	35%	9%
2014	20%	34%	32%	15%
2015	8%	37%	28%	27%

Source: Residential Momentum Savings Model

Again, the sales efficiency mixes determine how the efficiency mix of the stock changes each year. The stock efficiency mix is the final key input (along with the number of lamps in the installed stock, the application mix, and the UEC of each lamp type—all described above) to the calculation of the market's total annual energy consumption.

Market Energy Consumption

The research team calculated market energy consumption for each year of the analysis period for each of the two baseline cases and the actual case using Equation A-9. The only difference between the cases is the stock efficiency mix, which is driven by the different sales efficiency mixes assumed in each case. Where:

a = application

b = lumen bin

h = housing type

t = technology

y = year in study period

Table A-18 shows the results of the team's findings.

Equation A-9: Market Energy Consumption

$$\text{Annual Energy Consumption} = \sum_{h,a,b,t} \text{Installed Lamp Stock}_{h,y} \times \text{Stock Application Mix}_{h} \times \text{Stock Efficiency Mix}_{h,y,a,b,t} \times \text{Average Unit Energy Consumption}_{y,a,b,t}$$

Where:

a = application

b = lumen bin

h = housing type

t = technology

y = year in study period

Table A-18: Annual Market Energy Consumption (aMW)

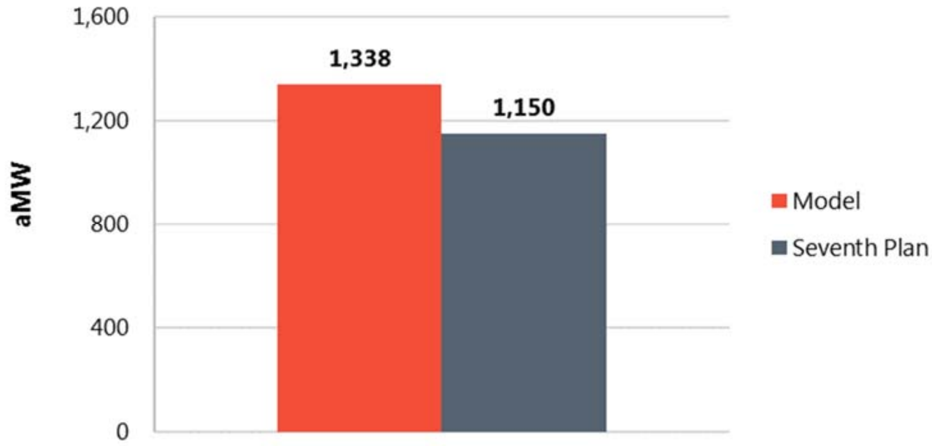
Year	Frozen Baseline	RTF Baseline	Actual
2009	1,338	1,338	1,338
2010	1,285	1,380	1,284
2011	1,244	1,374	1,209
2012	1,215	1,360	1,102
2013	1,194	1,341	989
2014	1,186	1,158	894
2015	1,188	1,002	813

Note: Does not account for HVAC interaction effects
Source: Residential Momentum Savings Model

Comparison to Seventh Plan

The team validated the reasonableness of the model's estimate of total lighting energy consumption in its base year (2009) by comparing it to the comparable estimate from the Council's Seventh Plan. As shown in Figure A-6, the team's model (1,338 aMW) and Seventh Plan (1,150 aMW) estimates were within 16% of each other.

Figure A-6: Comparison of Model and Seventh Plan 2009 Total Lighting Energy Consumption



Note: Does not include HVAC interaction effects
Source: Residential Momentum Savings Model, Seventh Power Plan end-use load data

Calculating Total Market Savings

The research team subtracted the actual stock energy consumption from each baseline to arrive at the cumulative savings in each year. It is important to note that direct comparisons of stock energy consumption in any given year yields **cumulative** energy savings—savings that includes efficiency improvements in prior years. In contrast, Momentum Savings are **first-year** savings, so an adjustment was necessary. To arrive at the first-year savings, the team deducted the prior year's cumulative savings. This approach, shown in Equation A-10 and Equation A-11, isolates first-year savings in each year of the analysis.[22]

Equation A-10: Cumulative Savings

$$\text{Cumulative Savings} = (\text{Baseline Stock Consumption} - \text{Actual Stock Consumption}) \times \text{Busbar Factor}$$

The busbar factor in Equation A-10 converts energy savings at the customer's meter to the generation source. The research team used a busbar factor of 1.09056 per BPA's guidance.

In 2010, the cumulative savings are equal to the first-year savings. For all other years, the team calculated first-year savings as the difference between the cumulative savings in that year minus the cumulative savings of the prior year (Equation A-11).

[22] In contrast to past Momentum Savings analyses, the research team had to calculate savings by monitoring changes in the stock because the conventional methodology—direct comparison of first-year consumption from lighting sales between the baseline and actual cases—overstates savings. This overstatement stems from a difference in sales volume between the baseline and actual cases. In this analysis, the actual case has fewer sales in each year because the market mix is longer lived than in the baseline mix (e.g.., more LEDs and CFLs, etc.). The prevalence of longer-lived products in the actual case slows the stock turnover, which results in fewer annual sales than in the baseline. However, this decrease in annual sales does not contribute to real savings as the same number of existing sockets need lamps in both scenarios.

Equation A-11: First-Year Savings

$$\text{First-Year Savings}_y = \text{Cumulative Savings}_y - \text{Cumulative Savings}_{y-1}$$

Where:

y = the analysis year

Table A-19 and Table A-20 show the first-year market savings by year calculated against the frozen baseline case and the RTF baseline case, respectively.

The actual stock consumption declines as CFL, halogen, and LED sales increase and become a larger portion of the installed stock.

The frozen baseline stock consumption also declines, though not as quickly as the actual consumption. Since the majority of failures are incandescent lamps (due to their shorter lifetime) and the 2009 sales mix is about 20% CFL, CFL saturation initially increases, which decreases consumption—even in the frozen baseline. Once CFL saturation plateaus, total consumption begins to grow along with the building stock due to new construction.

The resulting market savings relative to the frozen baseline are small to start. Since all efficient market share present in 2009 is part of the frozen baseline, only incremental gains in efficient technologies between 2009 and 2010 produce savings. For example, even though overall 2010 sales were 21% CFL, the CFL sales share only increased by 0.01% between 2009 and 2010. Thus, 2010 savings are small, but as the CFL and LED sales shares grow relative to the frozen baseline and these technologies grow in the stock, savings increase throughout the Sixth Plan period.

Table A-19: First-Year Market Savings by Year against the Frozen Baseline

Year	Frozen Baseline aMW	Actual aMW	Cumulative Market Savings	First-Year Market Savings
2009	1,338	1,338	0	0
2010	1,285	1,284	2	2
2011	1,244	1,209	30	28
2012	1,215	1,102	94	64
2013	1,194	989	168	73
2014	1,186	894	237	69
2015	1,188	813	302	65

Note: Consumption estimates do not account for HVAC interaction effects

Source: BPA Residential Momentum Savings Model

The RTF baseline stock consumption increases initially because the sales mix for 2010 and 2011 is 100% incandescent. With incandescent lamps replacing all failures during this period—and most failures in 2012 and 2013—the incandescent share of the stock increases until the RTF baseline sales mix becomes nearly all halogen and CFL in 2014. At this point, the efficiency of the stock technology mix improves rapidly and stock consumption drops accordingly.

Unlike the frozen baseline scenario, the sales shares in the RTF baseline scenario differ greatly from the actual scenario in 2010, yielding large annual market savings. These annual savings decline once the RTF baseline becomes more efficient. The negative market savings in 2014 and 2015 imply that the RTF baseline is more efficient than the actual sales in those years.

Table A-20: First-Year Market Savings by Year against the RTF Baseline

Year	RTF Baseline aMW	Actual aMW	Cumulative Market Savings	First-Year Market Savings
2009	1,338	1,338	0	0
2010	1,380	1,284	75	75
2011	1,374	1,209	128	53
2012	1,360	1,102	205	77
2013	1,341	989	283	78
2014	1,158	894	208	-75
2015	1,002	813	146	-62

Note: Consumption estimates do not account for HVAC interaction effects

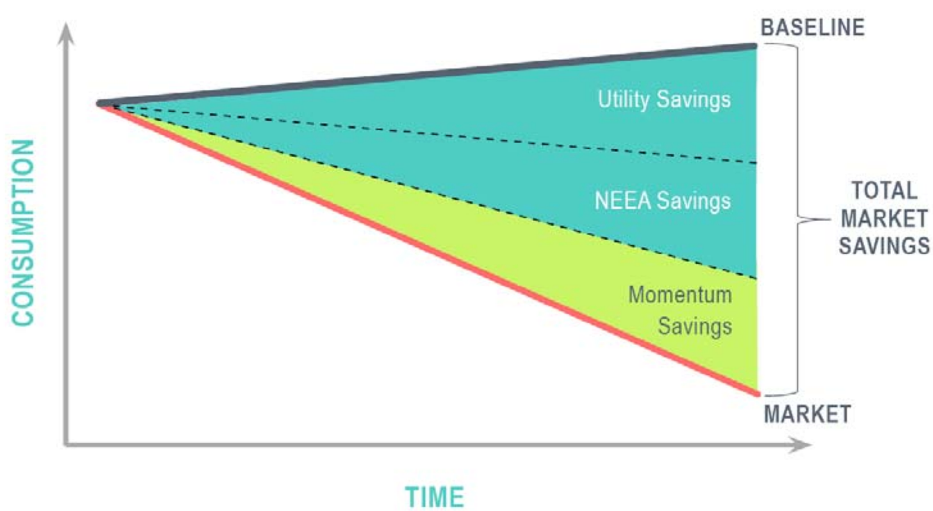
Source: BPA Residential Momentum Savings Model

Question 4: What are the program savings?

The final step in the Momentum Savings Analysis Framework corresponds to Question 4: What are the program savings? The actual energy consumption estimated in Question 3 relied, in part, on sales data that includes high-efficiency units, such as CFLs and LEDs, some of which were incentivized by programs or claimed by NEEA initiatives. Therefore, the last step in the Momentum Savings analysis is to subtract all reported residential lighting program savings from the total market savings calculated in Question 3. After subtracting these program savings, any remaining savings are Momentum Savings.

Figure A-7 summarizes the methodology graphically.

Figure A-7: How Momentum Savings Account for Program and NEEA Savings



To determine the residential lighting savings generated by regional upstream utility programs and NEEA initiatives, the research team gathered information regarding the following:

- **Utility program activity,** i.e., the number and type (that is, general purpose or specialty) of CFLs and LEDs incentivized through public utility and investor-owned utility (IOU) lighting programs in each year during the Council's Sixth Plan period
- **RTF savings,** i.e., the relevant per-unit savings, by lamp type and year, as determined by the RTF from 2010 to 2015
- **HVAC interactive effects,** i.e., the effect that changes in lighting technologies have on heating and cooling usage and, therefore, total residential energy consumption
- **Cross-sector sales,** i.e., the percentage of residential utility upstream lighting program sales installed in non-residential applications
- **NEEA net market savings,** i.e., NEEA's claimed savings for its CFL market transformation initiative and long-term market tracking efforts

Utility Program Activity

The research team primarily relied upon data from two types of utilities to determine total lighting program activity in the region; one provided information regarding public utility programs and the other provided information on IOU programs.

- **Public utilities.** The research team worked with BPA to extract the relevant program data from its IS2.0 database[23] in order to determine public utility program activity. BPA uses the IS2.0 database as a central repository to report program savings for its customer utilities. For lighting, the team extracted program details for BPA's Simple Steps, Smart Saving program[24] as well as any other lighting programs offered independently by BPA utilities.[25] From the database, the research team determined the total number of lamps—by lamp type, year, and program delivery (e.g., upstream, direct install, mail)—incentivized in each year from 2010 to 2015. The public utility program counts include both CFLs and LEDs.
- **IOUs.** Each year NEEA conducts a survey of local utilities to gather program information for all measures that NEEA tracks. As part of the effort, NEEA asks each regional IOU,[26] as well as BPA, to report the total number of general purpose and specialty CFLs[27] that the entity incentivized in the previous year. NEEA combines this programmatic information with a long-term forecast of CFL

[23] https://www.bpa.gov/EE/Policy/Solutions/Pages/default.aspx

[24] http://simplestepsnw.com/partners

[25] The research team determined which public utility lamps were part of Simple Steps, Smart Savings (S4) and which were incentivized through other public utility lighting programs using data collected by CLEAResult, which implements S4 for BPA. BPA's IS2.0 database can combine counts of multiple programs into single records when the programs involve overlapping measure reference numbers. Given that CLEAResult's data is a comprehensive account of all S4 measures completed, the team linked the counts in CLEAResults's data to the IS2.0 data on the basis of serving utility and reference number. Any remaining counts in the IS2.0 data beyond those present in CLEAResult's data were deemed to be from utility lighting programs unaffiliated with S4.

[26] Includes Avista (WA and ID), Idaho Power, Northwestern, Pacific Power WA, Rocky Mountain Power, Puget Sound Energy, and the Energy Trust of Oregon (Portland General Electric and PacifiCorp). Since only a portion of Northwestern's utility falls within the Columbia Basin—which establishes the bounds of the Council's regional planning efforts—the research team adjusted total reported program sales for Montana by 57%. This is consistent with how the Council and the research team adjusts RBSA data for Montana.

[27] Beginning in 2015, NEEA also began collecting program sales for LEDs.

growth to calculate any ongoing net market effects savings that result from its historical intervention in the region's CFL market.[28] To inform the research team's Momentum Savings efforts, NEEA provided the team the program counts it collected from IOUs from 2010 to 2015. The program survey data is less granular than the public utility data available through IS2.0. However, the data did provide the team with total program lamps by lamp type, year, and program delivery. Also, since NEEA did not collect LED program counts prior to 2015, the research team identified LED counts for 2014 from IOU program evaluations and annual reports available online.[29] The team reached out to select IOUs when unable to find this information in publically available documents.

The research team combined the public utility and IOU program participation data provided by BPA and NEEA, respectively, to quantify total regional utility activity for upstream, direct install, and give-away lighting programs (Table A-21).

Table A-21: Regional Upstream Lighting Program Participation (lamps): 2010-2015

Lamp Type	Year	Public Utilities	IOUs	Total
General Purpose	2010	4,126,022	3,016,331	7,142,353
Specialty	2010	742,942	2,534,778	3,277,720
General Purpose	2011	4,859,525	5,985,877	10,845,402
Specialty	2011	2,802,167	2,972,823	5,774,990
General Purpose	2012	3,310,219	5,029,940	8,340,159
Specialty	2012	821,437	2,928,638	3,750,075
General Purpose	2013	3,227,840	5,032,831	8,260,671
Specialty	2013	1,024,570	3,068,986	4,093,556
General Purpose	2014	3,604,793	7,527,188	11,131,981
Specialty	2014	1,370,567	4,529,095	5,899,662
General Purpose	2015	3,142,818	9,220,789	12,363,607
Specialty	2015	746,485	2,916,681	3,663,166
Total		**29,779,385**	**54,763,956**	**84,543,341**

Note: Includes Simple Steps, Smart Savings and other public utility lighting programs

[28] NEEA stopped directly incentivizing CFLs in 2008 but continues to claim net market effects savings due to its earlier market transformation effort through their long-term market tracking of residential lighting efforts.

[29] Prior to 2014, LEDs made up a very small portion of total programs sales. For examples, only 1.4% of the lamps incentivized by public utilities in 2013 were LEDs.

RTF Savings

To convert the general purpose and specialty lamp counts detailed in Table A-21 into energy savings, the research team determined the relevant RTF residential lighting measure unit energy savings (UES) for each lamp type and year. Since upstream or retail lighting programs represented the majority (~90%) of utility program savings between 2010 and 2015, the research team used the RTF's upstream UES to populate the model and estimate total programmatic savings.[30]

In some years (e.g., 2010), the RTF only had a single UES for either upstream general purpose or specialty lamps. However, in other years, the RTF offered more detailed UES values, which varied based on the lamp's application and/or lumen output. For these years, the research team calculated a weighted average UES that reflected the mix of the most common CFL and LED program lamps incentivized in that year.[31,32]

Table A-22 summarizes the RTF UES values used by the research team to estimate program savings by lamp type and year.

Table A-22: Relevant RTF Unit Energy Savings

Lamp Type	Year	RTF UES
General Purpose	2010	24.00
Specialty	2010	18.80
General Purpose	2011	24.00
Specialty	2011	18.80
General Purpose	2012	19.27
Specialty	2012	18.80
General Purpose	2013	16.01
Specialty	2013	19.01
General Purpose	2014	16.03
Specialty	2014	19.83
General Purpose	2015	14.04
Specialty	2015	20.56

Source: Research team analysis of Regional Technical Forum data

[30] The team also did not have sufficient information about where direct install lamps were installed to accurately estimate direct install savings; the RTF savings vary by room type.

[31] Specifically, the research team determined the UES associated with the 10 most common lamps and used these values to calculate a sales weighted UES for that particular lamp type and year. In most years, the top 10 lamps represented well over 90% of all program lamps.

[32] The team found relatively small differences in the annual per-unit savings between CFLs and LEDs, the latter of which became a larger part of program offerings in 2014 and 2015.

HVAC Interaction Factor

The RTF UES values shown in Table A-22 account for HVAC interaction effects—that is, the impact the lighting upgrade has on heating and cooling usage and, consequently, on total electric energy consumption.

As a result, the research team also needed to account for these impacts when comparing program savings with modeled regional lighting consumption. Again, the team relied on the RTF, using the same HVAC interaction factors (Table A-23) employed as part of the RTF's most recent residential lighting measure.[33] The factors vary by both application and lumen bin since these characteristics affect the amount of heating load increased by switching to a more efficient CFL or LED that puts less heat into the conditioned space.

Table A-23: HVAC Interaction Factors by Application and Lumen Bin

Lumen Bin	General Purpose	Decorative and Mini-Base	Globe	Reflector	3-Way	Linear	Outdoor: General Purpose and Reflector
250-1049 (24 in)	67%	70%	74%	69%	75%	86%	100%
1050-1489 (48 in)	61%	70%	72%	52%	75%	86%	100%
1490-2600 (96 in)	59%	71%	64%	22%	75%	86%	100%

Source: Research team analysis of Regional Technical Forum data

Cross-Sector Sales

Since the research team is assessing the changes in energy consumption in the residential lighting market, it should only subtract program savings that occurred within the residential sector from the team's assessment of total residential market savings. An evaluation of Puget Sound Energy's (PSE's) upstream residential lighting program in 2015 determined that 8% of the lamps incentivized by the program were purchased by customers that installed them in non-residential applications.[34]

Table A-24: Results of PSE Upstream Lighting Intercept Surveys

Sector	Percentage of Total Program Lamps
Residential	92%
Non-Residential	8%
Overall	**100%**

Source: Puget Sound Energy

Thus, the research team multiplied the utility program lamp counts and their corresponding savings shown in Table A-22 by 92% to limit those savings to only lamps installed in residential applications.

[33] https://rtf.nwcouncil.org/measures/res/ResLighting_Bulbs_v4_2.xlsm

[34] http://www.utc.wa.gov/_layouts/CasesPublicWebsite/GetDocument.ashx?docID=157&year=2013&docketNumber=132043.

Important context regarding PSE's evaluation:

- The 92% residential installation rate shown in Table A-24 is an overall weighted average (by program participation) of different residential installation rates by store type: DIY (90%), warehouse (93%), and big box (96%).
- PSE's evaluator intercepted customers at three different DIY retailers but was unable to complete intercepts at warehouses or big box locations. As a result, PSE relied on secondary data from a multiyear study by Commonwealth Edison for non-residential purchase rates for warehouses and big box locations.
- PSE's evaluator intercepted any customer buying an LED whether it was a program lamp or not. They also intercepted all applications—not just general purpose.[35]

NEEA Net Market Savings

As noted previously, NEEA uses its annual regional lighting survey to estimate net market effects that result from its long-term support of CFLs in the Pacific Northwest. Table A-25 summarizes NEEA's CFL net market effect savings by lamp type and year.

Important context for NEEA's net market effects saving claims includes:

- NEEA's savings methodology, which leverages regional market data collected and reported by CLEAResult, accounts for both CFL retirement and other utility lighting programs. In other words, NEEA does not claim savings for CFLs that replace CFLs, and their savings—similar to Momentum Savings analyses—are mutually exclusive of savings already claimed by regional programs, thus avoiding any potential double counting.
- Although NEEA tracked the regional CFL market throughout the entire Sixth Plan period, they stopped claiming savings associated with general purpose CFLs after 2012. As show in Table A-25, NEEA did not claim any net market effects for this lamp type between 2013-2015. In fact, NEEA's market tracking methodology, found that general purpose CFL retirements peaked in 2013, which resulted in a greater number of retirements than new purchases.
- Unlike general purpose CFLs, NEEA was able to claim savings for specialty CFLs for the entire Sixth Plan period. However, similar to general purpose CFLs in 2013, NEEA determined that the number of specialty CFL retirements and units incentivized through regional utility programs in 2015 was greater than new specialty lamp sales in that year. As a result, NEEA did not claim any net market for specialty CFLs in 2015.
- As shown in Table A-25, NEEA calculated and applied it's own per-unit savings (kWh/unit). These values differ from the comparable RTF UES values (Table A-22). For regional consistency, the research team applied the same set of RTF UES values to both utility program and NEEA net market savings. As a result, the total NEEA net market savings—by lamp type and year—determined through the model differ somewhat from the total savings claimed by NEEA and shown below.

[35] The evaluation did not find statistically different rates by application.

Table A-25: NEEA CFL Net Market Savings: 2010-2015

Year	General Purpose			Specialty		
	Units	kWh/Unit	Total Savings	Units	kWh/Unit	Total Savings
2010	3,002,877	30.07	10.3 aMW	1,906,744	23.55	5.1 aMW
2011	651,916	30.07	2.2 aMW	886,023	23.55	2.4 aMW
2012	364,727	24.25	1.0 aMW	1,303,339	23.55	3.5 aMW
2013	-	0.00	0 aMW	1,636,184	23.55	4.4 aMW
2014	629,517	0.00	0 aMW	1,145,321	14.40	1.9 aMW
2015	289,500	0.00	0 aMW	-	14.40	0 aMW

Source: NEEA

Summary

Table A-26 combines the cross-sector-sales-adjusted utility program lamps with the lamps claimed by NEEA for each lamp type and year.

Table A-26: Total Lamps Claimed through Regional Efficiency Efforts, 2010-2015

Lamp Type	Year	Utility Programs (Adjusted for Cross-Sector Sales)	NEEA*	Total
General Purpose	2010	6,570,965	3,002,877	**9,573,842**
Specialty	2010	3,015,502	1,906,744	**4,922,246**
General Purpose	2011	9,977,769	651,916	**10,629,685**
Specialty	2011	5,312,990	886,023	**6,199,013**
General Purpose	2012	7,672,946	364,727	**8,037,673**
Specialty	2012	3,450,069	1,303,339	**4,753,408**
General Purpose	2013	7,599,818	0	**7,599,818**
Specialty	2013	3,766,072	1,636,184	**5,402,256**
General Purpose	2014	10,241,423	0	**10,241,423**
Specialty	2014	5,427,689	1,145,321	**6,573,010**
General Purpose	2015	11,374,519	0	**11,374,519**
Specialty	2015	3,370,112	0	**3,370,112**

**NEEA's net market effects analysis is limited to the residential sector and does not require a cross-sector adjustment. Also, as noted above, NEEA did not claim any net market effects savings for general purpose CFLs after 2012 or for specialty lamps in 2015.*
Source: Research team analysis of public utility, IOU and NEEA data

As illustrated in Figure A-7, the research team needed to remove the savings associated with program and NEEA market effect lamps from the team's estimates of total market savings to arrive at an estimate of residential lighting Momentum Savings. Table A-27 converts the lamp counts shown in the previous table, using the RTF UES values, into aMW savings. The removal of the program savings in Question 4, from the market savings calculated in Question 3 resulted in Momentum Savings.

Table A-27: Total Savings Claimed through Regional Efficiency Efforts: 2010-2015 (aMW)

Lamp Type	Year	Upstream Program Savings (Adjusted for Cross-Sector Sales)	NEEA Net Market Effects Savings	Total Program Savings
General Purpose	2010	20	9	**29**
Specialty	2010	7	4	**12**
General Purpose	2011	30	2	**32**
Specialty	2011	12	2	**15**
General Purpose	2012	18	1	**19**
Specialty	2012	8	3	**11**
General Purpose	2013	15	0	**15**
Specialty	2013	9	4	**13**
General Purpose	2014	20	0	**20**
Specialty	2014	13	3	**16**
General Purpose	2015	20	0	**20**
Specialty	2015	9	0	**9**

Source: Research team analysis of program and RTF data

Appendix

This appendix is organized into six sections with the following subsections:

1. **Model Dimensions**
    a. Housing Type
    b. Application
    c. Technologies
    d. Lumen Bin and Lamp Length
2. **Stock Turnover Model Inputs**
    a. Lifetimes
    b. Establishing Base Year (2009) Lamp Vintages
3. **Annual Lighting Sales Estimates**
    a. Top-Down (NEMA)
    b. Bottom-Up (Nielsen)
4. **Supporting Chain Logic Model Details**
    a. Quality Control
5. **Supporting RBSA Details**
    a. Calculating Lumens
    b. Linear Fluorescent Lamp Stock
    c. Applying Market Data by Home Type
    d. Applying Market Data to Outdoor Applications
6. **Sensitivity Analysis Findings**

1. Model Dimensions

Table A-28 shows the four dimensions of the residential lighting model. The table also lists the values associated with each dimension. The research team constructed the model in a manner that allows the user to view the results along any of these dimensions.

Table A-28: Summary of Model Dimensions and Associated Values

Housing Type (3)	Application (8)	Technology (7)	Lumen Bin/ Linear Length (3)
Single Family	General Purpose	Incandescent	250 to 1049 OR 24 in
Multifamily	3-Way	Halogen	1050 to 1489 OR 48 in
Manufactured	Decorative and Mini-Base	CFL	1490 to 2600 OR 96 in
	Globe	LED	
	Reflectors	T-12	
	Outdoor General Purpose	T-8	
	Outdoor Reflectors	T-LED	
	Linear		

In this section of the appendix, the research team discusses the decision points and rationale for both segmenting the model into these dimensions and selecting the values within each.

1a. Housing Type

The model will produce results for three different residential housing types: single family homes, multifamily homes, and manufactured homes. The team will leverage housing type-specific data collected through the RBSA to model lighting stock, including the number of each type of home and key lighting characteristics within each home type. These include the average number of sockets, the mix of applications, and the existing technologies installed.

1b. Application

In the model, the most common lamp types (e.g., general purpose screw-in, reflector, etc.) are referred to as applications. It is within these applications that different technologies (e.g., halogen or LED) compete for a given socket.

To determine the appropriate set of applications for modeling residential lighting Momentum Savings, the research team investigated the following factors:

- **Regional consistency.** What applications did the Council model in the Sixth and Seventh Plans? What applications does the RTF use for its residential lighting measure?

- **Comprehensiveness.** Do the Council/RTF applications sufficiently capture the residential market for the purpose of modeling Momentum Savings? For example, do they include linear fluorescents or are they limited to screw-in lamps? What about less common, niche applications—Christmas lights, night lights, and lamps with less than 250 or more than 2600 lumens? Do any of these merit inclusion in the team's analysis?
- **Data availability.** Is the necessary data available—both in the RBSA (stock) and Nielsen/shelf-stocking data (sales)—to develop inputs at this level of granularity?
- **Consistency with program data.** Does reporting on program activity support analysis by these applications? That is, will the research team be able to account for program sales at the same level of granularity?

After completing this investigation, the research team decided on the following applications (Table A-29).

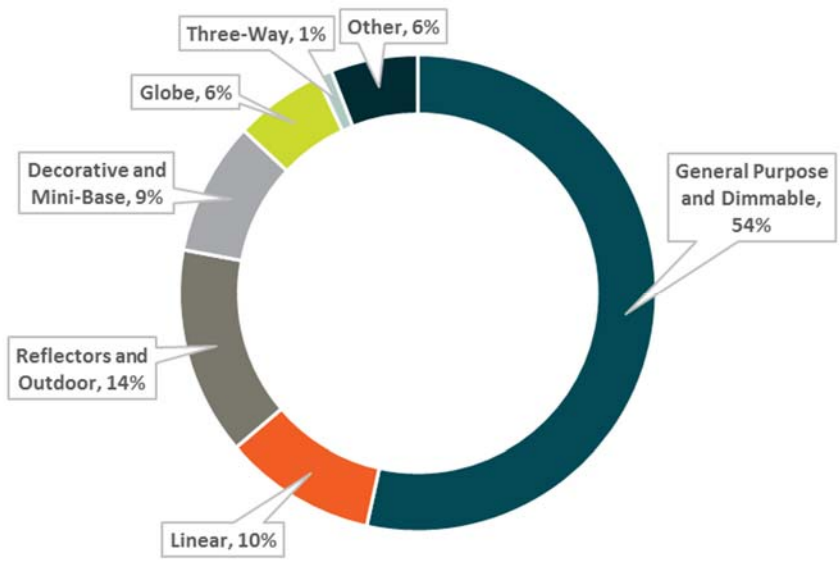
Table A-29: Model Applications

Application	Notes
General Purpose	Many of the applications are dimmable (i.e., it is not a mutually exclusive category). As a result, the research team does not believe dimmable should be called out explicitly as part of general purpose (as done by the Council and RTF). Similarly, the team does not believe it should be a separate application.
3-Way*	Creating a distinct 3-way application is consistent with the Council's Plan but not the RTF. The RTF opted to group 3-way lamps with general purpose and dimmable to prevent a scenario where 3-way savings are much higher than general purpose (because they are EISA-exempt) due to concern that this might result in programs over-supplying 3-way lamps. However, this is not a concern for the research team's analysis.
Decorative and Mini-Base*	Consistent with both the Council and RTF.
Globe*	Consistent with both the Council and RTF.
Reflectors*	Both the RTF and the Council include outdoor with reflectors. However, non-reflector lamps are commonly used in outdoor fixtures. The research team will model the turnover of outdoor general purpose and reflector lamps separately, as these lamps are subject to greater HOU.
Outdoor General Purpose	Similar to dimmable lamps, outdoor is not a mutually exclusive application (i.e., residential customers use a wide range of applications in outdoor sockets). Rather than create a separate outdoor sub-application for each one, the research team will use two: outdoor general purpose and outdoor reflector, which, per the RBSA, collectively represent 89% of all residential outdoor applications.
Outdoor Reflectors*	
Linear	Represents 10% of lamps per the RBSA.

**In the regional lighting program parlance, these applications are all specialty lamps.*

Additionally, the research team reviewed the mix and prevalence of applications identified through the 2011 RBSA and determined the proposed model applications represent 93% of the residential lighting stock (Figure A-8).

Figure A-8: 2011 RBSA Lamp Applications



Source: Research team analysis of 2011 RBSA for all socket types

1c. Technologies

Within a given application, the model will compete the relevant subset of seven technologies found in Table A-30 against each other, four of which pertain to screw-in lamps and three to linear applications.

Table A-30: Model Technologies and Mapping to Applications

Technology	Relevant Applications
Incandescent	All non-linear applications (i.e., screw-in lamps)
Halogen	
CFL	
LED	
T-12	Linear
T-8	
T-LED	

1d. Lumen Bin and Lamp Length

Residential customers can install lamps with a wide range of wattages and/or lumen levels in a given application (e.g., a 40W, 60W, 75W, or 100W equivalent lamp in any given medium screw base socket). Thus, the research team will model lumen bins. Including lumen bins as a model dimension provides several benefits.

First, modeling lumen bins allows the research team to more accurately account for EISA and its impact on the RTF residential lighting measure updates, which the US DOE phased in incrementally by lumen bin over a three-year period.

Second, as noted previously, including lumen bins as a model dimension ensures that the existing and replacement technology (once the model turns over a given socket) deliver similar light output.

The research team investigated the lumen bins used by the Council and RTF to determine the most appropriate lumen bins for the model. The team determined that the RTF's most recent residential lighting measure (v4.2) and the Council's Seventh Plan use the same three lumen bins: 250-1049, 1050-1489, and 1490-2600 lumens. After confirming these three lumen bins encompassed 92% of total screw-in lamps sales and wattages based on analysis of 2014 sales data, the research team decided to use these same bins in its analysis (Table A-31).

Table A-31: Model Lumen Bins

Lumen Bin
250-1049
1050-1489
1490-2600

It is important to note that these lumen bins differ from EISA's lumen bin categories (310-749, 750-1049, 1050-1489, and 1490-2600). In essence, the RTF opted to group and slightly expand (from 310 to 250 lumens) the first two EISA lumen bins. The rationale behind this was that "current incandescent and halogen products marketed as '60W equivalent' fall in the 310 to 749 lumen range, whereas CFL and LED products marketed as "60W equivalent" fall into the 750 to 1049 lumen range."[36] Since these technologies will compete within the model for similar light-producing sockets, the RTF's aggregation of EISA lumen bins also makes sense for estimating Momentum Savings.

While lumen bins are important parameters for bounding screw-in lamp turnover decisions (i.e., consumers typically replace lights with similarly bright bulbs, regardless of the technology), the replacement decision for linear lamps is different. Customers replacing failed linear lamps search out lamps of similar length that fit their existing fixture. As a result, the research team categorized the linear application by length rather than lumen bin.

Specifically, the research team modeled two lamp lengths: 2-foot (24 in) and 4-foot (48 in). The RBSA found that T-8 and T-12 lamps for these two lengths capture nearly 80% of total linear lamps in residential homes. (See Table A-41 in the Supporting RBSA Details section of the appendix). It is also worth noting

[36] http://rtf.nwcouncil.org/measures/res/ResLighting_Bulbs_v4_2.xlsm

that T-LEDs, while a technology included in the team's analysis, were not found in any homes at the time of the RBSA.

Table A-32: Model Linear Lengths

Linear Length
2-Foot (24 in)
4-Foot (48 in)

2. Stock Turnover Model Inputs

2a. Lifetimes

The research team used the lifetimes shown in Table A-33 from the US DOE's national lighting model to inform the team's stock turnover model. The model combines lamp lifetimes (in hours) with operating hours to calculate the lifetime (in years) for each combination of technology and application.

For CFLs, the team adjusted the rated lifetime due to the effects of switching using the ratio of in situ to rated lifetimes for ENERGY STAR CFLs in the RTF measure workbook. This de-rated lifetime estimate is based on a 2008 study on the effects of switching on residential CFL lifetimes.[37] The RTF measure workbook also specifies a maximum measure life of 15 years for linear lamps and 12 years for all other lamps. The "Modeled Lifetime" column reflects the CFL de-rate factor and the maximum lifetime caps.

[37] Jump, C. et al. "Welcome to the Dark Side: The Effect of Switching on CFL Measure Life." 2007 ACEEE Summer Study.

Table A-33: Model Lifetimes

Technology	Application	Rated Lifetime	Modeled Lifetime
CFL	Decorative and Mini-Base	10	5.1
CFL	General Purpose	10.3	5.2
CFL	Reflector	10	5.1
CFL	3-Way	10.3	5.2
CFL	Globe	10.3	5.2
Halogen	Decorative and Mini-Base	1.2	1.2
Halogen	General Purpose	1.5	1.5
Halogen	Reflector	3	3
Halogen	3-Way	1.5	1.5
Halogen	Globe	1.5	1.5
Incandescent	General Purpose	1.4	1.4
Incandescent	Reflector	2.5	2.5
Incandescent	3-Way	1.4	1.4
Incandescent	Decorative and Mini-Base	1	1
Incandescent	Globe	1.4	1.4
LED	Decorative and Mini-Base	25	12
LED	General Purpose	25	12
LED	Reflector	25	12
LED	3-Way	25	12
LED	Globe	25	12
T-8	Linear	21	15
T-12	Linear	15	15

Sources: US DOE lighting model input data, RTF workbook "ResLighting_Bulbs_v4_2.xlsx"—"Lifetime" tab

2b. Establishing Base Year (2009) Lamp Vintages

To estimate the age of lamps installed in the baseline year (2009), the research team used a stock tracking model to simulate the growth in lamp stock prior to the baseline year. The model accounts for the lifetimes and survival distributions of various technologies, the historic rate of growth in sales,[38] retrofit rates (if considered), and building stock demolition rates. With information about the rate of growth in sales, the model accumulates sales for each technology beginning in 1984 (25 years prior to 2009) and simulates like-for-like replacement for lamp turnover. By tracking these dynamics for 25 years, the model can determine a reasonable approximation of the age distribution of the stock at the beginning of 2009.

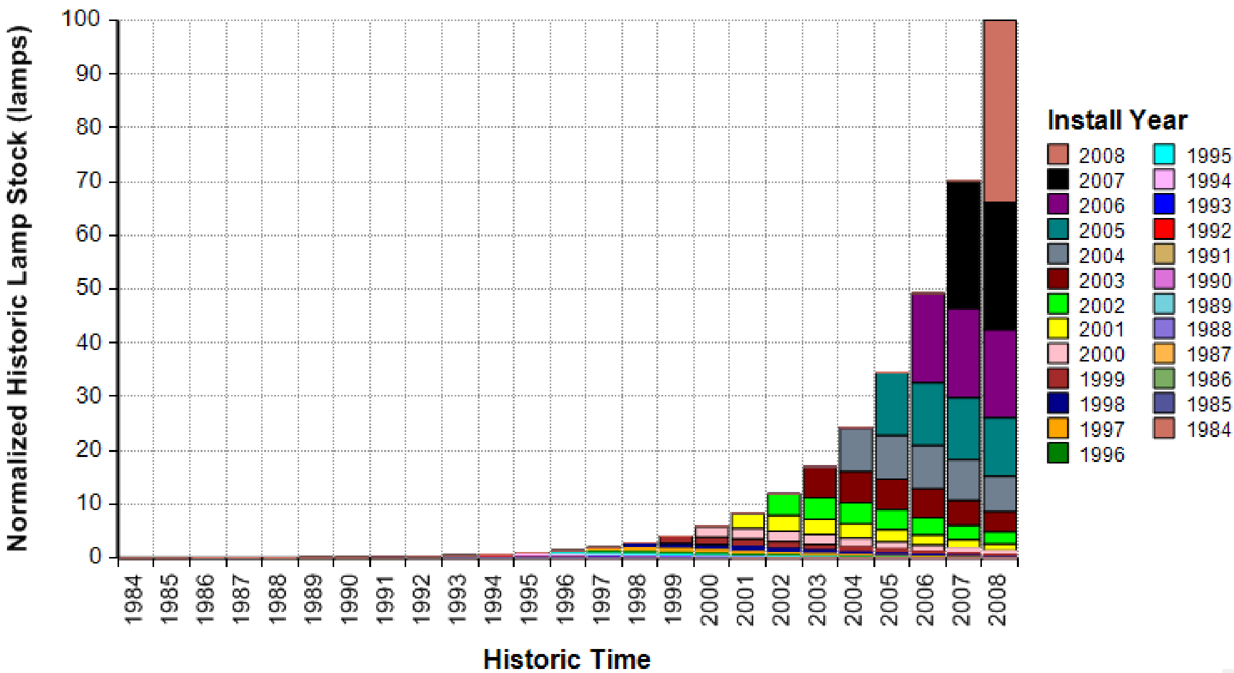
[38] Where data was available, the model used historic rate of growth in sales. When data was not available, the model used historic building stock growth rates as a proxy for the growth rate in sales.

In addition, the historic stock tracking routine applies the same turnover dynamics as the logic used for the 2009-2020 horizon, ensuring internal consistency.

The pre-2009 stock tracking routine does not make any assumptions about the relative mix of technologies because that adjustment takes place after computing the age distribution. Additionally, the routine does not need to know the absolute quantity of sales for a given technology to determine an age distribution. As such, the pre-2009 stock tracking relies upon a normalized representation of stocks—meaning that the quantity of lamps is not tied to historic quantities; rather, it is tied to historic growth rates.

As shown in Figure A-9, the historic stock tracking model provides an estimate of how the stock has grown up to 2009 (in a normalized representation) and what percentage of stock comes from different installation years. This information inherently captures the age of lamps included in the residential model's initial lamp stock for its baseline year.

Figure A-9: Illustrative Normalized CFL Lamp Stock for Historic Years (Lamps)



Source: Residential Momentum Savings Model development

By examining the end-of-year 2008 lamp stock (i.e., the beginning-of-year 2009 lamp stock), the model determines the percentage of that stock coming from various installation years. As shown in Table A-34, this information regarding how much of the stock was installed in each year provides an age distribution for the baseline year. The age distributions reflect the different operating hours for each application, the different rated lifetimes for each technology, and the different demolition rates by housing type.

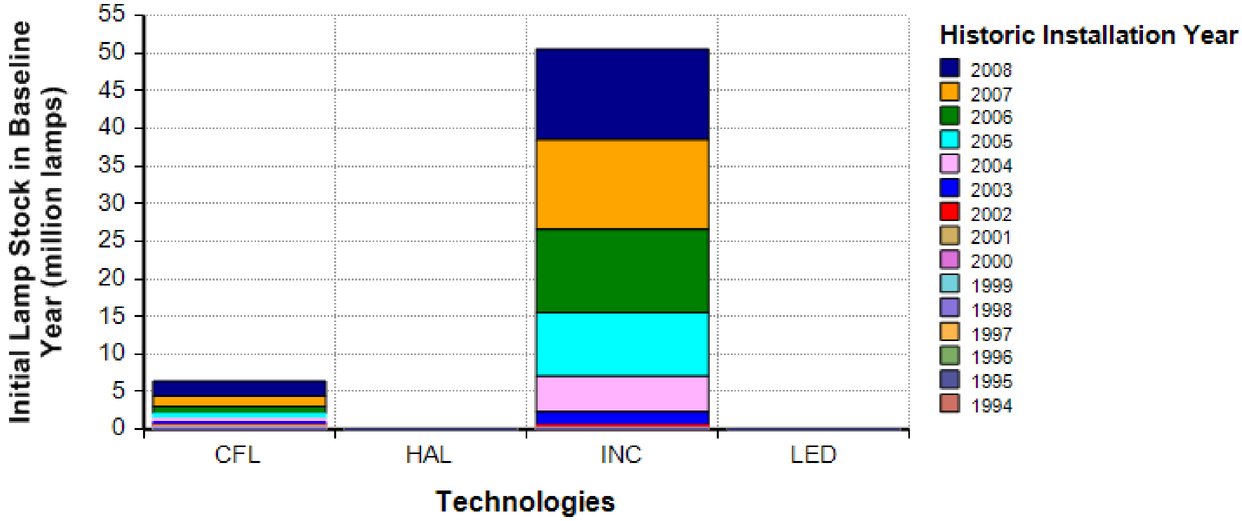
Table A-34: Illustrative Base Year Age Distribution by Application for CFLs in Single Family Homes

Installation Year (Proxy for Age)	Decorative and Mini-Base	General Purpose	Globe	Outdoor: General Purpose	Outdoor: Reflector	Reflector	3-Way
1995	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1996	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%
1997	0.0%	0.0%	0.3%	0.0%	0.0%	0.0%	0.0%
1998	0.0%	0.1%	0.5%	0.0%	0.0%	0.0%	0.1%
1999	0.2%	0.4%	0.9%	0.0%	0.0%	0.0%	0.3%
2000	0.6%	1.0%	1.5%	0.0%	0.0%	0.1%	0.9%
2001	1.5%	1.9%	2.3%	0.0%	0.0%	0.5%	1.8%
2002	3.0%	3.3%	3.5%	0.0%	0.0%	1.9%	3.2%
2003	4.9%	5.1%	5.1%	0.6%	0.4%	4.2%	5.0%
2004	7.5%	7.5%	7.4%	4.3%	3.9%	7.4%	7.5%
2005	11.1%	10.9%	10.6%	11.1%	10.9%	11.4%	10.9%
2006	15.9%	15.6%	15.1%	18.4%	18.6%	16.6%	15.7%
2007	22.7%	22.3%	21.6%	27.0%	27.3%	23.8%	22.4%
2008	32.5%	31.8%	30.9%	38.5%	39.0%	34.0%	32.1%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**

Source: Residential Momentum Savings Model development

After determining the age distribution of the baseline year's lamp stock, the model distributes the 2009 lamps stocks across the appropriate installation years. The end result is a baseline lamp stock with the correct number of lamps for 2009 and a robust estimation of the age distribution. Figure A-10 provides an illustrative example.

Figure A-10: Illustrative Lamp Stock in Baseline Year (2009) by Technology (Million Lamps)



Source: Residential Momentum Savings Model development

3. Annual Lighting Sales Estimates

The research team estimated the number of screw-in and linear lamps installed in homes each year in the Pacific Northwest through the stock turnover model. As discussed previously, the model estimated lamp failures within a given year—and consequently replacement sales and installations in that same year—using a series of key model inputs including the age and technology mix of the existing lighting stock, annual HOUs, expected lamp lifetimes, and changes in the annual retail technology mix.

To test the reasonableness of the annual lighting sales estimated by the model, the research team estimated total annual sales outside the model. Due to data limitations, the team was only able to independently estimate 2014 sales for general purpose lamps. However, the team did employ complementary approaches to develop these separate estimates and compare them against the model results.

- **Top-down:** The research team's top-down approach centered on scaling down national lamp shipment indices from the NEMA to reflect likely shipments—and subsequently sales—in the Pacific Northwest.
- **Bottom-up:** The team's bottom-up approach relied on detailed retail sales data collected by Nielsen. Since only a subset of regional retailers provide sales information to Nielsen, the research team combined the total sales observed in the Nielsen data with its estimates of individual retailer market shares (described earlier in The Chain Logic Method section) to estimate the total market size in the Northwest. The team completed a second, similar bottom-up market size analysis using CLEAResult data in place of Nielsen data.

The following sections detail the data sources and assumptions for each approach. It is important to repeat that the research did not use either of these annual sales estimates to model total market or Momentum Savings. Rather, the team used these estimates to validate the reasonableness of the sales estimated by the stock turnover model. The research team's 2014 modeled sales of roughly 33 million lamps for general purpose applications is just below the lowest of the top-down and bottom-up estimates described here. While general purpose 2014 sales are not within the range of the team's top-down and bottom-up estimates, the model sales for the entire market over time are consistently higher than NEEA's estimates—though they show a similar trend.

Table A-35: 2014 Northwest General Purpose Lamp Sales

Approach	Estimated Lamp Sales	Model Estimate of Lamp Sales	Ratio
Top-Down (NEMA)	34,408,139	33,207,566	97%
Bottom-Up (Nielsen)	61,227,731		54%
Bottom-Up (CLEAResult)[39]	50,112,916		66%
Simple Average	48,582,929		68%

Source: BPA Residential Lighting Momentum Savings Model, research team analysis

Table A-36: Total Northwest Residential Lamp Sales over Time

Year	Model Estimate of Lamp Sales	NEEA Estimate of Lamp Sales	Ratio
2010	99,548,686	63,000,000	158%
2011	93,585,034	60,000,000	156%
2012	85,906,164	61,000,000	141%
2013	82,748,457	60,000,000	138%
2014	74,142,950	57,000,000	130%
2015	66,532,024	53,000,000	126%

Source: BPA Residential Lighting Momentum Savings Model, NEEA data provided by Ryan Brown

Table A-37: Total Northwest Residential CFL Sales over Time

Year	Model Estimate of Lamp Sales	NEEA Estimate of Lamp Sales	Ratio
2010	20,540,990	18,721,049	110%
2011	22,325,098	16,454,685	136%
2012	25,617,768	17,254,906	148%
2013	21,445,308	16,867,125	127%
2014	16,590,545	14,935,976	111%
2015	12,569,281	11,052,650	114%

Source: BPA Residential Lighting Momentum Savings Model, NEEA data provided by Ryan Brown

[39] The evaluation team is unable to provide a detailed summary of the bottom-up approach using CLEAResult data (similar to Sections 3a and 3b below) since the estimate relies on non-public sales data.

3a. Top-Down (NEMA)

Table A-38: Top-Down Market Share Estimation Details

Data Point	Units	Sources and Assumptions
National NEMA A-line Shipments	825,025,437	**Assumptions:** • Shipments are equal to sales. • NEMA A-line shipments include only non-dimmable medium screw base A-line lamps under 2600 lumens. **Source:** The research team scaled up shipments from actual 2010 NEMA shipments using an estimated NEMA sales index and estimated the sales index using the text and charts in quarterly press releases.
National Non-NEMA Shipments	91,669,493	**Assumption:** • Non-NEMA shipments make up 10% of the market. **Source:** Research team's assessment of NEMA members list.[40]
Total National Shipments	916,694,930	Represents combined total of NEMA and non-NEMA shipments.
Rounded Total National Shipments	900,000,000	Rounded to avoid false precision.
National Residential Shipments	828,000,000	**Assumption:** • 8% of A-line shipments go to non-residential sector. **Source:** PSE 2014-2015 Residential Retail Lighting Impact Evaluation, August 26, 2015.
Total Pacific Northwest Residential Shipments	**34,408,139**	**Assumptions:** • Population size directly correlated with lamps per home. • Pacific Northwest is 4% of US market size. **Source:** US Census Bureau, Annual Estimates of the Resident Population of the United States, Regions, States, and Puerto Rico, 2014.

[40] NEMA Members List: https://www.nema.org/About/Pages/Members.aspx

3b. Bottom-Up (Nielsen)

Table A-39: Nielsen Data Bottom-Up Market Share Estimation Details

Data Point	Units	Sources and Assumptions
Nielsen Sales	15,652,464	**Assumption:** The general purpose category includes A-lamp and tube-style lamps, which are general purpose twisted CFL lamps. **Source:** Nielsen sales data on general purpose lamp sales in 2014.
Total Regional Sales	66,606,230	**Assumption:** Nielsen sales data represents 23.5% of the total residential lighting market. **Source:** Research team's Chain Logic Method retailer market share estimate.
Total Pacific Northwest Sales	**61,227,731**	**Assumption**: 8% of A-line sales go to the non-residential sector. **Source:** PSE 2014-2015 Residential Retail Lighting Impact Evaluation, August 26, 2015.

4. Supporting Chain Logic Method Details

4a. Quality Control

The research team continually reviewed input and output data to ensure reasonable results. At the outset of its analysis, the team cleaned each dataset to safeguard against inconsistencies in field names and values that can introduce errors when combining datasets. The team's process included the following:

- Identifying and screening out lamps outside the scope of the team's Momentum Savings analysis (e.g., heat lamps, candle wax warmers)
- Identifying and screening out records with values outside a reasonable range (e.g., lumens = 5601280)
- Standardizing inconsistent field formats (e.g., wattage value of "13; 19 ;23" compared to "50 100 150" for 3-way lamps)

Simultaneously, the research team validated and corrected specific records within each dataset. This included the following:

- Updating technology, application, lamp base (i.e., size and type), lumens, and watts values for over 1,600 records (corresponding to over 56 million units) in the Nielsen data based on model-specific research. The team updated these values while validating details for the specific records that represent the highest proportion of overall units.
- Verifying model numbers representing nearly 29 million lamps and 80% of incandescent lamps in the Nielsen data. This ensured the incandescent lamps did not include miscategorized halogen bulbs, an issue identified in a separate but related project.

Next, the team conducted a review of the cleaned and standardized datasets. This step included confirming the following:

- Data was loaded accurately (e.g., the correct number of records pre- and post-load)
- Results were reasonable, and observed ranges were within ranges the team expects to see for a given field (e.g., wattages for general purpose incandescent lamps in the 1050-1489 lumen bin were between 50W and 100W)
- Consistency (e.g., rules have been applied consistently across similar products)
- Accuracy (e.g., T-8 and T-12 lamps correspond to the linear category and not general purpose)

As part of this review, the research team also assessed the data using standardized queries, including:

- Overall record and lamp counts
- Record and unit counts by attributes such as stock code/UPC, state, year
- Record and unit counts by attributes such as bulb style (e.g., A-line, twist, reflector), base (e.g., medium screw, mini-base), application, technology, and an indicator field indicating if a specific record is flagged for exclusion from the analysis[41]
- Average wattage, lumen, and efficacy ranges
- Unique application and technology groupings

After analyzing the cleaned, standardized, and loaded data, the research team reviewed its results through multiple steps:

- Manually double-checked important calculations in Excel
- Reviewed detailed results for counterintuitive trends and anomalies, such as increasing overall average wattage, decreasing efficiency, or increasing LED costs over time
- Validated results through expert review as well as by comparing them to external resources such as national lighting sales indices published quarterly by NEMA

If the research team identified any issues during any of this process, it made the necessary corrections and repeated the validation process until it found no more issues.

5. Supporting RBSA Details

5a. Calculating Lumens

Since the RBSA did not collect information on lumens, the research team needed to map each RBSA lamp to one of the model's three lumen bins. To do so, the team used the same lamp efficacies as the RTF. Specifically, the team used the RTF table of lumens for each unique lamp wattage found in the RBSA. Because the RBSA made no distinction between bare bulb and covered bulb CFLs, the team used the "CFL – bare" lumens for all CFLs in general purpose applications and the "CFL – covered" lumens for all other applications. This follows the assumption that decorative, globe, 3-way, and reflector lamps are, by definition, covered bulbs. To limit the size of Table A-40, the team only shows lamps less than or equal to 100W. As this analysis was specific to mapping RBSA data to the model lumen bins, values may not match

[41] This review ensures analysis exclusion rules are applied consistently and accurately.

the average market efficacies for each technology, application, and lumen bin in the model. The model does not rely on efficacy to determine sales or stock shares.

Table A-40: Wattage and Lumen Output by Application and Technology: 2011

Unique Lamp Wattages in the RBSA	Incandescent	Halogen	CFL (Bare)	CFL (Covered)	LED
0	0	0	0	0	0
1	10	14	62	49	63
1.6	16	22	99	78	101
2	20	27	124	97	127
3	30	41	186	146	190
4	40	54	248	194	254
5	50	68	310	243	317
6	60	81	371	292	381
7	70	95	433	340	444
8	80	109	495	389	507
9	90	122	557	437	571
10	100	136	619	486	634
11	110	149	703	551	698
12	120	163	767	601	761
13	130	176	831	651	824
14	140	190	907	710	888
15	150	204	971	760	951
16	160	217	1036	811	1015
17	170	231	1101	862	1078
18	180	244	1166	913	1142
19	190	258	1230	963	1205
20	200	271	1295	1014	1268
21	210	285	1360	1065	1332
22	220	299	1425	1157	1395
23	230	312	1548	1209	1459
24	240	326	1616	1262	1522
25	250	339	1683	1335	1585
26	260	353	1750	1513	1649
27	270	366	1848	1571	1712
28	280	380	1917	1630	1776

Unique Lamp Wattages in the RBSA	Incandescent	Halogen	CFL (Bare)	CFL (Covered)	LED
29	290	394	1985	1688	1839
30	300	407	2054	1746	1903
31	310	421	2122	1804	1966
32	320	434	2191	1862	2029
33	330	448	2259	1921	2093
34	340	461	2328	1979	2156
35	350	475	2396	2037	2220
36	360	489	2464	2095	2283
37	370	502	2533	2153	2347
38	380	516	2601	2212	2410
39	390	529	2670	2270	2473
40	490	543	2738	2328	2537
41	502	556	2807	2386	2600
42	515	570	2875	2444	2664
43	527	785	2944	2503	2727
45	551	822	3081	2619	2854
46	564	840	3149	2677	2917
48	588	876	3286	2794	3044
49	600	895	3354	2852	3108
50	613	860	3751	2910	3171
52	637	894	3901	3026	3298
53	649	880	3976	3085	3361
54	662	897	4051	3143	3425
55	674	913	4126	3201	3488
56	686	930	4201	3259	3551
57	698	946	4276	3317	3615
58	711	963	4351	3376	3678
60	840	965	4501	3492	3805
65	910	1045	4876	3783	4122
67	938	1078	5026	3899	4249
67.5	945	1086	5063	3929	4281
68	952	1094	5101	3958	4312
70	980	1126	5251	4074	4439

Unique Lamp Wattages in the RBSA	Incandescent	Halogen	CFL (Bare)	CFL (Covered)	LED
71	994	1142	5326	4132	4503
72	1008	1280	5401	4190	4566
73	1022	1298	5476	4249	4630
74	1036	1316	5551	4307	4693
75	1190	1315	5626	4365	4756
76	1206	1333	5701	4423	4820
77	1222	1350	5776	4481	4883
80	1269	1403	6001	4656	5074
83	1317	1455	6226	4831	5264
85	1349	1490	6376	4947	5391
86	1365	1508	6451	5005	5454
87	1380	1525	6526	5063	5517
90	1428	1578	6751	5238	5708
95	1507	1666	7126	5529	6025
96	1523	1683	7201	5587	6088
100	1690	1753	7501	5820	6342

Source: Research team analysis of RBSA data

5b. Linear Fluorescent Lighting Stock

To determine the more relevant lamp length for inclusion in the Momentum Savings model, the research team analyzed the prevalence of linear lamps observed through the RBSA. Table A-41 summarizes the RBSA's linear fluorescent lamp findings by lamp length and technology. This table excludes all linear lamp lengths and technologies listed by NEEA as "Other." As noted previously, the RBSA did not identify any linear LED lamps or fixtures; all linear lamps found in the audits were fluorescent.

Table A-41: RBSA Linear Lighting Stock by Lamp Length and Technology

Lamp Length (Inches)	T-12	T-8	T-4	T-5	Total
12	0.1%	0.4%	0.5%	0.5%	1.5%
16	0.0%	0.2%	0.1%	0.1%	0.4%
18	0.2%	0.4%	0.1%	0.2%	0.8%
20	0.0%	0.0%	0.0%	0.1%	0.2%
22	0.1%	0.1%	0.0%	0.0%	0.2%
24*	**2.6%**	**1.5%**	**0.2%**	**0.7%**	**4.9%**
32	0.0%	0.2%	0.0%	0.0%	0.3%
36	1.4%	0.9%	0.3%	0.4%	3.0%
40	0.5%	0.0%	0.0%	0.0%	0.5%
44	0.9%	0.2%	0.0%	0.0%	1.1%
46	0.2%	0.0%	0.0%	0.0%	0.3%
47	0.2%	0.0%	0.0%	0.0%	0.2%
48*	**56.1%**	**18.5%**	**1.9%**	**0.5%**	**77.0%**
60	0.5%	0.3%	0.0%	0.1%	0.9%
72	0.3%	0.0%	0.2%	0.0%	0.5%
96	6.7%	0.2%	0.0%	0.1%	7.0%
Overall	**70.6%**	**23.3%**	**3.4%**	**2.8%**	**100.0%**

**Included in model*

Note: Table omits all lamp lengths that total less than 0.1% of the linear fluorescent lamp RBSA stock.
Source: Research team analysis of RBSA lighting data

5c. Applying Market Data by Home Type

Lacking data on the ultimate destination of lamp sales (i.e., which housing types accounted for which lamp sales), the research team decided to distribute the available retail sales/shelf data uniformly across all three home types. The RBSA supports this assumption—that customers that live in single family, multifamily, and manufactured homes do not make different lighting decisions because of their house type. While the RBSA found some minor differences in the technology mixes between single family, multifamily, and manufactured homes (Table A-42), the differences are not statistically significant.

Table A-42: RBSA Distribution of Lamps by Home Type

Technology	Single Family	Multifamily	Manufactured Home
Incandescent	58.7%	61.8%	61.0%
Halogen	5.3%	3.0%	1.7%
Compact Fluorescent	26.2%	28.0%	28.4%
Other	0.4%	0.2%	0.1%
Linear	9.5%	7.0%	8.8%

Source: Research team analysis of RBSA lighting data

5e. Applying Market Data to Outdoor Applications

It is not possible to tell from the market data whether a given general purpose or reflector lamp was sold for an interior or exterior application. Accordingly, the research team used the same technology mix observed in the overall market data for both interior and exterior applications for general purpose and reflectors. The team is confident that this assumption has little impact on the overall analysis as the technology shares between the interior and exterior applications of general purpose and reflector lamps in the stock are quite similar.

Table A-43: RBSA Distribution of Technologies between Interior and Exterior Applications

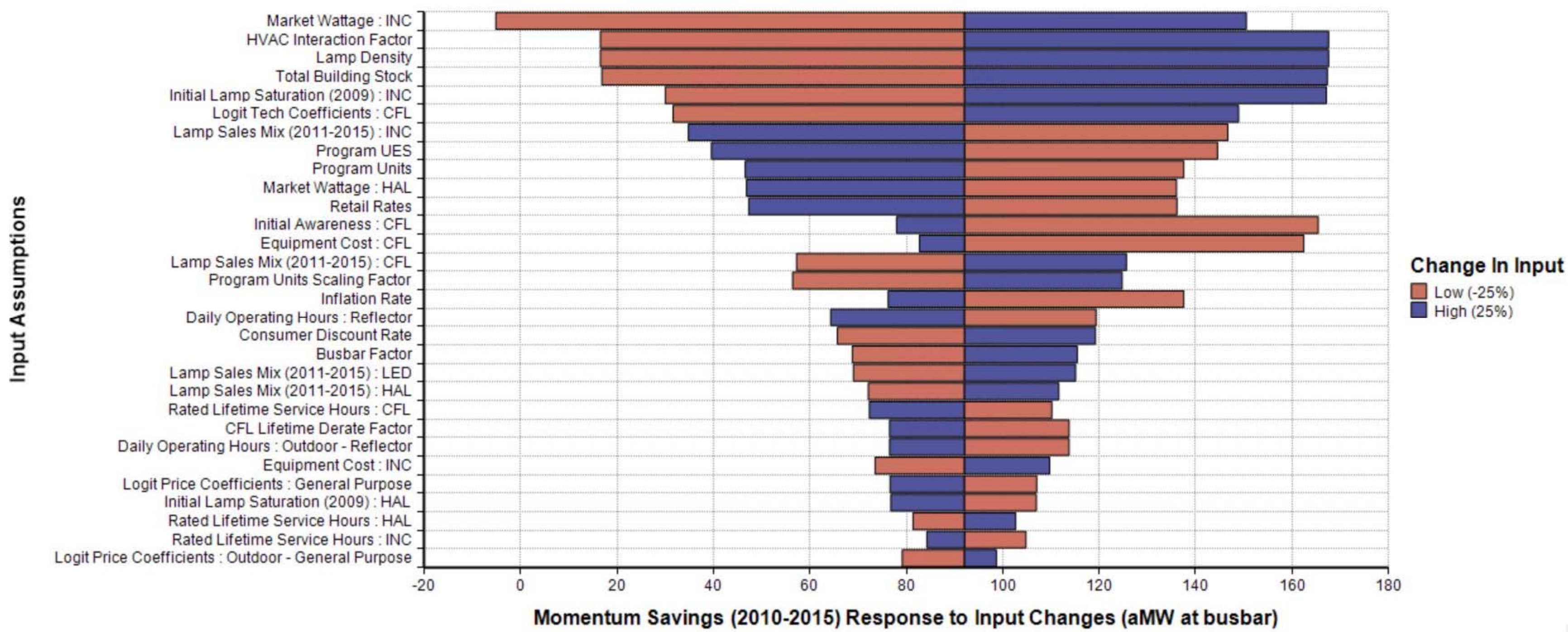
Technology	General Purpose		Reflector	
	Interior	Exterior	Interior	Exterior
Incandescent	60%	62%	54%	51%
Halogen	0%	0%	27%	37%
Compact Fluorescent	39%	37%	20%	12%
LED	1%	1%	0%	0%

Source: Research team analysis of RBSA lighting data

6. Sensitivity Analysis Findings

The research team built a sensitivity module into the model to assess the effects of changing individual parameters on the overall results. Figure A-11 summarizes the effect of increasing and decreasing parameters by 25%, with results ranked from the most to least effect on momentum savings. These results are approximate as the model does not recalibrate every time an input changes; thus, for example, while CFL cost and logit parameters affect results, changes to these inputs could also result in unrealistic sales mixes. Some parameters, such as lamp wattages, hours of use, and stock and sales mixes—may be worth additional research. Others, such as the stock size, are already well-researched. Calibration parameters are difficult to inform through primary or secondary research: the team has included them in the sensitivity analysis for context, but the best gauge of whether the calibration parameters are reasonable is review of the sales and stock alignment with existing data. Unsurprisingly, two of the inputs with the largest effect are those that drive the size of the market: lamp density and building stock. Other important factors include lamp wattages, which drive total consumption and savings, and the HVAC interaction factor, which is a multiplier directly affecting savings.

Figure A-11: Ranked Sensitivity Diagram



Source: Residential Momentum Savings Model

Appendix B: Literature Review Findings Memo

To: Carrie Cobb, Bonneville Power Administration (BPA)

From: Nicole DelSasso, Sonrisa Cooper, Rudy Kahsar, Kelsey Stober, Jesse Foote, Navigant Consulting, Inc.; Doug Bruchs, Rob Carmichael, Fiona Skinner, Ben Barrington, Katie Arquiette, Cadeo Group; Michael Strom, Kiersten Von Trapp, Lauren Abraham, NMR Group

Date: December 28, 2015

Subject: Residential Lighting Market Characterization Literature Review

Introduction

The residential lighting market has changed considerably in recent years as a result of the lighting standards enacted by the Energy Independence and Security Act of 2007 (EISA) and the rapid advances of light-emitting diode (LED) technology. To keep pace, lighting stakeholders in the Pacific Northwest have increased market and consumer tracking and completed many residential lighting-focused studies.

This literature review highlights the secondary resources the Navigant team (the research team) will use to estimate residential lighting Momentum Savings during the Northwest Power and Conservation Council's (the Council's) Sixth Power Plan (Sixth Plan) period (2010-2015). The research team will also use the literature review to characterize the residential lighting market in the Pacific Northwest.

The research team conducted this literature review to improve research accuracy and efficiency by leveraging existing data. Although many team members were previously aware—and in some cases led—several of the reviewed studies, this literature review ensured that the research team thoroughly examined all existing secondary data before conducting primary data collection.

The research team specifically sought information it could use to model the evolution of the residential lighting market between 2009 and 2015.[1] The research team reviewed more than 30 documents including recurring market assessment reports, regional power planning efforts led by the Council, retailer sales and shelf-stocking data, and evaluations of upstream residential lighting programs across the country.

The research team focused on the following research topics:

[1] The research team will use 2009 as the baseline for estimating residential lighting Momentum Savings for 2010–2015.

- **Baseline market conditions.** What was the size and technology mix of the installed lighting stock and sales in the Pacific Northwest in 2009 before the start of the Council's Sixth Plan? How did the size and technology mix vary by lamp type (screw-in and linear fluorescent) and housing type?
- **Market evolution.** How have the installed stock and sales of residential lighting products changed in the region since 2009? What was the size and technology mix of the residential lighting market in each year from 2010– 2015? Have building codes and lighting standards had an impact?
- **Multifamily buildings, manufactured homes, and new construction.** As most residential lighting research has focused on existing single-family homes, the research team also searched for data specific to multifamily buildings, manufactured homes, and new construction. The research team sought subsector-specific information to avoid using single-family data to represent the entire residential sector, thereby improving the overall reliability of the Momentum Savings model.
- **Non-residential interaction.** As part of the Momentum Savings analysis, the research team will need to account for cross-sector program sales to accurately determine how many bulbs incentivized through upstream residential lighting programs were installed in the residential sector versus the non-residential sector. To do so, the research team investigated the intersection of the residential and non-residential lighting sectors.

Memo Structure

This memo offers the following:

- A Summary of Key Findings organized thematically
- A list of Research Questions the research team sought to answer through the literature review
- A list of the specific Key Sources the research team reviewed
- A Discussion of Key Findings by theme that summarizes how the research team's findings will inform the market characterization and Momentum Savings modeling efforts
- Conclusions and Next Steps related to the literature review and ongoing residential lighting market research

Summary of Key Findings

The research team identified considerable existing research focused on residential lighting. The team will use this data to inform ongoing Momentum Savings modeling and market characterization. This section highlights the research team's key findings for each of the research topics introduced in the previous section.

Baseline Market Conditions

The research team can use data from Northwest Energy Efficiency Alliance's (NEEA) Residential Building Stock Assessment (RBSA) and the U.S. Department of Energy's (DOE) 2010 U.S. Lighting Market

Characterization, in conjunction with the Council's Sixth Plan planning documents, to develop a reliable 2009 baseline for estimating Momentum Savings.

The 2010 U.S. Lighting Market Characterization provides useful information on installed lighting stock, estimated energy use, and lumen production of all lamps operating in the United States in 2010. The RBSA provides stock information by building type, lamp type, and state. These more granular data will enable the team to better model the entire region by avoiding overreliance on exclusively single-family and region-wide data. Neither resource is perfect—the RBSA home inventories, although regional, took place in 2011 and the DOE report is national and focused on 2010—but collectively they provide considerable insight into the condition of the lighting market early in the Sixth Plan.

LEDs had almost no presence in 2010. Specifically, the DOE reported that LEDs were less than 1% of national sales in 2010, and NEEA found so few LEDs in the 2011 RBSA that it did not report them separately. The RBSA reported a technology mix of 25% CFL, 7% halogen, 57% incandescent, and 11% linear fluorescent for single-family homes.

Market Evolution

The research team identified a number of studies from around the country and at different points during the Sixth Plan that break down the various lighting technologies found in residential homes. The most complete longitudinal effort is from Massachusetts, where electric utilities have been operating a substantial upstream lighting program and directly installing efficient lighting technologies through downstream retrofit programs for many years. Similar information, albeit for fewer years, is available for California and nationally. However, none of these studies is specific to the Northwest and most reflect the impacts of both naturally occurring measure adoption and region-specific program activity.

The research team has a strong preference toward region-specific sales data to inform year-over-year changes in the residential lighting market. However, the team currently only has access to 2014 sales data, and those data sets are missing information from several large retailers. The Bonneville Power Administration (BPA) is actively trying to gather data for the previous years (2009–2013) and from the omitted retailers. Without these data, it will be challenging for the team to accurately model annual changes in the size and efficacy of the lighting market and, in turn, to reliably estimate Momentum Savings.

In the meantime, the best proxy for sales available is the shelf data gathered regularly through NEEA's Long-Term Market Tracking (LTMT) study, as shown in Table B-1.

Table B-1: Percentage of Lamps Stocked by Technology

Technology	2011	2012	2013	2014
Incandescent	78%	61%	50%	47%
Halogen	-	12%	21%	24%
CFL	20%	24%	24%	21%
LED	2%	2%	4%	8%

Source: NEEA, Northwest Residential Lighting Long-Term Market Tracking Study, 2010-2014. [2]

Multifamily Buildings, Manufactured Homes, and New Construction

Aside from the subsector-specific RBSA reports, the research team found little information about the changes in lighting practices between 2010 and 2015 for residents in multifamily buildings, manufactured homes, or newly constructed homes. A detailed characterization of these subsectors for the purpose of calculating a Momentum Savings estimate may require additional research tasks.

Non-Residential Interaction

The research team identified many studies, including several meta-studies, revealing the interaction between upstream retail-based lighting programs and commercial market actors. The research team can likely rely on these meta-studies to determine the percentage of residential program bulbs installed in non-residential applications without undertaking additional primary data collection. Puget Sound Energy (PSE) estimated the portion of LED bulbs sold through their residential lighting discount program but installed in the non-residential sector at approximately 8%. The research team corroborated this value by a meta-study of similar cross-sector research completed by lighting program administrators in Massachusetts.

Modeling Overall

The research team's review of secondary data not only helped identify inputs for Momentum Savings modeling but also provided insight into methodologies for developing the Momentum Savings model itself. For example, the DOE's Residential Lighting End-Use Consumption Study outlines its approach to estimating total lighting consumption. Beyond potentially using this estimate in the Momentum Savings analysis, the team may adapt the DOE study's methodology to other instances in which incomplete national data (e.g., several state or regional studies) may be scaled to reflect states in the Pacific Northwest.

Resources

Table B-2 provides a high-level summary of the documents the research team reviewed and includes research topic references (e.g., existing stock or multifamily-specific information) that each resource informed.

[2] Calculated by DNV GL using sample expansion weights by strata applied to each sample retailer to represent the population of retailers in the region that sell residential lamps.

Table B-2: Reviewed Studies by Category of Information

Funding Organization	Source	Year Published	Baseline Market Conditions	Market Evolution	Multifamily Buildings	Manufactured Homes	New Construction	Interaction with Non-Residential
NEEA	Residential Building Stock Assessment	2012	X		X	X	X	
NWPCC	Sixth Plan Supply Curves (Existing)	2010	X		X	X		
NWPCC	Sixth Plan Supply Curves (New)	2010			X	X	X	
NEEA	2014 Nielsen Sales Data	2014		X	X	X		
NEEA	Q4 NEEA Shelf Data	2014		X				
BPA	Simple Steps Data	2014		X				
NEEA	Upstream Lighting Program Data Survey	2014		X				
CA IOUs	Draft Measure Information Template	2011			X		X	
MA PAs	Results of Massachusetts Onsite Lighting Inventory	2013	X	X				
MA	Massachusetts ENERGY STAR Lighting Program: Early Impact of EISA	2013	X	X				
EPA	U.S. EPA Report on Opportunities to Advance Efficient Lighting	2011		X				
DOE	Data Collection and Comparison with Forecasted Unit Sales of Five Lamp Types	2012	X	X				
DOE	Standards & Test Procedures: Fluorescent Lamp Ballasts	2014		X				
NEEA	Residential Building Stock Assessment: Metering Study	2014	X					
DOE	Residential Lighting End-Use Consumption Study	2012			X	X		
NEEP	Impact of EISA on Residential A-Lamps	2014		X				
OSRAM	OSRAM SYLVANIA Socket Survey 6.0 2013 Research Results	2013	X	X				
DOE	2010 U.S. Lighting Market Characterization	2010	X		X	X		
MA PAs	Massachusetts Residential Lighting Cross-Sector Sales Research Memo	2015						X
PPL	Final Annual Report to the PA Public Utility Commission (June 2012–May 2013)	2014		X				X
CPUC	California Residential Replacement Lamp Market Status Report: Upstream Lighting Program and Market Activities in California Through 2013	2014						X
Eff. MA	Efficiency Maine Retail Lighting Program Overall Evaluation Report	2015		X				
MA PAs	MA Lighting Market Assessment Onsite Visit & Survey Results	2015	X	X				

Funding Organization	Source	Year Published	Baseline Market Conditions	Market Evolution	Multifamily Buildings	Manufactured Homes	New Construction	Interaction with Non-Residential
ACEEE	Mobilizing Energy Efficiency in the Manufactured Housing Sector	2012		X		X		
DOE	Energy Savings Forecast of SSL Lighting in General Illum. Applications	2014		X				
DOE	Residential Lighting End-Use Consumption	2012	X	X				
Navigant	Residential Energy Efficient Lighting and Lighting Controls	2014	X	X				
MA PAs	NTG Estimates Saturation Differences in MA and NY	2015		X				
PSE	2014-2015 Residential Lighting Impact Evaluation	2015						X
NWE	NEW CFL Lighting Market Study	2015	X	X				

Source: Research team analysis

Research Questions

The research team discussed the data needs for the proposed Momentum Savings modeling and market characterization efforts prior to conducting this literature review. The meeting generated the set of research questions described in this section.

The research team recognized that secondary information might not exist for all of the identified research questions. However, the team felt it was prudent to generate a comprehensive list of data needs and to verify whether the needed information was available through previous research before seeking to collect it through primary research. The research questions also provided valuable guidance to the team as it simultaneously developed market actor interview guides.

Baseline Market Conditions (2009)

- What was the total size of the residential lighting market before the Sixth Plan?
- What was the technology mix for screw-in and linear fluorescent lamps before the Sixth Plan?
- How many single-family, multifamily, and manufactured homes are in the Pacific Northwest?
- What is the average number of sockets, by base (medium screw base, mini, and pin), in each type of home?
- What is the mix of socket and lamp types for screw-in lighting (general purpose/dimmable, globe, reflectors/outdoor, decorative/mini-base, and 3-way) by home type?
- How prevalent is tube lighting (T12/8/5 and TLEDs) by home type?
- Do any of these values vary significantly across the region?

Market Evolution (2010–2015)

- How did the total size of the residential lighting market change each year during the Sixth Plan?
- How did the technology mix for screw-in and linear fluorescent lamps change each year during the Sixth Plan?
- How has the number and mix of home types changed between 2010 and 2015?
- How has the mix of socket types changed between 2010 and 2015?
- How has the mix of lamp types changed between 2010 and 2015?
- Do any of the previous values vary significantly across the region?
- What is the observed lag effect of the EISA standards?
- Did any new residential building codes affect lighting from 2010–2015?
- Are customers switching to EISA-exempt lights (e.g., rough service, 3-way) to avoid use of higher efficiency lamps?
- What types of lamp technology are end-users replacing with the new lamps?

- What percentage of residential customers install lamps proactively (early replacements) as opposed to when the existing lamp burns out?
- How many new bulbs do end-users purchase and install each year?

Multifamily and Manufactured Homes

- Is lighting turnover and efficiency in multifamily and manufactured homes different from turnover and efficiency in single-family homes? How so?
- Where do multifamily buildings get their lighting (retail, distribution)?
- How does this vary based on the building's tenants (owners/renters) or management strategy?

New Construction

- What percentage of builders' lighting comes from retail distributor sources?
- How do lamp sales for new construction differ from sales for existing homes?
- How does the socket mix in new construction homes differ from the mix in existing homes?
- Do builders install linear fluorescents? If so, how often and what kind?

Non-Residential

- What portion of retail lamps sold are installed in commercial spaces?
- Conversely, what portion of sold non-retail (e.g., wholesale distributor) lamps get installed in residential?
- Does the residential versus non-residential split vary by lamp type (e.g., fluorescent, screw-in), level of efficiency, or other factors?

Key Sources

This section provides an overview of the resources the research team reviewed, and found most relevant to the current research, listed by organization. These organizations include the following:

- NEEA
- Northwest Power and Conservation Council (the Council)
- California Public Utilities Commission (CPUC)
- Massachusetts Energy Efficiency Program Administrators
- DOE
- BPA

Appendix: Sources—Bibliography and Summary also includes the Modern Language Association (MLA) citation for each resource (Table B-1), a summary of each resource, and a short description of the strengths and weaknesses of each resource as it relates to the team's current research (Table B-2). Both tables include information about additional research not highlighted in this section.

Northwest Energy Efficiency Alliance

The research team reviewed two reports summarizing substantial NEEA-sponsored recurring research efforts in addition to reviewing sales data obtained by NEEA. NEEA is a non-profit group that represents more than 140 utilities and organizations in the Northwest. This group focuses on increasing energy efficiency in the entire region through market transformational programs and research.

The below list describes each NEEA-sponsored research source:

- The **RBSA** reflects findings from data collected at more than 1,850 residences across Oregon, Washington, Idaho, and Montana in 2011. Researchers designed the RBSA to characterize the entire residential sector, and the study takes into account the diverse climates, building practices, end-uses, and fuel choices across the region. As a result, the RBSA offers considerable insight into the state of residential lighting across the region early in the Sixth Plan. In addition to more than 1,400 single-family homes, the RBSA includes subsector-specific reporting for single-family, manufactured, and multifamily homes.

- The **Northwest Residential Lighting LTMT study** tracks regional lighting market metrics and has been updated on roughly an annual basis since 2005. NEEA completed the most recent report in 2015. The LTMT study explores a wide variety of lighting topics including customer awareness, retailer/manufacturer perceptions of efficient products, and stocking practices. Shelf-stocking data collection typically occurs in the early winter of each LTMT cycle. This data set is of particular interest to the research team as it provides insight into the likely purchasing and installation practices for lighting by year.[3]

- NEEA purchased **aggregated 2014 Nielsen-collected sales data** to complement the stocking data collected through the LTMT study. Unlike the shelf-stocking data, the Nielsen data reflects the actual sales that occurred in 2014 for a subset of contributing retailers. The Nielsen data provides insight into the volume of sales by technology, wattage, lumen bin, and pack size, which in turn allows for the direct estimation of average lighting efficacy. It is highly likely these sales data will play a prominent role in informing the average efficiency level in the team's Momentum Savings model. The Nielsen data is not fully representative of the market for program-supported bulbs, as several high-volume lighting retailers do not provide sales data to Nielsen. However, the Nielsen data are the best available proxy for actual sales activity.[4]

- NEEA works with CLEAResult to complete an **annual survey of regional lighting sales.** At NEEA's request, CLEAResult works with PNW retailers to gather sales data for lighting incentivized through BPA's Simple Steps program, other utility programs, and – to the extent possible – sold outside of programs. The annual survey of retail lighting sales provides a broader, regional perspective on the market than the program-focused Simple Steps dataset offers.

[3] The research team is aware that stocking practices do not perfectly reflect consumer purchasing behavior, as merchandising strategies and other market factors greatly affect the product volume and placement on shelves. However, in lieu of sales data, shelf-stocking data offer significant insight because changes in shelf-stocking patterns over time are a valuable indicator of market changes. The shelf-stocking survey is also a valuable source of pricing data.

[4] BPA is currently developing strategies to obtain sales data from the missing retailers as well as to gather Nielsen data for previous years (2009–2013).

Northwest Power and Conservation Council

The research team reviewed two workbooks developed by the Council as part of its Sixth Plan. The workbooks document assumptions the Council used to estimate anticipated lighting savings between 2010 and 2014.

The workbooks provide information about the lighting efficiency levels the Council recognized at the outset of the plan as well as the Council's expectation for how lighting efficiency would change during the five-year period. The workbooks also provide the Council's assumptions on code adoption during the Sixth Plan. One workbook focuses on lighting in existing residential buildings and the other is specific to lighting in anticipated residential new construction.

California Public Utilities Commission

The research team reviewed two reports sponsored by the CPUC. The CPUC sponsors research and evaluation on behalf of California ratepayers served by Pacific Gas and Electric Company (PG&E), Southern California Edison (SCE), San Diego Gas and Electric Company (SDG&E), and Southern California Gas Company (SCG). Collectively, the first three companies serve more than two-thirds of the total electricity demand throughout California.

The research team reviewed the following two reports:

- The **California Residential Replacement Lamp Market Status Report** provides information about statewide upstream lighting programs from 2010–2012. The study, completed in 2013, included more than 1,500 consumer telephone surveys, more than 2,000 home lighting inventories, more than 600 in-store stocking assessments, in-depth interviews with lighting suppliers, shopper surveys, and a lighting choice model. The lighting choice model predicts the probability that a consumer will choose a particular lamp based on the market context. The model results are of particular interest to the research team because it could inform model inputs pertaining to lamp installation and replacement behavior.
- A draft Measure Information Template for **Lighting in Multifamily and Hotel Corridors,** created by the California Utilities Statewide Codes and Standards Team, provides an overview of a proposed mandatory modification of lighting control/switching requirements in hotel/multifamily building corridors in California.

Massachusetts Energy Efficiency Program Administrators

The American Council for an Energy-Efficient Economy (ACEEE) recognizes Massachusetts as an energy efficiency leader, having ranked the Commonwealth first for the past five years in its State Energy Efficiency Scorecard. During this time, the state's eight electric and gas energy efficiency program administrators have completed a significant number of residential lighting program evaluations, many of which include market assessment/tracking components. Alongside NEEA's LTMT and the large-scale evaluations in California, Massachusetts has collected as much lighting data as any entity in the country over the past five years.

The research team reviewed the following Massachusetts-focused research reports:

- The **2014 Onsite Lighting Inventory** compiles the results of more than 400 whole home lighting inventories in three states: Massachusetts, Georgia, and Kansas (the latter two states served as control states for a concurrent net-to-gross study). The onsite visits in Massachusetts include return visits to 111 previously inventoried homes. These homes, referred to as panel participants, provided the Cadmus Group and NMR Group with insight into the changes in lighting technology between years for specific sockets. The research team may use these findings to model socket turnover depending on the final Momentum Savings model methodology.

- The 2013 **Massachusetts ENERGY STAR Lighting Program: Early Impacts of EISA** report summarizes the current and likely effects of EISA on the residential lighting market in Massachusetts. This NMR Group research focuses specifically on EISA's effect on the availability and purchase of inefficient lamps, potential stockpiling, and consumer awareness and understanding of the EISA standards and lighting terminology.
- In the **Massachusetts Residential Lighting Cross-Sector Sales Research Memo,** the Cadmus Group and NMR Group summarize findings from a comprehensive review of secondary sources on the residential and commercial lighting markets for screw-in lamps. The memo summarizes 23 cross-sector estimates from outside Massachusetts and assesses the relative strengths and weaknesses of each study as well as each study's applicability to Massachusetts.

U.S. Department of Energy

The DOE, primarily through the Office of Energy Efficiency and Renewable Energy (EERE), has completed a number of nationwide studies in recent years aimed at characterizing, tracking, and forecasting the residential lighting market. Navigant led many of these studies.

The research team found the following four DOE reports the most relevant to BPA's ongoing research:

- The **2010 U.S. Lighting Market Characterization Report** published by the DOE in January 2012 provides a comprehensive summary of the installed lighting stock, estimated energy use, and lumen production of all lamps operating in the United States in 2010. The report, which provides information for residential, commercial, industrial, and outdoor lighting, also seeks to characterize changes in the lighting market leading up to 2010. The report relies almost exclusively on publicly available data, including data from the Census and Energy Information Administration (EIA).
- The **Residential Lighting End-Use Consumption Study: Estimation Framework and Initial Estimates** study followed the market characterization study, published in December 2012. The study develops a regional estimation framework that allows for the estimation of lamp usage and energy consumption at multiple levels. The levels include national and U.S. regions, household characteristics, location within the home, and lamp characteristics. The study was built from four previous evaluations and research completed around the country, mostly collected in 2009. The study also provides estimates of hours of use, average lamp power, and total lighting energy usage at the state level.
- The article **"Energy Conservation Program: Data Collection and Comparison with Forecasted Unit Sales of Five Lamp Types"** published in March 2012 in the Federal Register by the DOE's EERE office compared projected sales models of five lamp types (rough service, vibration service, 3-way, incandescent, and shatter-resistant) with actual shipment National Electric Manufacturers Association (NEMA) data from 2011. The purpose of the comparison was to determine whether sales exceeded projections to the point that regulatory action was required. For the research

team, the article provided insight into the magnitude of and sales trends for non-EISA-compliant lamps.

- The DOE's **Energy Savings Forecast of Solid-State Lighting in General Illumination Applications Report** provides a forecast of LED sales through 2030. Although this forecast extends well beyond the Sixth Plan timeframe, Navigant, which led the study, gathered information about actual LED uptake to inform its forecast. This data set may be of use when the research team models Momentum Savings.

Bonneville Power Administration

BPA, the sponsor of the research team's current residential lighting Momentum Savings modeling and market characterization efforts, also provided the team with access to two data sets:

- BPA offers the **Simple Steps, Smart Savings** (Simple Steps) regional program, which BPA designed to increase the adoption of energy-efficient residential products. The program offers rebates for a variety of measures sold through retail stores but has historically focused on lighting. The research team reviewed cumulative Simple Steps program data from 2010 through 2014. These data provide important insight into program activity in the region during the Sixth Plan, and the research team must account for this activity when estimating Momentum Savings. The Simple Steps data BPA provided includes information regarding quantity, incentive payment, and energy savings.

Discussion of Key Findings

This section details the key findings, by research area, from the research team's literature review.

Baseline Market Conditions

The research team found that NEEA's 2011 RBSA provides the most useful information regarding the existing lighting stock in the Pacific Northwest, including the following information.

Total Installed Stock of Lamps and Fixtures

To estimate the total number of installed lamps in the Northwest, the team generated two separate estimates relying on two different datasets: the RBSA and the 2010 DOE Lighting Market Characterization.

The RBSA provides detailed information on the installed lighting stock in the Northwest. Single-family homes average approximately 63 lamps and 40 fixtures across the Northwest. Although the total number of lamps per home varies across building types (Table B-3), the density of lamps and fixtures is comparable at approximately three lamps per 100 sq. ft. Average lamp and fixture counts are relatively consistent across states, although results for Montana are typically lower than the other three Pacific Northwest states.

Table B-3: Average Number of Lamps per Home by State

Lamp Type	ID	MT	OR	WA	Region
Single-Family	63.6	56.7	63.2	64.1	63.2
Multifamily	-	-	-	-	23.2
Manufactured Homes	33.2	29.9	37.1	34.1	34.5

Source: RBSA for Single-Family, Multifamily, and Manufactured Homes, 2011

Table B-4 shows the population sample frame used in the RBSA, which was developed using census data and detailed utility information. The research team multiplied the sample frame by the average number of lamps per home to arrive at an estimate of the total number of installed lamps in the region, approximately 293 million units.

Table B-4: Total Single-Family, Multifamily and Manufactured Homes and Installed Lamps

Lamp Type	Total Homes	Total Installed Lamps
Single-Family	4,023,937	254,312,818
Multifamily	863,104	20,024,013
Manufactured Homes	543,730	18,758,685
Total	5,430,771	293,095,516

Source: RBSA for Single-Family, Multifamily, and Manufactured Homes, 2011; Navigant and Cadeo analysis

The research team then generated a second estimate using the DOE 2010 Lighting Market Characterization study, which reported a nationwide average 51.4 lamps per residential home, and a total installed stock of 5.8 billion lamps. After scaling this number to the Northwest (4% of the country by population), the team arrived at a slightly lower estimate of the total installed stock in the region: 232 million lamps.

Total Annual Sales of Lamps

To estimate the number of lamps purchased by residential customers annually in the Northwest, the team generated two separate estimates.

First, the team employed a "bottom-up" approach of scaling up the Nielsen sales data, which the team believes captures approximately 30% of regional retail lighting sales, to reflect the entire Pacific Northwest. Using the Chain Logic Method and the Nielsen data's estimate of 16 million general purpose A-line lamp sales in 2014, the team developed an initial estimate of annual regional for lamp sales. The team then subtracted out 8% of these lamps to account for lamps sold through retailers going to non-residential applications. [5] Using this approach, the team estimates approximately 49 million lamps were sold to residential customers in 2014.

[5] PSE 2014-2015 Residential Lighting Impact Evaluation estimated the portion of LED bulbs sold through PSE's residential lighting discount program that were installed in the non-residential sector at approximately 8%.

Second, the team employed a "top-down" estimate using lighting shipment data for NEMA member manufacturers. While not every lighting manufacturer is a NEMA member, the team believes the data represents approximately 90% of total A-line lamp shipments. Applying this assumption, the team estimated that approximately 1 billion lamp shipments arrived in the United States in 2014. The team again subtracted out 8% of these lamps to account for lamps going to non-residential applications. Scaled down the national shipment data to reflect only the Northwest (4% of the country by population), the research team estimates regional A-line shipments at approximately 39 million annually.

This top-down approach (i.e., scaling down national shipments to represent the PNW) produces a lower estimate of the total market size than the bottom-up approach (scaling up a subset of regional retail sales). The research team proposes using the average of the two approaches, 44 million units, as an approximation of the total annual sales of residential lighting in the Northwest.

Technology Mix

The RBSA also provides information on the distribution of lighting technologies by building type and state, which will likely serve as important Momentum Savings model inputs.[6] The majority of lamps in single family residential homes in 2011 were incandescent (Table B-5). Other technologies include compact fluorescent (25.0%), linear fluorescent (10.8%), and halogen (6.5%). The RBSA did not explicitly identify LEDs, but they were included in the "Other" category, which comprised only 0.7%. Multifamily units averaged 1.7 fluorescent tubes compared to manufactured and single-family homes, which had an average of 3.63 fluorescent tubes.

Another useful finding from the RBSA is the difference in technology mix by state. For single-family homes, Montana had the highest percentage of incandescent lamps (65.0%), and Washington had the highest percentage of CFLs (27.7%), as seen in Table B-5. Overall, Washington had the most efficient technology mix while Montana had the least efficient.

Table B-5: Technology Mix - Single-Family Homes by State

Lamp Type	ID	MT	OR	WA	Region
CFL	24.9%	21.4%	21.3%	27.7%	25.0%
Halogen	2.7%	2.8%	6.7%	8.0%	6.5%
Incandescent	61.0%	65.0%	60.5%	52.8%	57.0%
Linear Fluorescent	11.1%	10.7%	11.1%	10.5%	10.8%
Other	0.3%	0.1%	0.5%	1.0%	0.7%

Source: Baylon, D., Storm, P., Geraghty, K., & Davis, B. (2012). 2011 Residential Building Stock Assessment: Single-Family Characteristics and Energy Use. Seattle, Washington: Northwest Energy Efficiency

The RBSA also provides information on the technology mix by state in manufactured homes. Similar to single family homes, Table B-6 shows the majority (59.4%) of lamps in manufactured homes were also incandescent. Manufactured homes in Washington had the highest share of compact fluorescent lamps (29.7%) and the lowest share of incandescent lamps (56.7%).

Table B-6: Technology Mix - Manufactured Homes by State

Lamp Type	ID	MT	OR	WA	Region
CFL	26.0%	26.6%	25.9%	29.7%	27.7%
Halogen	3.0%	0.6%	2.0%	2.3%	2.2%
Incandescent	62.8%	62.6%	60.8%	56.7%	59.4%
Linear Fluorescent	7.8%	10.2%	11.3%	10.8%	10.5%
Other	0.4%	-%	0.0%	0.4%	0.3%

Source: Baylon, D., Storm, P., Geraghty, K., & Davis, B. (2012). 2011 Residential Building Stock Assessment: Manufactured Homes Characteristics and Energy Use. Seattle, Washington: Northwest Energy Efficiency

The RBSA also provides information on the in-unit technology mix for multi-family buildings as shown in Table B-7. Similar to the other residential housing types, the majority of lamps in multi-family units were incandescent (62.2%) and compact fluorescent (26.8%).

Table B-7: Technology Mix – Multifamily Homes

Lamp Type	Region
CFL	26.8%
Halogen	3.3%
Incandescent	62.2%
Linear Fluorescent	6.3%
Other	1.2%

Source: Baylon, D., Storm, P., Geraghty, K., & Davis, B. (2012). 2011 Residential Building Stock Assessment: Multi Family Homes Characteristics and Energy Use. Seattle, Washington: Northwest Energy Efficiency

Table B-8 shows the technology mix of NEMA A-line lamp shipments. Although the NEMA index does not include linear fluorescent lamps, the data are comparable to the RBSA findings in showing that together incandescent (76%) and compact fluorescent (23%) lamps dominate the market.

Table B-8: 2010 NEMA A-Line Lamp Shipments

Technology	Share
Halogen	1.3%
Incandescent	75.7%
CFL	22.8%
LED	0.2%
Total	**100.0%**

Source: NEMA Consumer Lamp Index, 2010

Market Evolution

Momentum Savings come from changes in efficiency over time. The research team looked at the change in technology mix, lamp replacement decisions (including switching to non-compliant lamps), and the impact of EISA on the market to understand how the residential lighting market has evolved since 2011. The team will use findings related to the residential lighting market's evolution as inputs for the Momentum Savings calculation as well as to determine the appropriate overall model methodology.

Technology Mix

NEEA's LTMT studies provide data on retailer lamp stocking practices from 2011–2014. Notably, the share of incandescent lamps decreased by 31% from 2011–2014. The share of halogen and LED lamps increased over the same time period, while the share of CFLs remained relatively steady between 20% and 25%.

Table B-9: Percentage of Lamps Stocked by Technology

Technology	2011	2012	2013	2014
Incandescent	78%	61%	50%	47%
Halogen	-	12%	21%	24%
CFL	20%	24%	24%	21%
LED	2%	2%	4%	8%

Source: NEEA, Northwest Residential Lighting Long-Term Market Tracking Study, 2010-2014.[7]

The Massachusetts Onsite Lighting Inventory found that from 2009 to 2013 the market penetration of specialty CFLs increased from 25% to 62% and LEDs increased from 7% in 2012 to 12% in 2013 (Table B-10). The number of households that use at least one CFL increased from 88% in 2009 to 96% in 2013. The team compared this non-Pacific Northwest result with a study by NorthWestern Energy, whose service territory covers western Montana, eastern South Dakota, and central Nebraska. This study found that 63% percent of respondents reported acquiring at least one CFL in 2014, compared with 24% for LEDs. The survey estimated socket saturation rates of 16% for CFLs and 3% for LEDs in 2014.

Table B-10: Percentage of Households That Use at Least One CFL, Incandescent, or LED in 2009 and 2013

Technology	2009	2013
Incandescent	65%	55%
All CFLs	88%	96%
Specialty CFLs	25%	62%
LEDs	-%	12%

Source: NMR Group, Inc. Results of the Massachusetts Onsite Lighting Inventory, 6th July 2013.

[7] The research team noticed a discrepancy in the reported data between the 2012 and 2013 reports.

The 2013 OSRAM SYLVANIA Socket Survey, an annual survey on consumer behavior around lighting, collected technology trend data early in the Sixth Plan period by conducting 300 interviews over a 10-day period. OSRAM reported that the portion of respondents who have LEDs and halogens in their homes increased from 2010 to 2013, while the portion of respondents who had incandescent and CFLs in their homes decreased from 2010 to 2013 (Table B-11).

Table B-11: Percentage of Respondents Owning Specific Bulb Types

Technology	2010	2013
Incandescent	82%	76%
Halogen	39%	42%
CFL	72%	67%
LED	27%	30%

Source: OSRAM SYLVANIA Socket Survey 6.0 2013 Research Results.

Replacement Decisions

According to the NEEA LTMT study, the share of CFL purchasers that are waiting for lamps to burn out before installing additional CFLs (Table B-12) has decreased by 21% from 2010–2014 (Table B-12).

Table B-12: Percentage of CFL Purchasers Who Have CFLs Installed in Their Homes Waiting for Incandescent Lamps to Burn Out

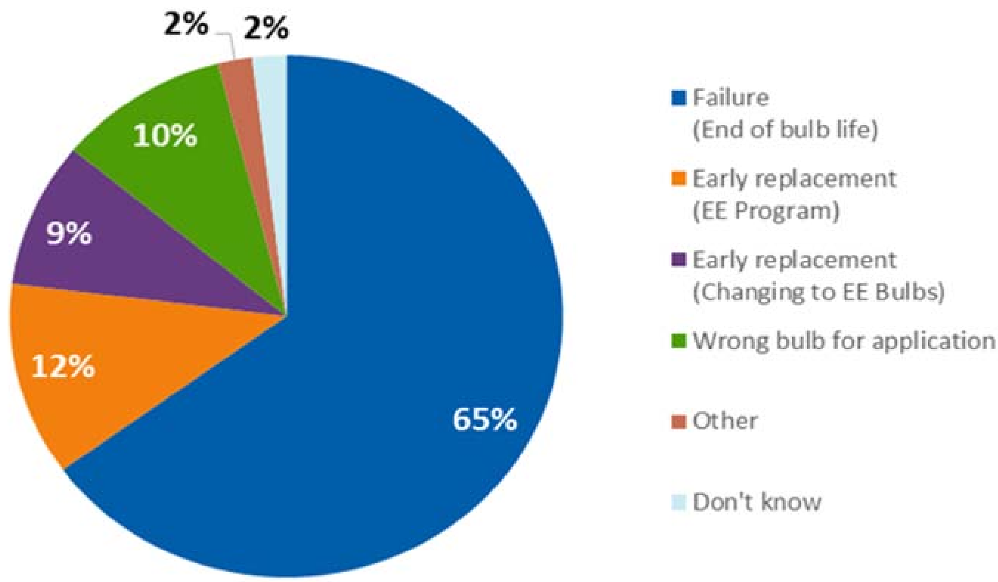
2010	2011	2012	2013	2014
29%	22%	18%	21%	8%

Source: NEEA, Northwest Residential Lighting Tracking and Monitoring Study, 2010-2014.

The research team may also use the Massachusetts Onsite Lighting Inventory and the Massachusetts Lighting Market Assessment to gain insight into replacement decisions and whether end-users proactively installed efficient lighting or simply replaced lamps on failure. Although these studies are specific to Massachusetts, the findings may still be relevant to Momentum Savings research since customer's installation decisions and practices may not differ dramatically by region.

The 2015 Massachusetts Lighting Market Assessment included a panel study that looked at actual changes in specific fixtures observed by auditors. The study found that sampled customers replaced the majority of bulbs (65%) due to failure. Just over one-fifth (21%) of bulbs were replaced before the end of their useful lives; 12% were replaced by direct-install energy efficiency programs, and 9% were replaced by customers on their own because they wanted a more efficient bulb (Figure B-1). The research team may use this information to inform decisions on whether to use a stock turnover model or another approach that better accounts for non-failure replacements for the Momentum Savings calculation.

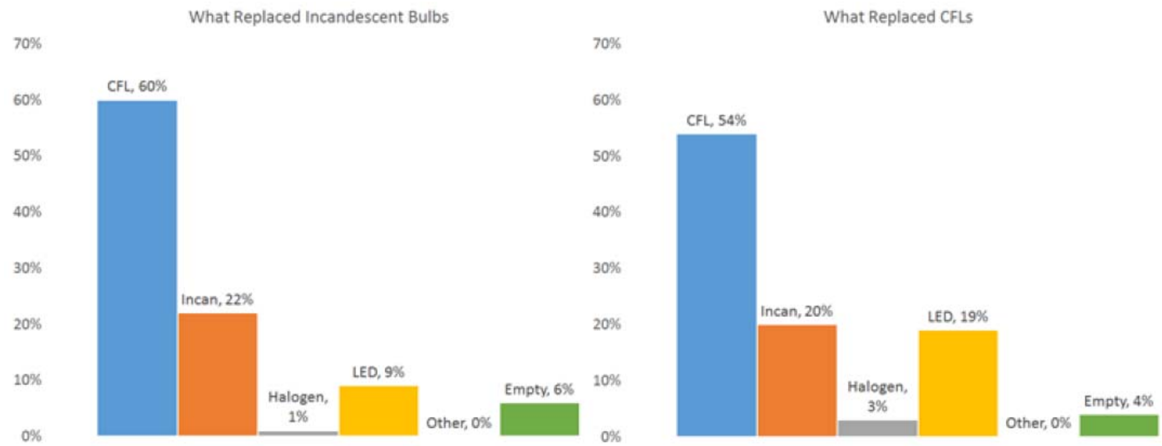
Figure B-1: Panelists Primarily Replace Bulbs at Failure or When Switching to Energy Efficient Bulbs



Source: Cadmus. MA Lighting Market Assessment Onsite Visit and Consumer Survey Results. Waltham: Cadmus, 2014.

The 2014 Massachusetts study also determined that 13% of total observed sockets had a lamp replaced between 2013 and 2014. The study results show a large increase in the share of efficient lamps for the replaced sockets, as households were nearly three times as likely to choose a CFL instead of an incandescent to replace an existing incandescent lamp. The share of CFLs in sockets where lamps that sampled customers replaced increased from 25% in 2013 to 60% in 2014 (Figure B-2). Of the sockets that previously held CFLs, respondents replaced 59% with new CFLs, 22% with LEDs, and only 11% with incandescent bulbs.

Figure B-2: Technologies that Replaced Incandescent and Compact Fluorescent Lamps: 2013-2014



Source: Cadmus, Results of the Massachusetts Onsite Lighting Inventory, March 2015.

Switching to Non-Compliant Lamps

The Massachusetts Onsite Lighting Inventory also assessed whether households were switching from standard to specialty lamp shapes when replacing incandescent bulbs with new incandescent bulbs following EISA. It found that 70% of sockets had traditional A-line incandescent lamps in 2013 but only 53% did in 2014. Almost all of the shifts were to spot/reflector/flood bulbs, which went from 7% in these sockets in 2013 to 24% in 2014.

The study also examined whether there were any differences in replacement practices between specialty incandescent lamps and standard (A-line) incandescent lamps. The reason is likely that consumers found it difficult to locate comparable CFL and LED lamps at a price point they were willing to pay. Similarly, CFLs and LEDs both increased by 24% between 2013 and 2014 among replaced dimmable and 3-way lamps. In contrast, A-line CFLs increased by only 2%.

Impact of EISA

The research team compared the mix of technologies in the NEEA shelf data and the Nielsen sales data and found that the full-year 2014 Nielsen data displayed a significantly higher proportion of incandescent lamps than did the Q4 2014 NEEA sales data. The research team believes this is the case because the full-year Nielsen data likely includes the sell-through of lamps manufactured before the January 1, 2014 EISA deadline for 40W and 60W lamps. This inclusion inflates the share of incandescent lamps in the technology mix. The research team will need to consider this disparity when modeling Momentum Savings.

Similarly, a shelf-stocking survey referenced in the Massachusetts ENERGY STAR Lighting Program: Early Impacts of EISA report found numerous packages of 100W incandescent lamps on store shelves in August and September 2012, nearly nine months after their initial phase-out in January 2012. One-half of consumers shopping for such lamps could still find them during the last three months of 2012, nearly one year after the start of the phase-out period.

D+R International's report on the impact of EISA on residential A-line lamps indicates that EISA reduced the sales of incandescent general service lamps by approximately 7% between 2012 and 2013. Unit sales of incandescent lamps fell from 2012 to 2013, but incandescent lamps remained the dominant technology type, accounting for 79% of products sold in 2013.

Multifamily Buildings, Manufactured Homes, and New Construction

The research team looked for resources aside from the subsector-specific 2011 RBSA that would provide information about the changes in lighting practices in multifamily buildings, manufactured homes, and new construction.

Multifamily Housing

The RBSA showed relatively little difference in the lighting power density for common areas (around 0.7 W/sq. ft.) across building ages, suggesting that building owners have already retrofitted much of the existing multifamily building stock with efficient common area lighting.

The research team obtained additional information through the National Apartment Association (NAA). Contact with the NAA confirmed the absence of a specific report documenting lighting sourcing and replacement methods within multifamily residential communities. The research team posed questions of lighting sourcing and turnover to an assortment of NAA market research employees that provided the following verbatim responses:

- "Upgrades or replacements are many times driven by money."
- "Another driving factor is upgrades: how to change the look of the building and payback. Right now there are big pushes with energy companies to change to LED because of less maintenance, energy savings and color options. Back when wall packs and High Pressure Sodium were the thing the negative was color, but savings were there to make up for the color. Now LED has many colors and savings associated but big up front cost. Price is coming down but still up there on the LEDs."
- "It seems that the biggest driving force to change the lighting is during upgrades, name changes when the capital dollar is available. There are some that will do it based on savings alone, but many times driven on upgrading the property to keep up with new construction."
- "Lights are bought from and through the vendor that is changing the lights. These vendors that do lighting upgrades do tremendous volume of work and get fantastic prices. Even with the volume that we buy the contractor can many times beat our pricing based on their volume."
- "The interior lights are driven by what looks good, when doing unit upgrades. Interior lights are bought more on what the light fixture looks like than it does energy savings. Many times the interiors might go through a couple of changes before the outdoor lights are even looked at."
- "Interiors are driven by what sells, what looks good, does it match the new appliances or flooring look."

Manufactured Homes

The research team found a lack of specific data on manufactured homes outside of the 2011 RBSA. A detailed characterization of manufactured homes may require additional research through other task order elements.

New Construction

The 2007 Single-Family Residential New Construction Stock Assessment survey found an average of 49 fixtures and 77 lamps per home. This compares with the 61.5 lamps per home found in the 2007 Single-Family RBSA and confirms the need to model new construction separately to existing buildings.

Non-Residential Interaction

The PSE 2014-2015 Residential Lighting Impact Evaluation estimated the portion of LED bulbs sold through PSE's residential lighting discount program that were installed in the non-residential sector by conducting an in-store survey of 200 customers. The study found that customers purchased approximately 8% of LEDs sold at PSE program retailers for non-residential applications.

The Massachusetts Residential Lighting Cross-Sector Sales Research Memo provides estimates on the portion of residential program sales going to non-residential programs. These estimates range from 0% (in which residential phone survey respondents in Maine and lamp purchasers surveyed at retail stores in California indicated not installing any lamps in business/commercial settings) to a high of almost 19% (based on a residential phone survey in the Southern California Edison program territory of California). The study recommends using a placeholder of 7% to apply to the Massachusetts upstream lighting program sales as an indicator of those bulbs used in commercial settings, thereby corroborating the PSE value of 8%.

Modeling Overall

In the course of its review, the research team identified two studies that make use of frameworks for modeling key elements of the Momentum Savings equation and a third study that mirrors the entire Momentum Savings calculation process itself.

The first identified study, the DOE's Residential Lighting End-Use Consumption study, offers a framework to estimate the average hours of use for lighting in the region. In this analysis, the DOE developed a national hours-of-use data set by "linking lamp usage from end-use metering studies with household characteristics and lighting inventory profiles." In doing so, the study provides an estimate of the hours of use for lighting in each state. Beyond using this estimate in the Momentum Savings analysis itself, this methodology may be adapted to other instances in which the research team may scale incomplete national data (e.g., several state or regional studies) to reflect states in the Pacific Northwest.

Additionally, to the extent the Momentum Savings methodology has yet to be determined, this study may prove useful as it presents an argument for a bottom-up approach to modeling savings. When developing estimates of hours of use and individual lamp energy consumption, the DOE study notes that a bottom-up approach is more accurate, as it preserves any correlation between lamp type and hours of use.

The DOE Residential Lighting End-Use Consumption study relies heavily upon findings from another study, the California Residential Replacement Lamp Market Status Report (CA RLMS), which is the second study the research team believes could potentially inform the Momentum Savings modeling approach. This study created a Lamp Choice Model that predicts consumer behavior regarding lamp purchases based on the market context (i.e., available technologies, prices, and type of retail channel through which customers purchased lamps). The output from this model reflects the changes in regulatory and market conditions between 2012 and 2013 as well as how those may have influenced consumer purchases. To the extent that the research team could calibrate this model to the technologies, prices, and retail channels in the Pacific Northwest, it may provide a means to predict the market mix through the analysis period.

The third study identified by the research team that could inform the team's Momentum Savings modeling approaches is the DOE's Energy Savings forecast of Solid-State Lighting. The forecast, developed by Navigant using the Analytica modeling platform, closely matches the traditional Momentum Savings methodology. Specifically, it used the following methodology to calculate savings from solid-state lighting:

1. "Project annual lumen demand forecast assuming constant lumen demand per square foot of floor space in each sector, the lighting market model forecasts U.S. lumen demand from 2013 to 2030."

2. "Each year, new lamps enter the market as old lamps are replaced or fixtures are installed or retrofitted. This creates an annual lumen market turnover, which may be satisfied by a suite of lighting technologies. The lighting market model considers three possible events that create lumen market turnover: 1) new installations due to new construction; 2) units replaced upon failure of existing lamps; and 3) units replaced due to lighting upgrades and renovations."

3. "Recognizing that the incumbent conventional lighting technologies will compete with new LED lighting products, the lighting market model allows for both cost reductions and performance improvements in efficacy and lifetime for conventional lighting technologies."

4. "The lighting market model predicts market share as an aggregate of many individual purchase decisions using two analytic components: an econometric logit model that considers cost factors influencing each decision, and a technology diffusion curve that considers time dependent market factors influencing each decision."

5. "Annual energy savings are then estimated by comparing the lighting energy consumption projected by the lighting market model to that of a counter-factual LED-absent scenario."

Steps 1 and 2 effectively equate to establishing the market size, while steps 3 and 4 establish the market mix. Lastly, the comparison outlined in step 5 could just as easily examine the Sixth Power Plan baseline as the counter-factual scenario. While there is some concern over the use of stock turnover modeling for lighting, this model appears to account for any savings caused by proactive or non-failure replacement by including a category that captures proactive lighting upgrades (i.e., upgrades to functioning lamps). This model closely matches the process by which the research team has historically estimated Momentum Savings for other technologies, so the research team will further explore the possibility of adapting this model to assess the residential lighting market in the Pacific Northwest.

Conclusions and Next Steps

Overall, the research team identified a large inventory of existing resources to inform the team's impending residential lighting Momentum Savings analysis. The existing data are more robust at the sector-level or for single-family homes than the multifamily, manufactured home, and new construction residential subsectors. However, greater reliance on additional retail sales data (BPA is currently seeking data for 2009 through 2013) would help, as these retailers sell to customers from all subsectors. These retailer sales data are key to producing reliable Momentum Savings results.

The research team's next steps are two-fold:

- **Determine appropriate Momentum Savings methodology.** The literature review shed significant light not only on likely model inputs but also on potential modeling methodologies. The research team will build upon the literature review's findings to develop a detailed, draft Momentum Savings methodology for BPA and stakeholder review.
- **Identify and fill remaining data gaps**. Concurrent with the model selection process, the research team will identify any remaining data gaps that require primary research in order to reliably estimate Momentum Savings. At this time, the research team does not anticipate significant primary research beyond the tasks already planned for the Residential Lighting market research. However, it is not possible to definitively make this determination until the team defines the methodology and maps the identified secondary sources as inputs.

Appendix: Sources—Bibliography and Summary

Table B-1: Bibliography Summary Table

Source Name (As Referenced in Memo)	Funding Org.	Year of Publication	Citation	URL (If Available Online)
RBSA—Single-Family	NEEA	2012	Baylon, D., Storm, P., Geraghty, K., & Davis, B. (2012). 2011 Residential Building Stock Assessment: Single-Family Characteristics and Energy Use. Seattle, Washington: Northwest Energy Efficiency Alliance.	http://neea.org/docs/reports/residential-building-stock-assessment-single-family-characteristics-and-energy-use.pdf?sfvrsn=8
RBSA—Multifamily	NEEA	2012	Baylon, D., Storm, P., Geraghty, K., & Davis, B. (2012). *2011 Residential Building Stock Assessment: Multifamily Characteristics and Energy Use*. Seattle, Washington: Northwest Energy Efficiency Alliance.	http://neea.org/docs/default-source/reports/residential-building-stock-assessment--multifamily-characteristics-and-energy-use.pdf?sfvrsn=4
RBSA—Manufactured Homes	NEEA	2012	Baylon, D., Storm, P., Geraghty, K., & Davis, B. (2012). *2011 Residential Building Stock Assessment: Manufactured Homes Characteristics and Energy Use*. Seattle, Washington: Northwest Energy Efficiency Alliance.	http://neea.org/docs/default-source/reports/residential-building-stock-assessment--manufactured-homes-characteristics-and-energy-use.pdf?sfvrsn=8
NWPCC Sixth Plan—Existing Homes	NWPCC	2010	Northwest Power and Conservation Council, EstarLighting_ExistingFY09v1_1, Accessed July 2015, https://www.nwcouncil.org/energy/powerplan/6/supply-curves.	https://www.nwcouncil.org/energy/powerplan/6/supply-curves
NWPCC Sixth Plan—New Homes	NWPCC	2010	Northwest Power and Conservation Council, EstarLighting_ExistingFY09v1_1, Accessed July 2015, https://www.nwcouncil.org/energy/powerplan/6/supply-curves.	https://www.nwcouncil.org/energy/powerplan/6/supply-curves
2014 Nielsen Sales Data	BPA	2014	2014 Nielsen Sales Data	
Q4 2014 NEEA Shelf Data	NEEA	2014	N/A	
Simple Steps Data	BPA	2014	N/A	
Upstream Lighting Program Data Survey	NEEA	2014	N/A	

Source Name (As Referenced in Memo)	Funding Org.	Year of Publication	Citation	URL (If Available Online)
Draft Measure Information Template—Lighting in Multifamily and Hotel Corridors	CA IOUs	2013	California Utilities Statewide Codes and Standards Team, *Draft Measure Information Template-Lighting in Multifamily and Hotel Corridors*, 2013 California Building Energy Efficiency Standards, March 2011.	
Results of Massachusetts Onsite Lighting Inventory	MA PAs	2013	NMR Group, Inc. Results of the Massachusetts Onsite Lighting Inventory, 6th July 2013. http://ma-eeac.org/wordpress/wp-content/uploads/Onsite-Lighting-Inventory-Results-Final-Report-6.7.13.pdf.	http://ma-eeac.org/wordpress/wp-content/uploads/Onsite-Lighting-Inventory-Results-Final-Report-6.7.13.pdf
Massachusetts ENERGY STAR lighting Program: Early impacts of EISA	MA	2013	NMR Group, Inc. Massachusetts ENERGY STAR Lighting Program: Early Impacts of EISA, 12th June 2013. http://ma-eeac.org/wordpress/wp-content/uploads/Energy-Star-Lighting-Program_Early-Impacts-of-EISA-6.12.13.pdf.	http://ma-eeac.org/wordpress/wp-content/uploads/Energy-Star-Lighting-Program_Early-Impacts-of-EISA-6.12.13.pdf
Energy Conservation Program: Data Collection and Comparison with Forecasted Unit Sales of Five Lamp Types	DOE	2012	United States Department of Energy, Energy Conservation Program: Data Collection and Comparison with Forecasted Unit Sales of Five Lamp Types. http://energy.gov/sites/prod/files/2015/03/f20/five_exempted_lamps_noda.pdf.	http://www1.eere.energy.gov/buildings/appliance_standards/pdfs/five_lamp_types_noda_fr_2012.pdf
Standards & Test Procedures: Fluorescent Lamp Ballasts	DOE	2014	United States Department of Energy. (2014). Appliance & Equipment Standards: Fluorescent Lamp Ballast. Retrieved from http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/62.	http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/62

Source Name (As Referenced in Memo)	Funding Org.	Year of Publication	Citation	URL (If Available Online)
Residential Building Stock Assessment: Metering Study	NEEA	2014	Larson, B., Gilman, L., Davis, R., Logsdon, M., Uslan, J., Hannas, B., Baylon, D., Storm, P., Mugford, V., Kvaltine, N (2014). *Residential Building Stock Assessment: Metering Study*. Seattle Washington: Northwest Energy Efficiency Alliance.	https://www.neea.org/docs/default-source/reports/residential-building-stock-assessment--metering-study.pdf?sfvrsn=4
Residential Lighting End-Use Consumption Study: Estimation Framework and Initial Estimates	DOE	2012	Gifford, W.R., M.L. Goldberg, P.M. Tanimoto, D.R. Celnicker, and M.E. Poplawski. Residential Lighting End-Use Consumption Study: Estimation Framework and Initial Estimates. Portland: Pacific Northwest National Laboratory, 2012. Print.	http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/2012_residential-lighting-study.pdf
The Impact of EISA on Residential A-Lamps	NEEP	2014	*The Impact of EISA on Residential A-Lamps*. Lexington: Northeast Energy Efficiency Partnerships, 2014. Print.	http://www.neep.org/impact-eisa-residential-lamps-report
Results of the Massachusetts On-site Lighting Inventory	MA PAs	2015	Barclay, David, Kiersten von Trapp, Scott Walker, Lisa Wilson-Wright, Pam Rathbun, David Basak, Ken Seiden, Dough Bruchs, Bryan Ward. *Results of the Massachusetts On-site Lighting Inventory* 2014. Waltham: Cadmus. Print.	http://ma-eeac.org/wordpress/wp-content/uploads/On-Site-Lighting-Inventory-Final-Results.pdf
OSRAM SYLVANIA Socket Survey 6.0 2013 Research Results	OSRAM SYLVANIA	2013		https://assets.sylvania.com/assets/Documents/Socket%20Survey%206%200%202013%20web.ace8e42b-1aa1-4d10-897c-78e40ff72ccb.pdf
2010 U.S. Lighting Market Characterization	DOE	2010	Ashe, Mary, Dan Chwastyk, Caroline de Monasterio, Mahima Gupta, and Mika Pegors. *2010 U.S. Lighting Market Characterization. Chicago: Navigant Consulting*, 2012. Print.	http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/2010-lmc-final-jan-2012.pdf
Massachusetts Residential Lighting Cross-Sector Sales Research Memo	MA PAs	2015	Strom, Michael, Chris Russell, Lisa Wilson-Wright, Lynn Hoefgen, Doug Bruchs, and Bryan Ward. *Massachusetts Residential Lighting Cross-Sector Sales Research*. Somerville: NMR Group, 2015. Print.	
Final Annual Report to the Pennsylvania Public Utility Commission For the Period June	2014	PPL Electric	*Final Annual Report to the Pennsylvania Public Utility Commission For the Period June 2012 through May 2013 Program Year 4*. Waltham: Cadmus, 2014. Print.	https://www.pplelectric.com/~/media/PPLElectric/Save%20Energy%20and

Source Name (As Referenced in Memo)	Funding Org.	Year of Publication	Citation	URL (If Available Online)
2012 through May 2013 Program Year 4				%20Money/Docs/Act129_Phase2/PY4AnnualReportrevised11514clean.pdf
California Residential Replacement Lamp Market Status Report: Upstream Lighting Program and Market Activities in California Through 2013	CA IOUs	2014	Canseco, Jenna. *California Residential Replacement Lamp Market Status Report: Upstream Lighting Program and Market Activities in California Through 2013*. Oakland: DNV GL, 2014. Print.	http://www.calmac.org/publications/WO13_CA_Res_Ltg_Mkt_Status_Report_-_FINAL.pdf
Efficiency Maine Retail Lighting Program Overall Evaluation Report	Efficiency Maine	2015	*Efficiency Maine Retail Lighting Program Overall Evaluation Report*. Somerville: NMR Group, 2015.	http://www.efficiencymaine.com/docs/Efficiency-Maine-Retail-Lighting-Program-Evaluation-Report-2015.pdf
MA Lighting Market Assessment Onsite Visit and Consumer Survey Results	MA PAs	2015	Na'im, Alyssa, Kiersten von Trapp, Scott Walker, David Barclay, Lisa Wilson-Wright, Pam Rathbun, David Basak, Ken Seiden, Scott Reeves, and Bryan Ward. *MA Lighting Market Assessment Onsite Visit and Consumer Survey Results*. Waltham: Cadmus, 2014. Print.	
Mobilizing Energy Efficiency in the Manufactured Housing Sector	ACEEE	2012	Talbot, Jacob. "Mobilizing Energy Efficiency in the Manufactured Housing Sector." Washington, DC: American Council for an Energy-Efficient Economy. 2012. http://aceee.org/sites/default/files/publications/researchreports/a124.pdf.	http://aceee.org/sites/default/files/publications/researchreports/a124.pdf
Energy Savings Forecast of Solid-State Lighting in General Illumination Applications	DOE	2014		http://energy.gov/node/1057401/
Residential Lighting End-Use Consumption	DOE	2012		http://energy.gov/eere/ssl/residential-lighting-end-use-consumption
Residential Energy Efficient Lighting and Lighting Controls	Navigant	2014	Not a publicly available report.	http://www.navigantresearch.com/research/residential-energy-efficient-lighting-and-lighting-controls
Net-to-Gross Estimates Based on Saturation Differences in	MA PAs	2015	Wilson-Wright, Lisa, Lynn Hoefgen, and Bryan Ward. *Net-to-Gross Estimates Based on Saturation*	

Source Name (As Referenced in Memo)	Funding Org.	Year of Publication	Citation	URL (If Available Online)
Massachusetts and New York (Memo to Massachusetts Program Administrators)			*Differences in Massachusetts and New York*. Somerville: NMR Group, 2014. Print.	
U.S. EPA Report on Opportunities to Advance Efficient Lighting	EPA	2011	U.S. Environmental Protection Agency, *Next Generation Lighting Programs: Report on Opportunities to Advance Efficient Lighting*, 2011. https://www.energystar.gov/ia/partners/manuf_res/downloads/lighting/EPA_Report_on_NGL_Programs_for_508.pdf.	https://www.energystar.gov/ia/partners/manuf_res/downloads/lighting/EPA_Report_on_NGL_Programs_for_508.pdf
2014-2015 Residential Lighting Impact Evaluation	PSE	2015	Puget Sound Energy, 2014-2015 Residential Retail Lighting Impact Evaluation 2015.	http://webcache.googleusercontent.com/search?q=cache:HU2_Bsi93JwJ:https://conduitnw.org/_layouts/Conduit/FileHandler.ashx%3FRID%3D2966+&cd=1&hl=en&ct=clnk&gl=us

Source: Research team analysis

Table B-2: Literature Review Sources—Summary, Strengths, and Weaknesses

<table>
<tr><th>Source Name</th><th>Summary</th><th>Strengths</th><th>Weaknesses</th></tr>
<tr><td>Residential Building Stock Assessment—Single-Family</td><td>Summarizes field surveys of more than 1,850 sites across the Northwest (OR, WA, ID, and MT), including more than 1,400 single-family homes. Establishes the 2011 regional baseline for housing stock for single-family homes.</td><td rowspan="3">Regionally specific, large sample size, employs complex sampling strategy, differentiates by housing type, includes a corresponding database</td><td rowspan="3">Dated (2011), so it provides high-quality information only about the beginning of the analysis period for this study</td></tr>
<tr><td>Residential Building Stock Assessment—Multifamily</td><td>Summarizes field surveys with more than 1,850 sites across the Northwest (OR, WA, ID, and MT). Establishes the 2011 regional baseline for housing stock for multifamily homes.</td></tr>
<tr><td>Residential Building Stock Assessment—Manufactured Homes</td><td>Summarizes field surveys with more than 1,850 sites across the Northwest (OR, WA, ID, and MT). Establishes the 2011 regional baseline for housing stock for manufactured homes.</td></tr>
<tr><td>NWPCC Sixth Plan—Existing Homes</td><td>The Council develops a plan, updated every five years, to ensure the region's power supply is sufficient and acquire cost-effective energy efficiency. The Council's Sixth Plan includes a detailed analysis of efficiency potential in hundreds of applications.</td><td rowspan="2">Regionally specific, differentiates by housing types, five-year analysis period</td><td rowspan="2">Seventh Plan is still in development</td></tr>
<tr><td>NWPCC Sixth Plan—New Homes</td><td>The Council develops a plan, updated every five years, to ensure the region's power supply is sufficient and acquire cost-effective energy efficiency. The Council's Sixth Plan includes a detailed analysis of efficiency potential in hundreds of applications.</td></tr>
<tr><td>2014 Nielsen Sales Data</td><td>Sales data compiled from a variety of major retailers in the Pacific Northwest organized by lamp, base, and bulb style; provides information on wattage, lumens, price, and quantities.</td><td>Regionally specific, large sample size, and employs complex sampling strategy to ensure most accurate results</td><td>Provides data only for the years 2012–2014</td></tr>
<tr><td>Q4 NEEA Shelf Data</td><td>Shelf data for a variety of retailers with information on lamp, bulb and socket style, wattage, lumens, price, and quantity.</td><td>Regionally specific to retailers</td><td>Provides data only for Q4; data is shelf data, so it may not accurately portray sales activity</td></tr>
</table>

Source Name	Summary	Strengths	Weaknesses
Simple Steps Data	Provides an overview of incentives utilities completed between the years 2010 and 2014; data includes information on the quantity, incentive payment, and savings for incentives.	Good understanding of savings related to incentives per year	Some incentives did not span the entire range
Upstream Lighting Program Data Survey	Simple Steps, other program data and limited non-program data, for LEDs and CFLs covering 2013–2014.	Provides in-depth data for incentivized versus non-incentivized sales	Spans only the years 2013–2014
Draft Measure Information Template—Lighting in Multifamily and Hotel Corridors	Provides an overview of a proposed mandatory modification of lighting control/switching requirements in hotel and multifamily building corridors in California.	Detailed in terms of energy benefits, non-energy benefits, and environmental impact	Was dated 2011 and does not pertain specifically to the Pacific Northwest
Results of Massachusetts Onsite Lighting Inventory	Details the findings of a lighting inventory conducted to understand the use, saturation, and purchase of lighting products in Massachusetts in support of the ENERGY STAR lighting program and implications of EISA.	Good insight regarding consumer behavior related to lamp usage, purchase, and potential stockpiling	Performed only 150 onsite inventories and covers only December 2012–March 2013
Massachusetts ENERGY STAR Lighting Program: Early Impacts of EISA	Summarizes the results of four research efforts to identify current and likely effects of EISA on the residential lighting market in Massachusetts; addresses the availability and purchase of lamps, potential stockpiling, and consumer awareness and understanding of EISA.	Provides insight on early impacts of EISA on the lighting market	Potentially too early to see large-scale impacts of EISA
Energy Conservation Program: Data Collection and Comparison with Forecasted Unit Sales of Five Lamp Types	Compares projected sales models of five lamp types (rough service, vibration service, 3-way, incandescent, and shatter-resistant) with actual NEMA shipment data from 2011.	Uses NEMA sales data and looks at several lamps specifically identified for this literature review	Does not extend to 2014; relies on shipment data from NEMA, which may not be as accurate as actual sales data

Source Name	Summary	Strengths	Weaknesses
Standards & Test Procedures: Fluorescent Lamp Ballasts	Identifies key points of the energy conservation standard for fluorescent lamp ballasts.	High accuracy of data and the impacts forecasted from the standard	Unclear dates of actual implementation of the standard
Residential Building Stock Assessment: Metering Study	Details the results of a whole house metering study covering most energy end-uses in 101 homes in the Pacific Northwest.	In-depth look into residential home lighting preferences and practices	Small sample size, which may not be representative of the region as a whole; due to budget, typically only 35% of all fixtures were measured across all homes
Residential Lighting End-Use Consumption Study: Estimation Framework and Initial Estimates	Provides a regional estimation framework that works with a national sample design; allows for the estimation of lamp usage and energy consumption nationally and by U.S. region, as well as for household characteristics, location within the home, lamp characteristics, and categorical cross-classifications (e.g., dwelling type and lamp type, or fixture type and control type).	Based on data from four studies that were designed to be unbiased and achieve a certain degree of accuracy	Data not available for all regions, including the South; most data are from 2009, with some from 2008 and 2010
The Impact of EISA on Residential A-Lamps	A retrospective market model that investigates the impact of EISA on the A-lamp market; simulates the interaction between the demand generated by lamp failures in the installed base and A-lamp sales of the available technologies (LED, CFL, EISA-compliant halogen, and incandescent).	Data sources are reliable and include NEMA A-lamp sales data, DOE 2010 U.S. Lighting Market Characterization, NMR Results of the Massachusetts Onsite Lighting Inventory, U.S. Census, Navigant 2010 Northeast onsite data, and national socket data	Focuses on the Northeast; authors do not provide information to support the following two model assumptions: 1) failed lamps are replaced by lamps with equivalent lumen output, and 2) failed efficient lamps are replaced by efficient lamps of the same technology
Results of the Massachusetts Onsite Lighting Inventory	Summarizes comprehensive onsite lighting inventories of homes in Massachusetts, Georgia, and Kansas.	Panel study allows for tracking of bulb replacement characteristics; onsite verification is more reliable than self-reports	Focuses on MA, GA, and KS, none of which are in the Northwest
OSRAM SYLVANIA Socket Survey 6.0 2013 Research Results	Provides insight into consumer attitudes and behaviors around lighting options; conducted annually since 2008.	Survey has been repeated year to year, allowing for comparison of results year to year	Self-reported bulb usage can be unreliable

Source Name	Summary	Strengths	Weaknesses
2010 U.S. Lighting Market Characterization	Provides summary estimates of the installed stock, energy use, and lumen production of all lamps operating in the United States.	Strong data sources, including Census and EIA and includes recent studies such as one by NMR and one by Navigant	Most information is presented at the national level
Massachusetts Residential Lighting Cross-Sector Sales Research Memo	Provides summary and discussion of estimates of residential program bulbs that go into commercial applications. These estimates come from 23 studies.	23 studies of various methods (telephone survey, store intercept, etc.) included in this review	None of the data sources are in the Pacific Northwest
Final Annual Report to the Pennsylvania Public Utility Commission For the Period June 2012 through May 2013 Program Year 4	Summarizes an evaluation of a residential lighting program.	The population surveyed were small businesses that could speak to their lighting purchases	Self-report phone survey can be unreliable
California Residential Replacement Lamp Market Status Report: Upstream Lighting Program and Market Activities in California Through 2013	Provides supply- and demand-side market activity data as well as Upstream Lighting Program activities as of 2013.	Intercept observations can be more reliable than telephone self-reports	The relevant finding is presented just as a footnote to a table; it was not a focus of the research and is, therefore, not sufficiently robust
Efficiency Maine Retail Lighting Program Overall Evaluation Report	Summarizes impact and process evaluation of a retail lighting program in Maine.	Telephone survey sample precision at the 90% confidence level is ±4.4%; n-site visits n=67; 10% sampling error at the 90% confidence level for all households in Maine,	Study was for Maine, which is not in the Pacific Northwest

Source Name	Summary	Strengths	Weaknesses
MA Lighting Market Assessment Onsite Visit and Consumer Survey Results	Summarizes onsite lighting inventory study in Massachusetts.	Panel visits allowing for tracking of what bulb replaced what; onsite observations can be more reliable than self-reported data; MA panel onsites n=203, with 6% sample error at the 90% confidence level	Study is in Massachusetts, which is not in the Pacific Northwest
Mobilizing Energy Efficiency in the Manufactured Housing Sector	Describes energy savings potential in the manufactured homes market through retrofit measures and new homes.		New home savings are calculated as aggregate GWh, not broken out into separate categories; limited in scope for this study's purposes, as manufactured homes are only a small subset of the residential market
Energy Savings Forecast of Solid-State Lighting in General Illumination Applications	Provides results from a lighting model that estimates LED adoption and energy savings through 2030 in U.S. residential and commercial buildings.	Robust model acknowledged as one of the best forecasts for LED adoption in the United States	As LEDs are largely near the beginning of the adoption curve, future predictions can be difficult
Residential Lighting End-Use Consumption	Detailed study of residential lighting, split by census region.	Large-scale study with data file provided that allows for further analysis beyond the charts and tables provided in the report	Data from 2010 is dated for 2015, especially for LEDs
Residential Energy Efficient Lighting and Lighting Controls	Describes the residential lighting and controls market, with sales forecasts through 2023.	Synthesis of information from organizations such as the DOE as well as interviews with numerous industry stakeholders	This report is not publicly available, which would make the Momentum Savings documentation more opaque

Source Name	Summary	Strengths	Weaknesses
Net-to-Gross Estimates Based on Saturation Differences in Massachusetts and New York Memo	Describes the steps taken to develop a 2013 net-to-gross value based on the differences in CFL and LED saturation in Massachusetts and New York. The evaluation team conducted onsite lighting saturation surveys in both states in 2013 and 2015. In 2012, NYSERDA ended its support for standard CFLs and had limited support for specialty CFLs and LEDs through 2014.	Onsite data is not dependent on respondent recall	Study is in Massachusetts and New York, which are not in the Pacific Northwest; New York discontinued support for standard CFLs in 2012, Massachusetts did not; the sample sizes for New York are relatively small, and there is possible non-response bias (particularly in New York)
2014-2015 Residential Retail Lighting Impact Evaluation	Summary of PSE's Home Energy Reports Program Impact Evaluation, which provides an estimate on share of retail lamps going to the residential sector.	Regionally specific; intercept observations can be more reliable than telephone self-reports	Performed only 200 intercepts

Source: Research team analysis

Appendix C: RTF Baseline Methodology Memo – Screw-in Lamps

To: Carrie Cobb, Bonneville Power Administration; Ryan Firestone, Ptarmigan Research

From: Navigant and Cadeo team

Date: May 22, 2015

Subject: Residential Lamp Baseline Methodology Memorandum (Screw-In Lamps)

READER NOTE: The research team provided this memo to BPA, and subsequently to the RTF, in May 2015. While developing the regional residential lighting model in 2016, the research team made a number of enhancements to the Chain Logic Method (which aggregates retailer-specific sales data and market shares to reflect regional averages) detailed in this memo. As a result, the 2014 market averages shown in this memo differ from the 2014 market averages used in the residential model and those used to calculate the Momentum Savings contained in this report. The research team has included the May 2015 memo in its original form, since the RTF used it for a measure update, but recommends readers refer to the final model, and associated export tables, for all market information for 2009 through 2015.

Executive Summary

This memo details the methodology and results for estimating baselines for residential lamp types in the Pacific Northwest. This methodology has two major analytical components:

1. Estimating the market share of each retailer serving the Northwest residential lighting market using an analytical framework called the Chain Logic method.
2. Estimating the average lamp wattage sold by each retailer based on shelf survey data from the 2015 NEEA Northwest Residential Lighting Long-Term Market Tracking Study and Sales data from 2014 provided by Nielsen (hereafter referred to as "Nielsen sales data").

The team used the results of the first component, each retailer's market share, to weight the results of the second component, each retailer's average watts per lamp, thereby computing an overall market average baseline.

The team calculated a separate baseline for each measure category (i.e., each lamp type and each lumen bin).

The team calculated the baseline for the five RTF lamp types:

1. General purpose and dimmable
2. Globe
3. Decorative and mini-base
4. Reflector and outdoor
5. 3-Way

Table C-1 shows the lumen bins included in the analysis. Notably, the lumen bins are different from current RTF lumen bins in that they now align with the delineations in EISA. The team also included <310 lumen and >2600 lumen bins.

Table C-1: Lumen bins analyzed

Lumen Bins
310-749
750-1049
1050-1489
1490-2600
<310 Lumens
>2600 Lumens

Source: Cadeo team analysis, 2015

The baseline results are shown in Table C-2 below.

Table C-2: Average Lamp Wattage by Lamp Type and Lumen Bin

Lamp Type	<310 Lumens	310-749	750-1049	1050-1489	1490-2600	>2600 Lumens
General Purpose and Dimmable	25	30	28	46	42	103
Globe	31	37	20	68	67	NA
Reflectors and Outdoor	39	42	30	46	92	115
Decorative and Mini-Base	24	49	18	100	23	30
3-Way	43	NA	100	118	112	269

Source: Cadeo team analysis of Northwest Energy Efficiency Alliance, "2013-2014 Northwest Residential Lighting Long-Term Market Tracking Study" January 22, 2015 and Nielsen Sales Data, 2014.

Methodology

The following methodology discussion is divided into the two main components of the baseline calculation.

1. Determine the market share for each lamp retailer or group of retailers in Pacific Northwest.
2. Determine a technology-weighted average wattage per retailer, lamp type and lumen bin for both shelf data and Nielsen sales data.

Determine Market Share for Each Lamp Retailer or Group of Retailers in Pacific Northwest

Segment by Store Categories

Using information gathered during the 2014 Energy Star Partners Meeting, the team segmented the market by store categories: DIY (51%), Mass Merchandise (17%), Club Stores (17%), and Drug, Grocery and Small Hardware (15%).

Table C-3: Market share by store category

Store Category	Share
DIY	51%
Mass Merchandise	17%
Club Stores	17%
Drug, Grocery and Small Hardware	15%

Source: Cadeo team analysis, 2015

Key Assumptions

'DIY', 'Mass Merchandise', 'Drug, Grocery and Small Hardware' and 'Club Stores' categories cover all stores in which residential lamps are sold. Also, that retailer store counts and relative number of lamps stocked reflect retailers' respective market shares.

Table C-4: Stores by store category

Store Category	Retailer
Home Center	The Home Depot
	Lowe's
	Other
Mass Merchandise	Walmart
	Target
	K-Mart
	Other
Club Stores	Costco
	Sam's Club
Drug, Grocery and Small Hardware	Other

Source: Cadeo team analysis, 2015

Determine Technology-Weighted Average Wattage by Retailer, Lamp Type and Lumen Bin for Both Shelf Data and Nielsen Data

Having determined the market share for each retailer or group of retailers, the team then found the technology distribution for each retailer across lumen bins, using the 2015 NEEA Northwest Residential Lighting Long-Term Market Tracking Study and the Nielsen sales data. The following steps were used for both datasets to compute the baseline estimate:

Clean NEEA Shelf Data and Nielsen Sales Data

The shelf and sales data include many more lamp types and styles than would be practical to break out individually for baseline analysis. The team screened each lamp type to determine, first, if it was appropriate to include in the analysis and, second, which measure category it should be mapped to. For example, the "general purpose and dimmable" lamp type comprised A-lamps, spiral/twister shape lamps, tube lamps and Circline lamps. To the extent possible, the team matched the binning choices made by the RTF in the current measure workbook. The lamp styles mapped to each lamp type are shown in Table C-5: Lamp styles included in each .

Table C-5: Lamp styles included in each lamp type

Lamp type	Lamp Styles Included
General Purpose and Dimmable	Spiral/Twister
	A-lamp
	Tube
	Circline
Globe	Globe
Reflector and Outdoor	Spotlight/Reflector/Flood
Decorative and Mini-base	Candelabra/Intermediate base, Candelabra with Medium Screw Adaptor
3-Way	3-Way

Source: Cadeo team analysis, 2015 of Northwest Energy Efficiency Alliance, "2013-2014 Northwest Residential Lighting Long-Term Market Tracking Study" January 22, 2015

Table C-6 illustrates lamp styles that were excluded from the analysis because they are not typically associated with the five lamp types.

Table C-6: Lamps excluded from shelf data

Lamps Excluded	Excluded from	Rationale
Linear fluorescent	Technology	Separate analysis
HID	Technology	Specific application not part of measure scope
Pin-base	Base type	Specific application not part of measure scope
GU-base	Base type	Specific application not part of measure scope
Large screw-base	Base type	Specific application not part of measure scope
Bug light	Lamp style	Specific application not part of measure scope
Night Light	Lamp style	Specific application not part of measure scope
Other/Unknown	Other	Not enough data to categorize

Source: Cadeo team analysis of Northwest Energy Efficiency Alliance, "2013-2014 Northwest Residential Lighting Long-Term Market Tracking Study" January 22, 2015

The lamp styles associated with each lamp type are shown in Table C-7.

Table C-7: Lamp styles included in each lamp type

Lamp type	Lamp Styles Included
General Purpose and Dimmable	Tube
	A-lamp
Globe	Globe
Reflector and Outdoor	Spotlight/Reflector/Flood
Decorative and Mini-base	Candle base
3-Way	3-Way

Source: Cadeo team analysis of Nielsen sales data, 2014

Table C-8 illustrates lamp styles that were excluded from the analysis because they are not typically associated with the five lamp types.

Table C-8: Lamps excluded from Nielsen sales data

Lamp style removed	Rationale
Linear fluorescents	Separate analysis
Night lights	Specific application not part of measure scope
Holiday lights	Specific application not part of measure scope
High-intensity lamps	Upon manual inspection appear to be appliance lamps either 12W or 40W.
Heat lamps	Specific application not part of measure scope
Glitter and lava lamps	Specific application not part of measure scope
Aquarium/reptile lamps	Specific application not part of measure scope
Appliance lamps	Specific application not part of measure scope
BRS Bedrooms entryways HW	No data, few sales and no additional information

Lamp style removed	Rationale
Decorative indoor Menorahs	Specific application not part of measure scope
Decorative Indoor Outdoor lamps	Upon manual inspection appear to be holiday lights
Decorative Outdoor	Upon manual inspection appear to be holiday lights
DI Outdoor	Upon manual inspection appear to be holiday lights
DH Indoor Outdoor	Upon manual inspection appear to be holiday lights
Flicker	Specific application not part of measure scope
Metal Halide	Specific application not part of measure scope
Mercury vapor	Specific application not part of measure scope
HDNL	Upon manual inspection appears to be pin-based lamp
Indoor parties	Upon manual inspection appears to be black light
I-O WET Location	Specific application not part of measure scope
Lamps	Vehicle lights, except GE branded ones because those were unmarked and appear to be basic A19 LED.
NB and NB BCRHSA	No additional data available
Outdoor	Landscape lamps
Outdoor landscape	Specific application not part of measure scope
Plant	Specific application not part of measure scope
Plug-in warmers	Specific application not part of measure scope

Source: Cadeo team analysis of Nielsen sales data, 2014

Compute Technology Mix for Each Lumen Bin, Retailer and Lamp Type

We computed the technology mix found in the NEEA shelf data and Nielsen sales data for each lamp type, lumen bin, and retailer or group of retailers. For example, Table C-9 below shows the technology mix for general purpose lamps, per the Nielsen sales data.

Table C-9: Technology mix for general purpose lamps (Sales data)

Technology	Lumen Bins					
	<310	310-749	750-1049	1050-1489	1490-2600	>2600
CFL	4%	15%	37%	41%	63%	16%
HAL	1%	32%	31%	57%	32%	1%
INC	73%	51%	31%	2%	5%	83%
LED	21%	1%	1%	0%	0%	0%
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

Source: Cadeo team analysis of Nielsen sales data.

Key Assumptions

The mix of technologies stocked by retailers is proportional to the technology mix purchased and installed.

Compute Average Watts for Each Lumen Bin, Retailer and Lamp Type

The team computed average watts for lamp each lumen bin, retailer and lamp type, for both datasets. The team used sales data where it was available and used the NEEA shelf data for the remaining retailers. For example, Table C-10 displays the average watts for general purpose lamps, for the Nielsen sales data.

Table C-10: Average watts for general purpose lamps

Technology	Lumen Bins					
	<310	310-749	750-1049	1050-1489	1490-2600	>2600
CFL	16	14	15	24	26	45
HAL	21	38	51	70	103	400
INC	24	49	71	95	134	174
LED	4	8	10	16	16	NA

Source: Cadeo team analysis of Nielsen sales data.

Key Assumptions

The average lamp wattage shown in the datasets by lamp type and lumen bin represents the average wattage of lamps purchased and installed.

Compute Technology-Weighted Average Watts per Lumen Bin for Each Lamp Type and Retailer

The team computed the technology-weighted average watts per lumen bin for both datasets by calculating the weighted average of the average wattages for each technology and the technology mix found for each retailer.

Summary of Findings

The baseline results are shown in Table C-11 below.

Table C-11: Average Lamp Wattage by Lamp Type and Lumen Bin

	Lumen Bins					
Lamp Type	<310 Lumens	310-749	750-1049	1050-1489	1490-2600	>2600 Lumens
General Purpose and Dimmable	25	30	28	46	42	103
Globe	31	37	20	68	67	NA
Reflectors and Outdoor	39	42	30	46	92	115
Decorative and Mini-Base	24	49	18	100	23	30
3-Way	43	NA	100	118	112	269

Source: Cadeo team analysis of Northwest Energy Efficiency Alliance, "2013-2014 Northwest Residential Lighting Long-Term Market Tracking Study" January 22, 2015 and Nielsen Sales Data, 2014.

Some of results in Table C-11 ware counterintuitive because the average wattage did not fit with the expected trend of decreasing wattage with decreasing lumen output. The team investigated these anomalies and provides explanation in the following bullets. Typically, an abrupt change in the technology mix from one lumen bin to the next is the cause of the counterintuitive result. For reference, the team includes the full technology mix for each lamp type and lumen bin in Table 14 and 15.

- **General Purpose, 750-1049 lumens:** Counterintuitively, the average watts for this lumen bin are lower than the lower lumen bin. However, the technology mix in both datasets reveals that this lumen bin has a significantly lower incandescent share than the lower lumen bin.
- **General Purpose, 1490-2600 lumens:** The average watts in this lumen bin are lower than the lower lumen bin. The technology mix in the shelf data reveals that the CFL share in this lumen bin is significantly higher than in the lower bin.
- **Globe, 750-1049 lumens:** This lumen bin is 0% incandescent for all retailers in the shelf data, compared to 97% in the lower lumen bin which explains the unusually low average wattage.
- **Globe, >2600 lumens:** No lamps stocked or sold in this lumen bin.
- **Reflector and Outdoor, 750-1049 lumens:** This lumen bin is significantly lower than the lower lumen bin. However, the LED share is 57% in the shelf data, compared to 15% in the lower lumen bin. The sales data shows a 54% CFL share for this lumen bin, compared to 4% in the lower lumen bin.
- **Decorative and Mini-Base, 750-1049 lumens:** The average wattage in this lumen bin appears extremely low, but can be explained by the fact that the majority of the lamps in both datasets are CFLs, whereas the next highest lumen bin is 100% incandescent.
- **Decorative and Mini-Base, 1490-2600 lumens:** This lumen bin is 100% CFL, explaining the significantly lower average wattage than the lower lumen bin, which is 100% incandescent.
- **3-Way, 310-749 lumens:** No lamps sold or stocked for this lumen bin.

Although the team emphasized consistency and quality control, the following three core weaknesses in the methodology remain.

- **Shelf data is not sales data.** The team computed the average wattage using Nielsen sales data for those retailers that were covered in the dataset and used shelf data for the remaining retailers. Shelf data is only a proxy for product flow and may not accurately reflect the current practice baseline.
- **Timing of data collection.** Nielsen sales data is covers all of 2014, whereas the shelf data reflects only what was stocked in December of 2014. The Nielsen data is therefore likely to include the sell through of lamps manufactured before the 1/1/2014 EISA deadline, inflating the share of incandescent lamps in the technology mix.
- **Difficulties with data cleaning.** Differences in the lamp codes between the two datasets led to difficulties with data cleaning and the binning process. For example, the Nielsen sales data used "Tube" as a base type code for CFL spiral A-lamps, while the same code was used in the shelf data for actual tube-style lamps. The data cleaning process involved several judgement calls where

additional information on lamps was not available. For these reasons, there may be meaningful differences between the datasets, both in terms of the lamp styles removed and included in the analysis and the binning process.

Additional Details

Table C-12 shows the technology distribution of lamps by lumen bins and lamp types for the shelf data. The technology mix often reveals what is driving the final average wattages. As the share of incandescent lamps increases, the average wattage increases. Predictably, the incandescent share is the highest for the unregulated lumen bins. For example, general purpose lamps have the highest incandescent share at <310 lumens, >2600 lumens and across lumen bins in the 3-way lamp type.

Table C-12: Technology distribution of lamps stocked by lumen bins and lamp type in shelf data

General Purpose						
Technology	**<310 LUMENS**	**310-749**	**750-1049**	**1050-1489**	**1490-2600**	**>2600 LUMENS**
CFL	5%	15%	48%	38%	61%	18%
HAL	5%	41%	30%	51%	32%	0%
INC	83%	31%	7%	6%	3%	73%
LED	8%	13%	14%	5%	5%	9%
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**
Globe						
Technology	**<310 LUMENS**	**310-749**	**750-1049**	**1050-1489**	**1490-2600**	**>2600 LUMENS**
CFL	0%	9%	18%	0%	0%	NA
HAL	0%	2%	74%	4%	0%	NA
INC	91%	55%	8.%	96%	100%	NA
LED	9%	34%	0%	0%	0%	NA
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**
Reflector and Outdoor						
Technology	**<310 LUMENS**	**310-749**	**750-1049**	**1050-1489**	**1490-2600**	**>2600 LUMENS**
CFL	1%	12%	22%	26%	0%	0%
HAL	15%	19%	10%	42%	86%	6%
INC	80%	55%	11%	3%	13%	93%
LED	5%	15%	57%	29%	1%	1%
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

Decorative and Mini-Base						
Technology	<310 LUMENS	310-749	750-1049	1050-1489	1490-2600	>2600 LUMENS
CFL	2%	6%	91%	NA	100%	0%
HAL	0%	5%	8%	NA	0%	1%
INC	84%	87%	2%	NA	0%	98%
LED	13%	2%	0%	NA	0%	0%
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**
3-Way						
Technology	<310 LUMENS	310-749	750-1049	1050-1489	1490-2600	>2600 LUMENS
CFL	0%	NA	0%	0%	18%	0%
HAL	0%	NA	0%	1%	8%	0%
INC	100%	NA	100%	99%	71%	100%
LED	0%	NA	0%	0%	4%	0%
Total	**100%**	**NA**	**100%**	**100%**	**100%**	**100%**

Source: Cadeo team analysis of Northwest Energy Efficiency Alliance, "2013-2014 Northwest Residential Lighting Long-Term Market Tracking Study" January 22, 2015.

Table C-13 shows the technology distribution of lamps by lumen bins and lamp types for the Nielsen sales data. It is worth noting again that this dataset represents all of 2014 and includes the sell through of lamps manufactured before the 1/1/2014 EISA deadline. For this reason, the share of incandescent lamps in this dataset is noticeably higher than in the shelf data.

Table C-13: Technology distribution of lamps stocked by lumen bins and lamp type in Nielsen sales data

General Purpose						
Technology	<310 LUMENS	310-749	750-1049	1050-1489	1490-2600	>2600 LUMENS
CFL	4%	15%	37%	41%	63%	16%
HAL	1%	32%	31%	57%	32%	1%
INC	73%	51%	31%	2%	5%	83%
LED	21%	1%	1%	0%	0%	0%
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**
Globe						
Technology	<310 LUMENS	310-749	750-1049	1050-1489	1490-2600	>2600 LUMENS
CFL	0%	2%	81%	49%	0%	NA
HAL	0%	0%	19%	0%	0%	NA
INC	97%	97%	0%	0%	0%	NA
LED	3%	0%	0%	51%	100%	NA
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

Reflector and Outdoor						
Technology	**<310 LUMENS**	**310-749**	**750-1049**	**1050-1489**	**1490-2600**	**>2600 LUMENS**
CFL	0%	4%	54%	21%	15%	NA
HAL	13%	21%	43%	77%	84%	NA
INC	86%	71%	0%	0%	0%	NA
LED	1%	3%	3%	2%	1%	NA
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**
Decorative and Mini-Base						
Technology	**<310 LUMENS**	**310-749**	**750-1049**	**1050-1489**	**1490-2600**	**>2600 LUMENS**
CFL	0%	4%	62%	0%	NA	NA
HAL	0%	1%	38%	0%	NA	NA
INC	96%	95%	0%	100%	NA	NA
LED	4%	0%	0%	0%	NA	NA
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**
3-Way						
Technology	**<310 LUMENS**	**310-749**	**750-1049**	**1050-1489**	**1490-2600**	**>2600 LUMENS**
CFL	0%	0%	0%	1%	45%	0%
HAL	0%	0%	0%	2%	3%	0%
INC	100%	100%	100%	97%	51%	100%
LED	0%	0%	0%	0%	0%	0%
Total	**100%**	**NA**	**100%**	**100%**	**100%**	**100%**

Appendix D: RTF Baseline Methodology Memo – Linear Fluorescent Lamps

To: Carrie Cobb, Bonneville Power Administration (BPA)

From: Rob Carmichael, Fiona Skinner, and Katie Arquiette, Cadeo

Date: August 10, 2015

Subject: Residential Lamp Baseline Methodology Memorandum (Linear Fluorescent Lamps)

READER NOTE: The research team provided this memo to BPA, and subsequently to the RTF, in August 2015. While developing the regional residential lighting model in 2016, the research team made a number of enhancements to the Chain Logic Method (which aggregates retailer-specific sales data and market shares to reflect regional averages) that impacted these findings. As a result, the 2014 market averages shown in this memo differ from the 2014 market averages used in the residential model and those used to calculate the Momentum Savings contained in this report. The research team has included the August 2015 memo in its original form, since the RTF used it for a measure update, but recommends readers refer to the final model, and associated export tables, for all market information for 2009 through 2015.

Linear Fluorescent Baseline Analysis

This memo details Cadeo's methodology for estimating the residential wattage baseline for four foot linear fluorescent lamps in the Pacific Northwest. This analysis leveraged the 2015 NEEA Northwest Residential Lighting Long-Term Market Tracking Study and 2014 sales data provided by Nielsen (hereafter referred to as "Nielsen data"). Using an analytical framework called the Chain Logic method, the team estimated the market share and average wattage and average lumens associated with each retailer (or group of retailers) in the region. Cadeo then combined the retailer-specific market shares and wattages to compute the average wattage and average lumens for linear fluorescent lamps in the Pacific Northwest. In the fall of 2015, Cadeo will use these average wattages to estimate Momentum Savings for the residential lighting market.

The section below discusses the methodology Cadeo used to estimate the residential wattage baseline, which consisted of two primary tasks:

1. Estimate the market share for each retailer or group of retailers in the Pacific Northwest (the team used the same process as outlined in the Residential Lamp Baseline Methodology Memorandum, May 22, 2015).

2. Determine the average wattage and lumens per retailer for four foot linear fluorescent lamps from shelf data and Nielsen sales data.

The team conducted the following steps on both datasets to compute the average wattage and lumens per retailer:

a. Computed the total watts and total lumens for four foot lamps.

b. Computed the total number of lamps.

c. Divided total watts and total lumens separately by the total number of lamps to compute average watts and average lumens.

The team used each retailer's market share (see previously mentioned Residential Lamp Baseline Methodology Memorandum for details) to weight the results and compute an overall market average baseline for four foot linear fluorescent lamps in the Pacific Northwest. The team used sales data when it was available to compute the average watts and lumens for linear fluorescents. The team used shelf data in the computations when sales data was not available.

Key Assumptions:

The team made the following important assumptions when completing this analysis:

- Analysis is limited to four foot linear fluorescent T12 (~70% of regional market) and T8 lamps (~30%). Analysis does not include T5 lamps.
- Lamps with fewer than 1490 lumens are specialty lamps and, therefore, not included in the baseline calculation.

Results

The market average baseline results for four foot linear fluorescent lamps are shown in Table D-1.

Table D-1. Average Lamp Wattage and Lumens

Lamp Type	Wattage	Lumens
4 ft. linear fluorescent	37	2,656

Source: Cadeo team analysis of Northwest Energy Efficiency Alliance, "2013-2014 Northwest Residential Lighting Long-Term Market Tracking Study" January 22, 2015 and Nielsen Sales Data, 2014

Although the team emphasized consistency and quality control, the following two core weaknesses in the methodology remain:

1. **Shelf data is not sales data.** Shelf data is only a proxy for product flow and may not accurately reflect current baseline conditions.

2. **Timing of data collection.** Nielsen sales data covers all of 2014, whereas the shelf data reflects only what was stocked in December of 2014.

Appendix E – LightFair Findings Memo

To: Carrie Cobb, BPA

From: Rob Carmichael and Doug Bruchs, Cadeo

Date: June 10, 2015

Subject: 2015 LightFair Findings Memo

As part of Residential Lighting Market Characterization Study, members of the Navigant/Cadeo research team attended LightFair 2015, the world's largest annual lighting trade show and conference. Alongside staff from BPA and NEEA, the research team completed over 20 in-person interviews with attending lamp, fixture, and controls manufacturers and their sales representatives. This memorandum summarizes the key findings of those interviews. The research team also provided BPA with all detailed interview notes from the conference.

Our findings are relevant to both the residential and non-residential sectors. They inform BPA's ongoing efforts to provide lighting program staff in the Pacific Northwest with the timely, actionable market intelligence needed to deliver effective efficiency programs in a dynamic lighting market.

Findings

We identified seven key findings relevant to BPA's lighting market research:

1. Most non-residential sales still flow through traditional wholesale distributors.
2. Online retailers are becoming increasingly relevant, though still relatively small, market players.
3. Manufacturer representatives are important brokers between manufacturers and end-users.
4. National Accounts are a customer segment, not a separate channel.
5. Integration is on everyone's mind: Lighting is no longer just about lighting.
6. Lamp and fixture companies are increasingly partnering with or acquiring controls manufacturers.
7. Market actors share some utility concerns about TLEDs… but are happy to sell them.

We discuss each of these findings in detail below.

Most non-residential sales still flow through traditional wholesale distributors.

Our team determined that the vast majority of sales – typically 85% or more – still "flow through distribution" in the either the form of the physical product itself or the payment for that product for all interviewed manufacturers. This means that electrical distributor sales data continues to represent the region's best data source for estimating momentum savings, even more so than previously recognized.[1]

Distributors are important customers for manufacturers. Most manufacturers we interviewed were wary of disrupting those relationships by selling direct to end-users. One manufacturer representative shared that distributors provide other important services beyond storing and distributing product. He noted distributors provide value to him by serving as "a bank" and mitigating any issues with dissatisfied end-users. Another manufacturer explained that distributors' detailed understanding of local markets is also a valuable asset for the manufacturers serving those markets.

Other notable findings related to distribution channels and product flow include:

- A NW manufacturer representative indicated that 95% of his sales go through distribution, with the small remainder going direct to large contractors and specialized lighting groups.
- Similarly, the national accounts manager for another manufacturer estimated that 98% of their commercial sales go through distribution.
- A smaller, new manufacturer said using distribution was 'company policy' and several smaller manufacturers reiterated that stance.

Online retailers are becoming increasingly relevant, though still relatively small, market players.

While the majority of sales continue to flow through distribution, interviewees noted that online retailer are becoming an increasingly important part of the supply chain. Interviewees believe these online retailers operate in a unique space, akin to a distributor, but functionally more as an e-retailer. 1000bulbs.com was the most commonly referenced website.

Manufacturer representatives are important brokers between manufacturers and end-users.

Several major manufacturers shared that the majority of their sales are initiated by independent manufacturer sales representatives. As a result, manufacturer representatives are important brokers between manufacturers and end-users, particularly for the new construction and renovation fixture market, and have significant influence on the final lighting product installed.

[1] Recently, the Navigant/Cadeo estimated non-residential lighting momentum savings for the region using sales data from 2010 to 2014 provided by 16 Pacific Northwest electrical distributors. While distributors have historically processed the overwhelming majority of non-residential sales recent market research indicates alternative paths to market, such as direct and online sales, have become increasing important. As a result, a primary goal of our team's research at LightFair was to determine whether we can continue to rely upon distributor sales data as a comprehensive and representative proxy for the entire non-residential lighting market.

In general, 'manufacturer reps' establish a relationship with a manufacturer, agree to an annual sales target, and sign a one-year contract. The representative then receives a negotiated commission (sometimes described as "points") based on the total value of the sale. A typical commission is 10 percent.

Manufacturer reps typically offer a wide variety of product "lines" (a single or suite of products made by a given manufacturer) from two to four different manufacturers. However, typically one – usually a larger fixture manufacturer– is their primary manufacturer and constitutes the majority of their lines and sales. The manufacturer reps select specific lines from other manufacturers to round out their lighting portfolio and to carry the specialized products sought by end-users in their service territory. It is not uncommon for these arrangements to last only a year (or less) and for manufacturer reps to frequently switch the manufacturers they work with. In essence, the manufacturer reps are continually competing with each other for both sales to end-users and for the right to carry manufacturer lines.

While most sales initiated and negotiated by a manufacturer rep, the transactions itself – with the exception of any direct sales handled by a manufacturer rep – is processed through traditional distribution channels.

Other notable findings related to manufacturer reps:

- One of the ways that sales representatives directly impact the quality and efficiency of the end product installed is through "value engineering". Value engineering is an industry term for when a sales representative leverages their relationship with an end-user (most often an electrical contractor) to convince them, after a job has been specified and won by a different representative with different products, to purchase their products at a lower price point instead. According to the interviewed sales representatives, value engineering outside of the formal specification and bidding process is commonplace and leads to differences between the specified and installed product when electrical specifications are loosely written (i.e., do not require a specific product).

"It is very frustrating. You think a deal is done and then someone else comes in at the last minute and says 'I can save you X% if you go with my products instead.'"

- Sales representatives often carry between 80 and 120 unique product lines.

National Accounts are a customer segment, not a separate channel.

All interviewed manufacturers noted that national accounts, due to their scale, are influential customers with the leverage to directly negotiate special pricing arrangements. They explained that profit margins are typically thinner for national accounts (versus standard stock and flow distribution) since national accounts successfully demand very competitive pricing. Manufacturers further explained that once you agree to a price, they are held to that price until the agreement is up for renewal. As a result,

"To be clear - when we talk about national accounts, we're talking about millions of bulbs."

these manufacturers shared that they typically make most of their profit during the final years of the deal (just prior to renewal) after manufacturing costs have dropped.

Manufacturers also noted that national accounts tend to purchase more fixtures, more controls, and generally more efficient products than other end-users. They explained that national accounts, both because of their scale and their sophistication, better understood the value proposition of efficient equipment and were more able to make upfront investments in such equipment.

It is important to note that national accounts are not a separate market channel akin to distribution, direct, or online. In most cases the products purchased by national accounts, even when they negotiate special pricing directly with the manufacturer, still flow through wholesale distribution (either the physical product or the purchase order). As a result, most national account sales are captured in the electrical distributor datasets collected by BPA and used to assess momentum savings. In rarer instances, transactions with national accounts occur outside distribution, are handled solely by the manufacturer, and are part of the direct market channel that the research team does not have information about.

Integration is on everyone’s mind: Lighting is no longer just about lighting.

Nearly every interviewee discussed the importance of integration – i.e., building controls into fixtures and developing easy-to-use interfaces for end-users to confidently manage their lighting systems. Interviewees also stressed the importance of interoperability with other manufacturer’s fixtures and lamps as well as with end-users’ existing energy management systems. However, most spoke of interoperability as more of a medium range goal rather than the current state of the market.

Several manufacturers were also promoting product lines that would allow end-users to use their lighting infrastructure to directly interact with their customers via their smart phones. The manufacturers noted that retail and hospitality were likely to be the early adopters, but that the concept of using lighting systems as conduits for non-lighting uses and communications was likely to expand quickly. One concept included engaging shoppers in new ways such as alerting retail customers of specials on products they’d previously purchased when they enter the store and providing directions for navigating the retail space.

Other notable findings related to integration and leveraging lighting infrastructure for non-lighting uses include:

- A NW manufacturer representative noted that one manufacturer currently offers TLED lamps with and without integrated controls at different price points. However, he predicted that the manufacturer would eventually build the controls into all its TLED lamps (to standardize and save on manufacturing costs) but only activate the functionality when the customers pay the premium price.
- Due to the enhanced lighting system’s ability to accurately track smart phone locations within the store, a manufacturer representative speculated that retailer (and later other end-users) can use the information to better understand customer’s paths through the retail environment and develop alternative layouts that optimize traffic flows and purchase patterns.
- As this line of products expands utilities will be faced with a new question: How will additional services bundled with lighting products change/obscure utilities’ goal of promoting energy

efficiency? Alternatively, how do you promote lighting efficacy when an end-user is selecting their lighting system for reasons other than lighting?

Lamp and fixture companies are increasingly partnering with or acquiring controls manufacturers.

Several interviewees suggested traditional lamp and fixtures companies are increasingly seeking partnerships with or the acquisition of controls companies.

> *"It will be very interesting to watch how all the companies in lighting that currently do different things start to partner up and compete with the larger/powerhouse companies."*

A manufacturer specializing in controls eagerly pointed out that the increasing importance of controls and integration had created a new seat at the table, alongside historical lighting market powers, for smaller, newer companies such as his. He noted that the shift toward integration served to level the playing field and that controls firms are now perceived as important potential partners by much larger manufacturers.

Market actors share some utility concerns about TLEDs… but are happy to sell them.

Nearly every lamp manufacturer at LightFair was promoting a suite of TLED products that compete with the linear fluorescent market. These product lines typically included TLEDs that worked with existing ballasts, systems with TLED-specific replacement ballasts, and lamps with integrated drivers. When pressed on their preferred TLED product or marketing strategy, most interviewees hedged. They acknowledged there is a wide variety of replacement scenarios and that any that do not include ballast replacement left them feeling vulnerable and were suboptimal from both a maintenance and energy savings perspective. The prevailing sentiment among manufacturers, particularly fixture manufacturers, was a desire to provide end-users with options and to not let the industry's pursuit of TLED perfection prevent or delay customers looking LED solutions right now from upgrading their existing lighting system.

Other notable findings related to TLEDs include:

- Several manufacturers said their TLEDs were not yet available through retailers, but that they expected they would within the next year.
- One sales representative remarked on the speed at which TLED prices were falling. He shared that two years ago he sold a TLED retrofit kit for $190 that now sells for $125. He went on to say his manufacturing contacts were telling him the prices would fall under $100 soon.
- Manufacturers also noted that relative to long-life T8 lamps at $3 per bulb, TLEDs are tough sell in areas where energy prices are not very high.
- More than one manufacturer lamented the lack of prescriptive utility incentives in some parts of the country. One remarked that, if utility incentives are meaningful, they "can sell those things all day long".

Appendix F – ENERGY STAR® Partner Meeting Findings Memo

To: Carrie Cobb, Bonneville Power Administration (BPA)

From: Nicole DelSasso, Dave Bluestein, Navigant Consulting, Inc.; Doug Bruchs, Rob Carmichael, Cadeo

Date: December 12, 2015

Subject: ENERGY STAR® Partner Meeting Findings Memo

Introduction

Bonneville Power Administration (BPA) tasked the Navigant/Cadeo research team (the research team) with characterizing the residential lighting market across the Northwest. As a part of this effort, the research team attended an ENERGY STAR® Partner Meeting in October 2015 where they conducted 10 in-depth interviews with lighting manufacturers and retailers—detailed in Table 1. These interviews covered a range of topics including the transformation of the LED market, the bleak future of CFLs, and how the industry is planning for Energy Independence and Security Act (EISA) 2020 standards. The following memo describes the key findings from these interviews, and provides insights from relevant market actors regarding the current state of the residential lighting market.

Table F-1: Market Actor Interviewee Details

Market Category	Company
Manufacturer	GE
	Lighting Science Group
	MaxLite
	Philips
	Sylvania
	TCP
Retailer	Amazon
	Costco
	Lowe's
	Walmart

Source: Navigant and Cadeo

Key Findings

The interviews at the conference revealed the key trends listed below. The remainder of this memo discusses the impact each topic has on the lighting market as a whole.

- Low-cost, non-ENERGY STAR LEDs are flooding the lighting market.
- Chinese contract manufacturers are beginning to bypass lighting "relabelers."
- Market actors are concerned about the stringent ENERGY STAR 2.0 specifications.
- Lighting manufacturers are looking to utilities for guidance on CFLs.
- Market actors do not consider the EISA 2020 to be set in stone.

Low-cost, Non-ENERGY STAR LEDs are Flooding the Lighting Market

Many lighting manufacturers recently introduced non-ENERGY STAR LED bulbs as a cheaper option than their ENERGY STAR certified counterparts. To reduce price, these manufacturers have relaxed certain ENERGY STAR LED requirements such as omni-directionality, dimmability, and expected useful life—only lasting between 10k–20k hours versus the 25k hours of an ENERGY STAR certified bulb. Market actors reported high consumer demand for these bulbs. One retailer, for example, cited a 2-pack of such bulbs for $4.99 that is "flying off the shelf." The demand for the non-ENERGY STAR LEDs could mean that customers value the price savings over the lost features, do not understand the features and therefore do not value them, or they are unaware of the bulb differences altogether. These are not problems that retailers necessarily care about, however, as they indicated, the high sales of these lamps confirmed consumer demand for value priced LEDs.

The quandary for BPA, utilities, and other energy efficiency program administrators is whether they should incentivize these low-cost LEDs. The shorter useful life as well as the lack of omni-directionality and dimmability prohibit these bulbs from achieving the ENERGY STAR certification. They do, however, meet the ENERGY STAR specs for lighting efficacy and therefore save the same amount—or sometimes even more—energy than comparable ENERGY STAR-qualified LEDs. So should the fact that these low-cost bulbs fail to meet ENERGY STAR certification standards keep them from getting an incentive? Do they even need an incentive given the reports of rapid sales or has the market been transformed? And what about the higher quality LEDs that are ENERGY STAR certified? Should they get an incentive to compete with their lower quality counterparts? These are all questions program administrators will confront when considering how to optimize lighting programs as non-ENERGY STAR LEDs gain traction in the marketplace. The research team sees the following program design possibilities:

1. Incentivize only the higher quality ENERGY STAR qualified LEDs
2. Incentivize all LEDs—including non-ENERGY STAR
3. Do not incentivize any A-line, screw-in LEDs in the residential market, and consider that portion of the market transformed

Option 1: Incentivize only ENERGY STAR Certified Bulbs

Programs could continue to incentivize only ENERGY STAR qualified LED lamps. The argument for this strategy is as follows: First, the non-ENERGY STAR bulbs are already flying off the shelves and do not need utility support to the degree the more expensive, longer lasting qualified bulbs do. Second, utilities are concerned about a “race to the bottom” in terms of quality. After experiencing the consumer reaction over poor CFL performance in the early days of lighting programs, utilities should work to ensure positive consumer experience with LEDs through the technology’s early adoption. Although some consumers are choosing the non-ENERGY STAR bulbs, they may not understand the quality difference between qualified and non- qualified bulbs. Lastly, this strategy continues the longstanding practice of basing rebates on the ENERGY STAR specification which helps to maintain the value of the ENERGY STAR and program brands and reduces the risk of confusing the market about eligible products. This practice has given consumers the luxury of knowing that if ENERGY STAR qualified a product, and the utility offered an incentive for the product, they could confidently purchase the product.

Option 2: Incentivize All LED Bulbs

A second option would be to incentivize all LED bulbs, regardless of quality or ENERGY STAR qualification. The argument for this strategy is as follows: First, programs are in the business of saving energy and non-qualified bulbs save as much energy as qualified bulbs. Non-ENERGY STAR bulbs should not be excluded simply because they lack non-energy features that consumers either do not understand or value. Furthermore, these non-ENERGY STAR LED bulbs compare well with CFLs (i.e., more efficacious and higher lighting quality), which do receive progam support. Why support one technology over another simply because ENERGY STAR has set a lower standard for CFLs?

The fact that non-ENERGY STAR LED bulbs are selling well compared to ENERGY STAR LED bulbs does not necessarily mean rebate support would not continue to move the market. The relevant metric for energy savings is not ENERGY STAR versus non-ENERGY STAR, but LED versus halogen. If the emergence of a cheaper LED bulb has captured a new slice of the market, would an even cheaper option—after a utility rebate on a non-ENERGY STAR bulb—open the door for LEDs to a new market segment of cost-conscious consumers? This is commonly the argument for continuing to incentivize CFLs.

Option 3: Do Not Incentivize LED Bulbs

The third option for program implementers is to halt incentives for A-line, screw-in LED bulbs altogether, regardless of quality. This strategy would be premised on the assumption that the LED market is transforming so quickly that incentives may no longer be needed to stimulate demand. While this may in fact be the case, it does leave the issue of product quality unresolved. Consumers may not know what omni-directionality is, or care that the bulbs are no longer dimmable, but they will notice if the quality of the LED is less than they expect it to be. Allowing consumer demand to completely drive the LED market could cause backlash if the quality of the LEDs suffers too much. This may require lighting programs to educate consumers on criteria such as useful life and dimmability, so they can make more informed purchasing decisions.

This would impact programmatic savings forecasts significantly, and limit the savings that energy-efficient lighting programs can achieve going forward. This option does allow program administrators and energy efficiency entities in the Pacific Northwest to potentially capture the energy savings generated by the sales of all LEDs through Momentum Savings.

Chinese contract manufacturers are beginning to bypass lighting "relabelers"

Smaller players in the lighting market who do not have "vertically integrated manufacturing", have relied on manufacturers in China to produce the components for their LED products. These small players, sometimes referred to as "re-labelers", acted as the middlemen between the overseas manufacturers and consumers, leveraging well-known brand names and distribution channels to bring their products to the U.S. market. These players claim they also offered an important quality control buffer for the newer LED technologies that were still being developed, to ensure consumers were getting only high quality LED products.

Discussions at the ENERGY STAR meeting revealed that this market is shifting. The Chinese manufacturers are starting to cut out the middleman, and take their products directly to the U.S. market. This move reduces the cost to the consumer—as it removes the price markup from re-labelers—but also potentially introduces lower quality products into the market. However, as mentioned in the non-ENERGY STAR qualified discussion above, consumers may not be overly concerned about quality as long as the price is right.

Market Actors are Concerned about Stringent ENERGY STAR 2.0 Specifications

Market actors are concerned the new, more stringent ENERGY STAR 2.0 specifications are "over-engineered" and not taking into account the changing market. Several manufacturers expressed particular concern about ENERGY STAR's omni-directionality requirement. One manufacturer cited omni-directionality as the most costly barrier—from a manufacturing perspective—to move an LED from non-ENERGY STAR to ENERGY STAR 2.0 compliance. Several manufacturers wondered about the importance of true omni-directionality to the average consumer and noted near omni-directionality was significantly less expensive to produce and, from their perspective, totally acceptable to the majority of residential lighting end-users. These manufacturers implied that the requirement was more about the Department of Energy's desire for the "perfect bulb" and not about the best interests of end-users, who don't value – or even perceive – the additional directionality over the incremental increase in retail price.

One manufacturer raised similar concerns about the 25,000 hour lifetime requirement, whereas another manufacturer said meeting that requirement was not a problem at all. In general, manufacturers wondered whether diminishing returns existed regarding lamp lifetime. They noted there was not anything "magical" about the new specification of 25,000 hours. They speculated whether a reduced hours requirement, something between the 10,000 hours common for non-ENERGY STAR LEDs and the 25,000 hours required by ENERGY STAR might provide better value (i.e., sufficiently long life at lower cost) to end-users.

Lighting Manufacturers are Looking to Utilities for Guidance on CFLs

Time is running short for CFLs and lighting manufacturers are looking to BPA, utilities, and other program administrators for guidance on how to proceed with this waning technology. Interviews showed that these manufacturers were worried that if and when lighting programs throw the switch on CFLs and turn off the incentive stream, they (i.e., the manufacturers) could be stuck with a large volume of tougher to sell, unrebated lamps. Even if the CFL market does not completely dry up, the range of bulb types associated with program offerings will likely diminish.

The new ENERGY STAR specifications for CFLs also pose issues for manufacturers. The manufacturers mentioned that they could easily meet the new specifications for "twist" CFLs, but not for "covered" versions.[1] Meeting the specs for the covered CFLs would require spending money on research and development, which manufacturers were not interested in doing given the larger market shift toward LEDs.

Some retailers, on the other hand, are not waiting for direction from utilities. For example, one retailer shared plans to stop selling a number of CFL bulb types in the first half of 2016, and to drop the technology entirely by the year's end.

Market Actors Do Not Consider the EISA 2020 to be Set in Stone

Some of the market actors interviewed expressed skepticism that the EISA standards set for adoption in 2020 will occur. The primary reason for this skepticism was that the loss of U.S. jobs—due to the closing of four halogen plants—would not be viewed favorably in the political arena. As a result, these retailers—and the manufacturers they work with—are not planning their research and development activities under the assumption the regulation will become effective as currently written.

Additional Market Intelligence

Retailers interviewed at the ENERGY STAR Partner meeting provided additional information about the changing lighting market that may benefit BPA and other stakeholders. This market intelligence includes information related to planograms, shelf space allocations, and profit margins.

Planograms

Retailers indicated that they update their planograms—depicting what sorts of products they will sell and where on the shelves these products will sit—at varying intervals throughout the year. Some major retailers reported that they update their planograms 2–4 times a year (most commonly in the spring and fall), while others do so only once a year. Updating planograms more often allows retailers to stay on top of the latest trends in lighting and offer customers the most desirable options on the market. In the opinion of some retailers, programs should work closely with retailers to focus incentive funding on efficient lighting products placed in more prominent shelf locations.

[1] A "covered" CFL has a variety of case types covering the actual twisting CFL lamp. These covers allow for applications such as flood lights and reflectors, or with lampshades that only fit over a rounded A-line bulb shape.

Understanding planogram updates and the timing of shelf stocking re-organizational efforts also has implications for energy efficiency advocates—such as the Northwest Energy Efficiency Alliance—that regularly conduct shelf-stocking surveys.

Appendix G – Lighting Showrooms Interview Findings Memo

To: Carrie Cobb, Bonneville Power Administration

From: Nicole DelSasso, Sonrisa Cooper, Chelsea Lamar, Navigant Consulting, Inc.; Doug Bruchs, Cadeo

Date: May 20, 2016

Subject: TO16.3 Residential Lighting Market Study: Lighting Showroom Interview Findings Memo

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This memo summarizes the findings of 14 interviews the Navigant team (the research team) conducted with regional lighting showroom staff to understand the role of showrooms in the residential and non-residential lighting market. Lighting showrooms are one of five market actor groups interviewed as part of the residential lighting market study. However, the findings are relevant for both the residential and non-residential markets. As such, the residential and non-residential market research teams will use the findings herein to characterize both markets.

The research team's interview objectives included identifying the following:

- The lighting showroom business model and supply chain
- What types of consumers are purchasing lamps from showrooms, including:
    - Non-residential building owners
    - Residential new construction builders
- Lighting technology trends
- Where the evolving lighting showroom market could inform program strategy

Summary of Key Findings

The research team identified the following key themes from the interviews:

- Showrooms are long-standing businesses with deep relationships in the industry. Each business has a unique supply chain based on the relationships they have built and the customers they serve.
- Customers are mainly residential new construction and remodel builders and homeowners who are interested in seeking guidance and design advice from showroom staff about fixtures, new technologies, and higher quality products.
- Light-emitting diodes (LEDs) are a popular technology and showroom topic.
- Lighting controls have yet to become a large seller.

This memo first discusses the interview findings and then identifies two preliminary program opportunities that Bonneville Power Administration (BPA) program staff may consider. The research team identified the following program opportunities from the interviews:

- Upstream lighting rebates at participating showrooms might offer an incentive for showroom staff to sell efficient products
- Savings opportunities might be available by incentivizing fixtures that house efficient lamps

Methods

The research team conducted interviews with staff from 14 regional lighting showrooms in September 2015 (4) and January/February 2016 (10).[1] The research team interviewed owners, co-owners, CEOs, and general managers of lighting showrooms in the Pacific Northwest. Although there was a break in interviewing between October and December, there is no discernable difference between the two sets of interviews, and the research team analyzed them as one sample. The research team identified interviewees by researching showrooms throughout the BPA region online. The research team chose interviewees from the largest, most popular showrooms within Washington, Oregon, and Idaho. Showrooms ranged from large chains with multiple locations across states to small local stores with only one location. Three members of the research team conducted the phone interviews, analyzed the interview notes, and contributed to this findings memo.

Discussion of Findings by Research Topic

This section discusses the research findings organized around four main research topics:

- Business model and supply chain
- Types of consumers
- Technology trends
- Program opportunities

Business Model and Supply Chain

This section discusses the supply chain and business models of lighting showrooms.

Business Model

Showrooms are long-standing businesses with deep relationships in the industry. Each business has a unique supply chain based on the relationships they have built and the customers they serve. As one interviewee stated about new lighting businesses emerging in the market: "It's unusual for someone outside the industry to pop in. This is an industry with tradition." Thirteen of the 14 showroom

[1] The research team used formal interview guides when speaking with showroom staff.

interviewees have worked in the lighting industry for more than 13 years. Together, the interviewees average 24 years of industry work experience, with the longest having 35 years of industry experience.

Showrooms have relationships with many local residential new construction builders and remodelers in the area. The staff that mentioned working with non-residential builders noted that their non-residential customers are geographically located in the same region as the store. Referral is their largest way of attracting new business. One interviewee even said that, "Home Depot and Lowe's refer customers to us for things that they don't carry in their stores."

The following sections define the products that showrooms display and the services they offer.

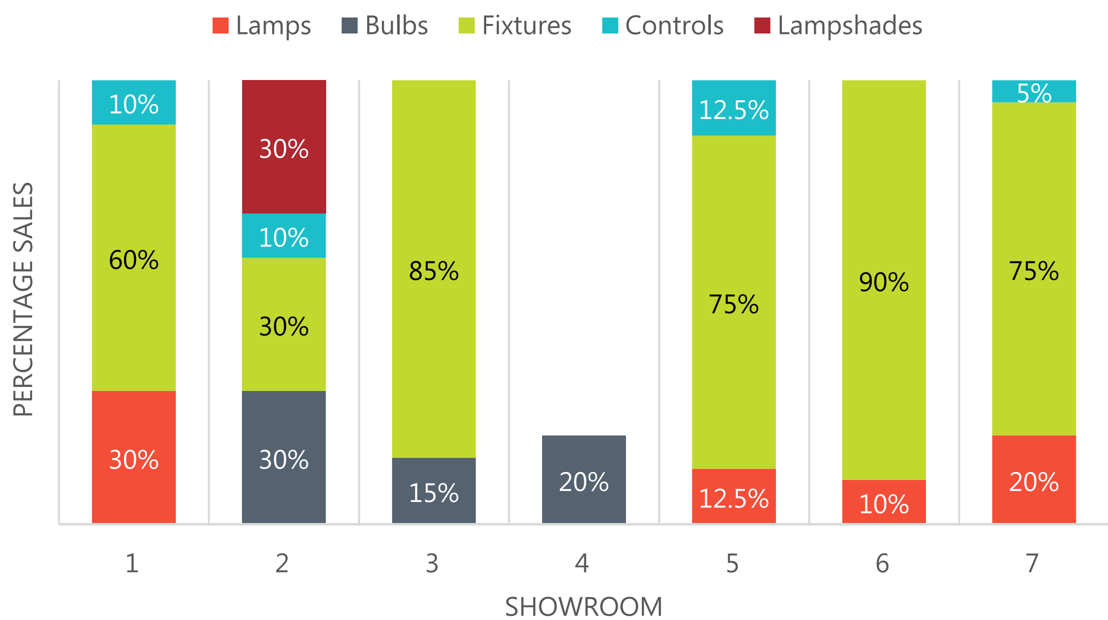
Products

Showrooms learn about products either through manufacturer representatives or by attending national lighting events. About once per year, manufacturer representatives send catalogs to showrooms or meet face-to-face with showroom staff to show new lines. The Dallas International Lighting Market, held biannually, is a major industry event for showrooms. Each vendor sets up a display at the convention where buyers can test and learn about new products. Showroom staff members use this event to network with existing vendors and build new relationships; some even go prepared with a purchase list.

Design trends seen on websites and design shows drive what manufacturers bring to market, and customers drive what is sold in showrooms. Customers learn about design trends from websites and televisions shows and request similar items when visiting showrooms. In general, interviewees suggested that showrooms stock shelves based on what these customers are purchasing and requesting. Some interviewees noted that women (over men) make the majority of lighting decisions and are the ones picking out and purchasing lights.

Fixtures are the best selling product at showrooms. In response to inquiries about the types of products they sell and the percentage of sales that fall into three categories—lamps and ballasts/drivers, fixtures, and controls—seven interviewees provided specific answers. Note that, on average, fixtures make up 70% of showroom sales. Figure G-1 outlines interviewee responses.

Figure G-1: Percentage of Sales by Product Category[2]



Source: Navigant phone interviews conducted in December 2015 and January/February 2016
***Note**: Interviewee #4 did not mention what the other 80% of sales were. It could be lamps, fixtures, controls, or lampshades, but the interviewee only mentioned that bulbs were a large portion of their sales.*

Design Services

Lighting showrooms offer lighting design services while customers are visiting the showroom. Showrooms do not typically provide in-home design services but often have relationships with and can recommend in-home design services, such as interior designers. In response to what percentage of sales is design services, one interviewee said, "The world of residential and light commercial lighting has changed so much that you can't just buy a fixture without some discussion of how it's being used and where it's being used. We are a very consultative-heavy company." Showroom lighting design services are either free or cost a small fee depending on the company.

Residential homeowners rather than builders commonly seek showroom lighting design services. Showroom staff members customize design recommendations based on homeowners' budget, style, and preference. An affluent homeowner may only want LEDs in their home, whereas a large homebuilder may go for a cheaper compact fluorescent lamp (CFL) option. The level of recommended efficiency or technological sophistication of these services is often dependent on the sales associate's expertise rather than dictated by the company—such is particularly true for lighting controls. One interviewee emphasized

[2] For Showroom 3, bulbs as 15% of total sales includes ballasts; for Showroom 5, lamps as 12.5% of total sales includes ballasts; and for Showroom 6, lamps as 10% of total sales includes ballasts.

the importance of having technical experts on staff for controls, and another interviewee described stocking complicated controls systems at a showroom location where a controls-trained employee works.

Although builders might buy lighting products to meet building specifications at the showroom, they likely are not seeking design services. Sales associates have a much smaller influence on products purchased for building specification compared to products purchased by residential homeowners with design in mind.

Supply Chain

Lighting showrooms purchase products from manufacturers and manufacturer representatives or a lighting supply company. Larger showrooms may store functional products intended for contractors in a central warehouse rather than displaying them in the showroom. The same is true for the storeroom itself, which will sometimes display one item and store the rest at the warehouse. This provides showroom space to display more product offerings for residential customers while saving money, as shipping costs for a small number of items from a manufacturer is high.

Lighting showrooms are one way for manufacturers to get their product to market. As one interviewee explained, "Showrooms aren't driving anything—we are a third-party distributor. We are a middleman." Nevertheless, showrooms directly interface with the customers and can provide guidance to manufacturers on what products customers are requesting. As noted by another interviewee, "[The] lighting showroom channel is very influential in that the showroom channel and electrical wholesale channel are exposing products to the public, and it flows upstream to the manufacturers from that."

Manufacturers and Representatives

Some lighting showrooms choose the manufacturers that they work with based on whether the showrooms are looking to sell the latest technologies or exclusive products. Of the showrooms that purchase from representatives, interviewees indicated that sales are based on relationships with the representatives. Many showrooms have worked with the same representative for years. The representative knows what the showroom wants to sell and markets to their needs. However, most showrooms specified that they do not go through manufacturer representatives and instead purchase products straight from the manufacturer or from a supplier. Of the 11 interviewees asked, seven responded that Satco is their number one or main lamp manufacturer.

Suppliers

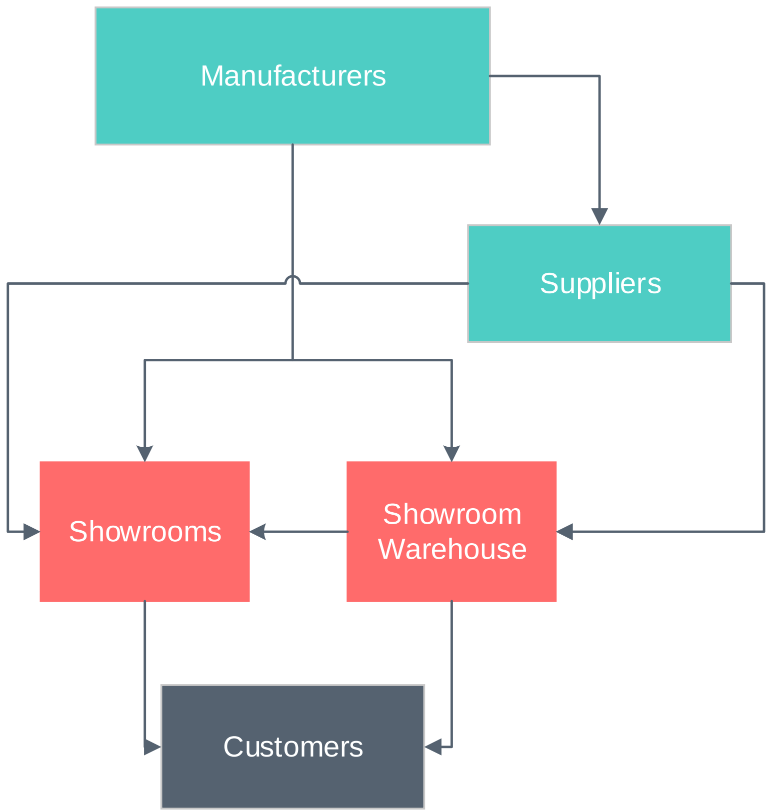
Some manufacturers, such as Sylvania, do not sell directly to showrooms, so showrooms have to buy from suppliers (i.e., distributors) that have Sylvania products. The cost from the supplier is sometimes cheaper than buying directly from the manufacturer because suppliers can buy more product at a lower price and then pass that savings on to showrooms.

Smaller showrooms that sell only decorative fixtures do not view suppliers as competition; however, larger showrooms see suppliers as competition for large homebuilder accounts. One interviewee viewed suppliers as competition only for recessed cans, but that competition depended on whether the contractor or the end-user initiated the job: "A lot of electricians provide recessed cans on jobs and then we provide decorative fixtures. Distribution is there for electricians and builders, not homeowners buying light fixtures." Another interviewee responded, "Distributors are absolutely competition for large residential accounts."

An interviewee indicated that showrooms and suppliers sometimes work in partnership: "We do have that competition at times, but in our industry, if a lighting distributor goes out and sells a product to a large spec builder for their next plot of homes, they still don't buy it direct. They have to buy it through a supplier like us, whether it's a lighting showroom or distributor. Our price point is dictated by what the distributor has told that builder. That builder has to come to us to order, but that distributor now guarantees that there is stock available and they won't have backorders. They will stock more in their facility so that we don't have to stock it all in ours. There is some partnership to that."

Figure G-2 provides a graphic display of the shipping supply chain.

Figure G-2: Lighting Showroom Shipping Supply Chain



Source: Research conducted as part of the 2016 Residential Lighting Market Research Study

Types of Consumers

Showroom customers are mainly residential new construction or remodel builders and homeowners who are interested in seeking guidance and design advice from showroom staff about fixtures, new technologies, and higher quality products. On a smaller scale, showrooms also serve residential and non-residential architects, engineers, and contractors. Recurring accounts with builders are commonplace: some with local large non-residential chains and others with smaller residential new construction builders. This section provides insights into the types of consumers purchasing products from showrooms.

Residential New Construction and Remodel

The vast majority of the showroom customer base is the residential homeowner purchasing products for new construction and remodel projects. Of the seven interviewees who responded to the question, "What percentage of your residential products would you estimate go into residential new construction?", three cited more than 50%, two responded 70%, one answered 90%, and one said 99%.

Interviewees noted that typically, a builder will purchase and install a portion of the lights in new construction homes, such as all the can lights, but send the homeowner to the showroom to choose additional lights that an electrician will install (a customer may decide to purchase additional can lights or decorative fixtures). In other instances, the builder may give the showroom a budget to light the whole house. When this occurs, if the builder is trying to hit an energy efficiency standard, they will ask the showroom to choose lighting that is rebated by the local utility.

When purchasing products, the builder is considering cost, whether there is a utility incentive available, the perceived value of the product by the homeowner, and the trusted relationship the builder has with the seller. Builders often have long-standing relationships with sellers and trust the products that the seller recommends.

Non-Residential Customers

Small showrooms do not stock and sell high-level commercial-grade products, but some large showrooms do. The large showrooms may sell commercial-grade products to local retailers or small restaurants. The interviewees noted differences between commercial and residential customers. One interviewee mentioned, "With commercial-specified projects, the specifier is more concerned with the components in that item, whether it's compliant. They'll ask more questions about power factor, lumens, watts consumed. The [residential] builder client sees it as just filling a hole, and is not as concerned." In general, showrooms do not sell commercial products to residential customers. The price point on commercial products is much higher and the improvement in quality is not typically worth the price for the home application.

Multifamily

Most showrooms have at least some multifamily customers. Lighting in multifamily buildings varies based on the specification and type of building. Builders will often install less efficient products in common areas, particularly if the building is for sale or needs to be paid off for investors quickly. However, if the builder is also the owner, there is greater incentive to install efficient lighting. One interviewee said, "Energy efficient, low maintenance are the driving factors. They may not be as decorative or expensive as what a homeowner might purchase. A homeowner may buy a nice glass-shielded ceiling fixture with a brass band. In the condo, they just want a white acrylic dome-looking thing on their ceiling." Another interviewee said, "I equate multifamily housing with starter home spec building or rental property. It's the same level of product. The contractor or developer is looking for ways to maximize their product, so we do that by going to a lower quality product." In comparison, "A custom builder has an interior designer that is picking paint colors and finishes, where fluorescent and LED will skew colors and change the appearance of finishes."

Online

Larger showrooms sell online. Those interviewees who mentioned selling online cited online sales relative to total sales as between 5% and 22%. Manufacturers may set up special deals with large showrooms for online sales. These showrooms' websites appear as if they stock all the products offered online, when they are actually a direct inventory feed from the manufacturer. Websites allow showrooms to offer a greater array of products, including non-lighting products, and to compete with the large online presence of companies such as Amazon.

Smaller showroom websites enable customers to browse products, but ordering is usually done through a sales associate. According to one interviewee, "Most manufacturers do not allow showrooms to sell online because it complicates shipping." He estimated that out of 1,100 lighting showrooms in the country, most manufacturers do business with 700 to 1,000 of them and do not want the hassle of shipping product to individual online customers in addition to their showroom clients.

Technology Trends

This section provides insights into the technology trends that showrooms are encountering.

LEDs

Unanimously, interviewees cited LED bulbs as the biggest trend right now, with the driving factor being the convenience of not having to change the bulbs as often. Most interviewees noted that LEDs are the largest requested item from customers entering the showroom.

Commercial-grade products are much higher quality than residential products, particularly for LEDs. As one interviewee put it, "It's like comparing a Ford to a Ferrari." The same interviewee also said that consumers are unaware of the difference in quality between commercial and residential products, and that product selection comes down to the sales associate understanding the customer's needs and often steering them to the residential-grade product.

Interviewees noted that sales of linear fluorescent lamps (LFLs) for home installation are declining but still happen occasionally, primarily for use in garages and utility rooms. As one interviewee noted, "People still buy LFLs for laundry rooms, garages, closets." Though another interviewee said, "There are linear LED options you can snap in. Even in existing lighting fixtures, you can pop out a fluorescent and put in an LED."

Controls

Most showrooms currently sell dimmers. Some sell integrated controls, but showroom staff described them as more of an emerging technology that has yet to fully reach all the showrooms, especially smaller ones. Interviewees indicated that customers are seeking out dimmers and integrated controls for comfort and simplicity. Customers want to be able to dim a light from their couch. "They want it to be simple, and that's where the iPad and smartphone control will come in."

This trend provides a growth opportunity in all showrooms, large and small. One recently interviewed large showroom built dedicated light labs to exhibit their controls and offers seminars on integrated controls to trade groups. However, this showroom is unique. Integrated controls may be appealing to customers, but they are not for do-it-yourself (DIY) homeowners. Although cost is decreasing and access to integrated controls is increasing, integrated controls still have a complicated installation process. Only experienced and educated electricians are currently installing them in homes. When customers purchase integrated controls, showrooms work with local electricians to install them.

Preliminary Program Opportunities

The research team identified two program opportunities to investigate further. These remain preliminary findings until the team finishes the residential and non-residential lighting market research studies. The two opportunities include the following:

- **Upstream lighting rebates at participating showrooms might offer an incentive for showroom staff to sell efficient products.** As one interviewee expressed, "Showrooms are the best way for manufacturers and utilities to have a knowledgeable person presenting whatever they're trying to express." Most customers shopping at lighting showrooms are residential new construction and remodel homeowners or builders. They are there to seek advice on their projects and purchase a lot of product at one time. This environment may provide the opportunity to help sway their decision to more efficient product.
- **Savings opportunities might be available by incentivizing fixtures that house efficient lamps.** Decorative fixtures make up, on average, 70% of sales at showrooms. One large showroom is capitalizing on this decorative trend and has expanded its business model to incorporate interior design and furniture in addition to lighting. Many decorative fixtures tend to house specialty lamps, which may not have efficient substitutes or are unregulated by the Energy Independence and Security Act of 2007 (EISA). This suggests that there may be an opportunity for savings in incentivizing fixtures that can house efficient lamps.

Appendix H – Residential New Construction Builders Interview Findings Memo

To:	Carrie Cobb and Jessica Aiona, Bonneville Power Administration (BPA)
From:	Nicole DelSasso, Chelsea Lamar, Navigant Consulting, Inc.; Doug Bruchs, Cadeo
Date:	May 20, 2016
Subject:	TO16.3 Residential Lighting Market Study: New Construction Builders Interview Findings Memo

This memo summarizes the findings from 10 interviews that the Navigant team (the research team) conducted with residential new construction builders in the Pacific Northwest. New construction builders are one of many market actor groups that the research team interviewed as part of the residential lighting market study. The goal of the interviews was to better understand the purchasing practices of single-family, residential new construction builders to enhance the characterization of the overall residential lighting market.

The research team's interview objectives included identifying the following:

- Who determines the lighting policy in new construction homes
- How lighting is specified, and when in the building process lighting is specified
- If linear florescent bulbs are still installed in new construction homes
- Who purchases the bulbs and fixtures and where are they purchased

The terms lighting policy, specification, and design are often used interchangeably in this market. In this document, the research team uses the following definitions for each term:

- **Lighting policy:** The expected lighting efficiency per company or per house that is implemented as company standard practice.
- **Lighting design specification:** A detailed design that documents how many and what type of bulb and fixture to install in each room.

Method

The research team conducted the 10 interviews in March and April 2016. Each interviewee's company builds between 8 and 800 homes per year, all of which are new construction.[1] One interviewee's company constructs mostly 2 to 40-unit multifamily homes, but all of the others are primarily or exclusively single-family builders.

The research team used the list of active and inactive builders on the ENERGY STAR® website as the interview sample frame. Based on input from the Northwest Energy Efficiency Alliance's (NEEA's) New Construction Program Senior Project Manager, the research team identified and targeted the 10 largest builders in the Pacific Northwest. One of the builders interviewed constructs ENERGY STAR-certified homes. The majority of the builders interviewed usually build above code but do not go through the paperwork to receive an efficiency rating. Three of the builders build code-compliant homes. Table H-1 shows how many interviewees fall into the three categories.

Table H-1. Interviewee Efficiency Ratings

ENERGY STAR	Above Code-Compliant	Code-Compliant
1	6	3

Source: Research for the BPA Residential Lighting Market Study

While the builders interviewed from the ENERGY STAR list build both efficient and code-compliant homes, the research team acknowledges that the origin of the sample frame may influence the findings provided in this memo to more efficient practices. Due to this potential bias, as well as the small number of targeted interviews, the team recommends readers interpret these findings as a general overview of lighting practices in new homes rather than a comprehensive or definitive assessment of the Pacific Northwest's new construction lighting market. While not statistically significant, the findings are valuable as they provide some insight into the residential new construction market and complement the other market research of this study.

Discussion of Findings by Research Topic

This section discusses the research findings, organizing the findings around four main themes:

- Lighting policy
- Lighting specification
- Linear fluorescents
- Purchasing decisions

[1] The research team surveyed 20 residential remodel builders in Washington, Oregon, and Idaho in 2015. The purpose of the survey was to understand how and when remodelers develop lighting specifications, their main considerations for bulb purchasing and decision-making, and their potential use of linear fluorescent bulbs.

Lighting Policy

All of the builders responded that they develop the lighting policy during the design phase of the house. Builders typically have either a company-wide lighting policy for all homes or a lighting policy established individually by house. Builders establish the policy based on the business model of the firm, not the efficiency rating of the homes they are building. For instance, the builders that have a house-specific policy typically build one house at a time versus whole subdivisions. The homeowner determines the efficiency of the lighting for the builders that construct one house at a time and have a house-specific efficiency policy.

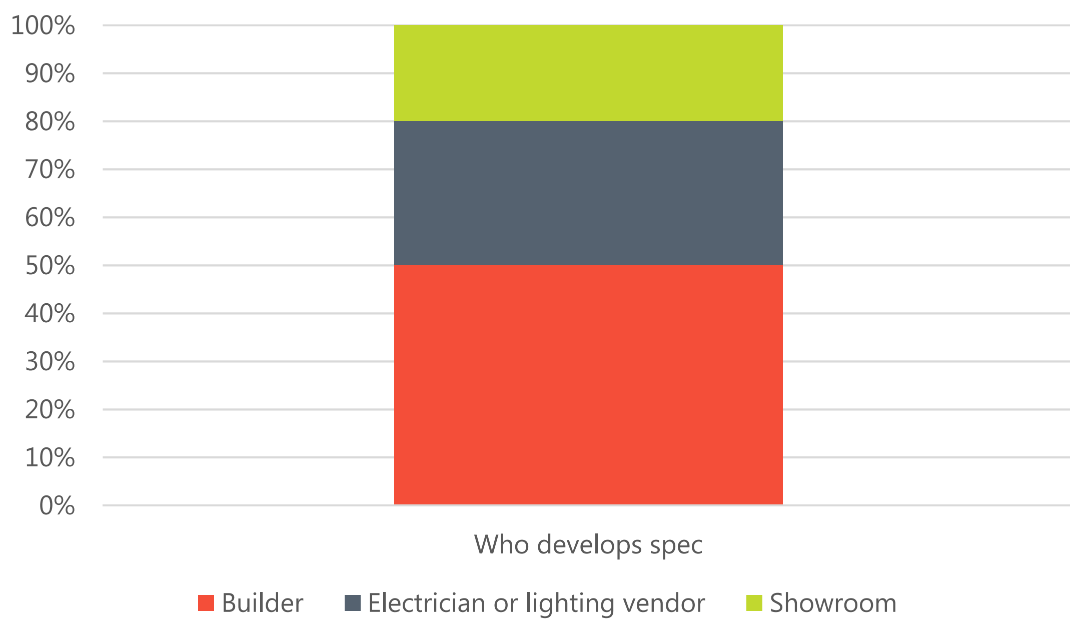
Lighting Specification

The lighting specification research objective centered on three main questions:

1. Who designs lighting specifications?
2. How is lighting specified?
3. At what point in the building process is lighting specified?

Only half of the builders interviewed develop the lighting specification in-house. The other half subcontract the specification to a local showroom, electrician, or lighting vendor. The interviewees used the two terms interchangeably. For this reason, electricians and lighting vendors are grouped together in the memo results. Figure H-1 shows who develops lighting specifications.

Figure H-1. Who Develops Lighting Specifications



Source: Research for the BPA Residential Lighting Market Study

Note*: It is hard to discern from the interviews whether electricians and lighting vendors behave in the same way.*

The amount of lighting that the builder specifies varies by builder. Some builders only specify the recessed ceiling can lights and allow the customer to choose all other bulbs and fixtures. Other builders specify a percentage of the lights and leave the remaining percentage to customer choice. Builders that specify a percentage of the lights typically identify 80% and leave 20% to the customer.

Several factors, including cost, aesthetics, code, and if the company has an efficiency target to meet, determine specifications. If the builder has an efficiency target, whether ENERGY STAR or something else, cost and aesthetics become secondary to meeting the standard. However, since all builders specify a percentage of the lighting, customers can choose the remaining portion of their lighting—either code-compliant or efficient products. The sample of builders interviewed all build homes only after they have an interested buyer; therefore, it is uncertain whether homeowners still have the option to choose a portion of the lighting if they purchase a house after it is built.

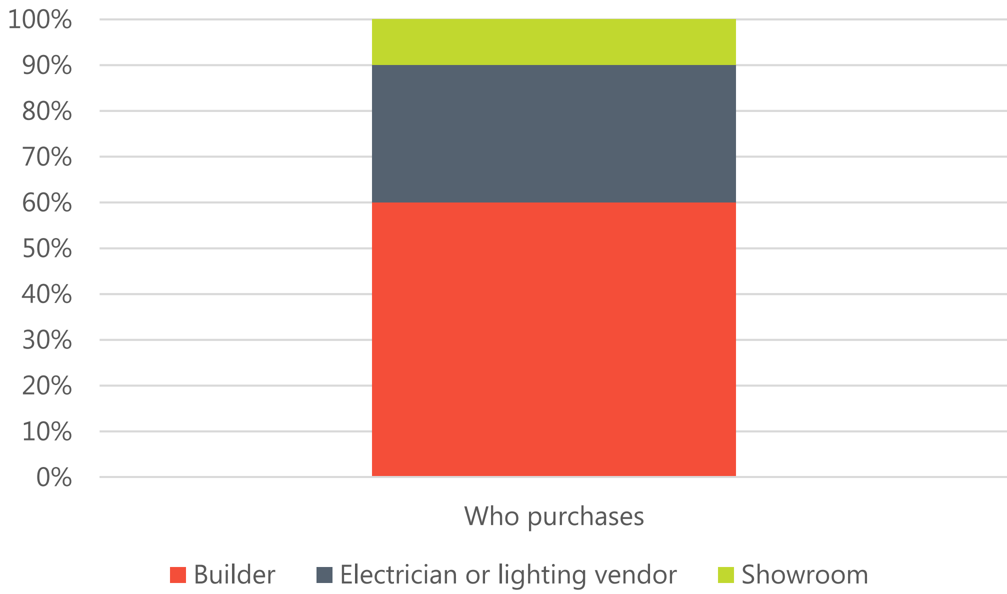
Linear Fluorescents

Three of the 10 builders responded that they no longer install any linear florescent bulbs. The remaining seven indicated that they sometimes install linear fluorescents in kitchens or storage areas, such as the garage and laundry room. Three of these seven builders estimated that they install linear fluorescents in about 5% to 15% of the homes they build, and the specification is typically to code. Four builders did not indicate the percentage of linear fluorescents they typically install in homes.

Purchasing Decisions

Six of the 10 builders interviewed choose the bulbs and fixtures to install in homes. The remaining four subcontract the purchasing decisions to a local showroom, electrician, or vendor. If customers choose a percentage of the bulbs and fixtures, they do not pay for them separately—builders include the cost in the total house purchase price. Customers have an agreed upon amount of money to spend on bulbs and fixtures and choose them during the build process. Should the customer choose more than the stipend, they are responsible for the incremental cost. Figure H-2 depicts who purchases the lighting.

Figure H-2. Who Purchases Lighting

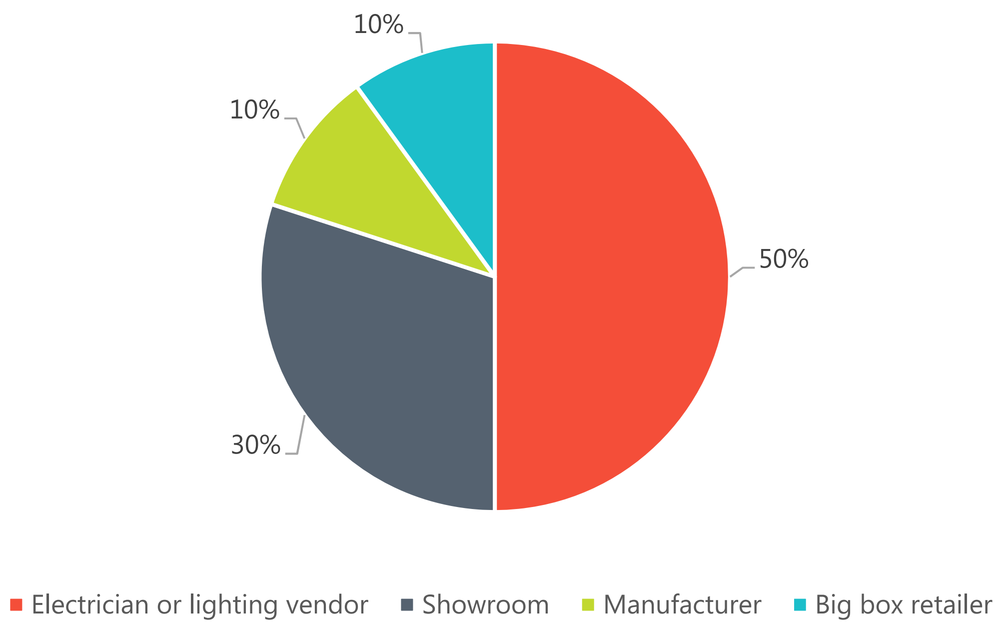


Source: Research for the BPA Residential Lighting Market Study

Typically, installation practices, not the type of lighting purchased (that is, bulbs versus fixtures), determine who purchases the lights. For instance, recessed can light fixtures are installed before other light fixtures in the building process. Sometimes a builder subcontracts with an electrician to specify, purchase, and install all the recessed can fixtures and bulbs first but purchases the remaining bulbs and fixtures through a lighting showroom, vendor, or retail store later in the build process.

The type of entity that purchases lighting sometimes affects where the lighting is purchased. For instance, a lighting showroom may purchase the bulbs and fixtures directly through a manufacturer, while an electrician without similar direct access may purchase lamps through a big box retailer like Home Depot. Figure H-3 shows where builders and their subcontractors purchase lighting.

Figure H-3. Residential New Construction Builder: Purchasing Channels



Source: Research for the BPA Residential Lighting Market Study

Appendix I: Online Retailers Interview Findings Memo

To: Carrie Cobb and Jessica Aiona, Bonneville Power Administration (BPA)

From: Doug Bruchs and Katie Arquiette, Cadeo; Laura Tabor, Navigant Consulting, Inc.

Date: November 17, 2016

Subject: TO16.3 Residential Lighting Market Study: Online Retailers Interview Findings Memo

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This memorandum summarizes the findings of three interviews that Navigant and Cadeo (the research team) conducted with market actors active in the online retail lighting market. Online retailers were the fifth and final market actor group interviewed as part of the research team's ongoing residential lighting market characterization study. Some of the findings from these interviews are also relevant to Bonneville Power Administration's (BPA's) concurrent non-residential lighting market research.

The research team's interviews focused on the following topics:

- Size of the online lighting channel (i.e., the percentage of residential and non-residential lamps sold online)
- Growth in the online lighting channel, both past and anticipated
- Customer profiles and common purchasing behavior
- Experience with utility programs

It is important to note that the limited number of market actor interviews completed means that the findings presented in this memo are anecdotal and not a definitive assessment of the online lighting channel.

Summary of Key Findings

The research team identified the following key findings:

1. **Online sales make up roughly 4% to 10% of the total residential lighting market.** Two of the three interviewed market actors estimated the size of the online retail channel. One estimated 4% of all residential lighting sales occur online, while the other said the channel was "at least 5% but no more than 10%." Both market actors acknowledged uncertainty associated with their estimates

and that the online channel was growing rapidly. Neither interviewee was able to estimate the percentage of non-residential lighting sold online.

2. **The online lighting channel is only going to get bigger**. One interviewee said their company has averaged double-digit year-over-year growth in its online sales over the last six years. All interviewees said they expect the growth to continue, in terms of lighting sales volume as well as the number of online lighting retailers. According to another interviewee, there are already as many as 30 residential and/or non-residential lighting-focused retailers active online as of late 2016.
3. **Online retailers may sell more incandescent lamps**. The research team compared the technology mixes (e.g., the percentage of total sales that were a specific technology) of online and traditional brick and mortar retailers. The team found that the online channel sold a higher percentage of general purpose incandescent lamps in 2015 than traditional retail channel did. Interestingly, both market actors sell similar proportions of inefficient lighting overall (i.e., incandescent and halogen lamps as a share of total sales). The difference is that the majority of the online channel inefficient sales are incandescent lamps, while most of the traditional retailer channel inefficient sales are halogen lamps. The definitive cause for the disparity is unknown, but one possible explanation is that online retailers are able to maintain larger inventories than traditional brick and mortar stores. This means they can stock a wider array of legacy products such as incandescent lamps. While interesting, it is important to note that these trends may change as the online lighting channel grows and matures.
4. **Customers are buying more of everything online, including lamps. They are also using online search functionality to purchase hard-to-find lamps with less hassle**. Online platforms work well for customers who know what they want and do not need the assistance of a lighting professional to identify a lamp. Online shopping is particularly convenient when customers are reordering replacements or searching out uncommon lamps.
5. **The most successful online retailers are those with the most sophisticated platforms.** Interviewees note that, like other online retail sites, the lighting-focused websites that can predict customer behavior and quickly lead shoppers to the items they want are more successful than websites with less sophisticated platforms. The easier the web interface and the more sophisticated the recommendation algorithm, the higher the likelihood of increased sales. Retailers also see the ease and sophistication of their platform as a way to differentiate themselves from other online retailers—not relying solely on competitive prices to entice customers.

Methods

The research team conducted three interviews with lighting professionals involved in the online sales channel. The team identified these interviewees through programmatic connections with BPA as well as through interviews completed for the concurrent non-residential market characterization (during which interviewees noted their ties to the online channel).

The limited interview sample, which included online retailers and lighting manufacturer staff that work directly with online retailers, offers preliminary insight into the growing online retail channel. Readers should view the findings as anecdotal and not a definitive assessment of the channel.

Discussion of Findings by Research Topic

This section discusses the research findings organized by topic.

Size and Dynamics of the Online Lighting Channel

Two of the interviewees provided estimates for the online lighting channel size. One estimated that residential customers purchase roughly 5% to 10% of their lamps online. The other interviewee estimated the online channel is approximately 4% of all residential sales.

To understand the dynamics of the online lighting channel as well as how the channel interacts with traditional retailers, the research team asked each interviewee whom they perceive as their competitors for lighting sales. One interviewee described their competitors as a "very broad set of competitors – an odd, cross-cutting niche." They added that online retailers compete with other online retailers as well as with traditional retail locations. One interviewee mentioned that more than 30 online lighting retailers are active in the online lighting market, and he/she expects that number to grow.

For the residential channel specifically, one interviewee stated that price is the most important driver of competition and sales, explaining: "it's how we all shop on Amazon, [we] sort by price." This echoes the sentiment of other interviewees—lamps are generally cheaper online.

The market dynamics of the non-residential online lighting channel are particularly complex. Online retailers view traditional distributors as both competitors and customers. Online retailers consider themselves similar to traditional distributors for non-residential products, but interviewees acknowledged that there are certain services, such as financing, technical support, and installation and operational troubleshooting, that they cannot yet provide online. The interviewees were clear that traditional distribution was a related, but different and complementary competitor and service, for non-residential customers. Online retailers also view traditional distributors as customers. Since online retailers typically carry large and diverse inventories, distributors will sometimes order lamps for their customers that they typically do not stock themselves or purchase through their primary lighting provider.

One interviewee explained that their lamps show up in several different places online: retailers they contract with directly, online resellers that purchase their lamps from a third party, and on utility program sites. Some sites may approach a manufacturer, but in other cases, the manufacturer may pitch a specific product or a portfolio of products to an online retailer's procurement manager. According to the interviewee, the direction of communication – manufacturer to retailer or retailer to manufacturer – usually depends on the maturity of the site. In most cases, more established sites already have a preferred primary provider so other manufacturers must pitch their products to the site as superior products or make the case that their lamps are complementary to those already on the site. However, when newer sites are launching they will often solicit bids from several different manufacturers.

Selling lamps online is not unlike selling consumer goods online. Lighting retailer sites differentiate themselves and generate business through the sophistication in their platforms. All interviewees agreed that the biggest online sellers are those with the best platforms and whose capabilities include data mining to predict customer behavior. "Customers also bought" algorithms, as one interviewee noted, increase sales as customers "are led to the products they think they need."

Growth in Online Lighting Sales, Past and Anticipated

All interviewees agreed that the online channel is growing—and quite rapidly—in both unit sales and in the number of players. One interviewee said his company averaged double-digit year-over-year growth in its online sales over the last six years.

Interviewees offered two theories for the rise in online sales: macro changes in consumer behavior and convenient access to a larger variety of lamps.

Interviewees explained that growth in online lighting sales is, in large part, simply a byproduct of the larger societal shift toward consumers buying more of their products online. They speculated that online lighting sales will increase proportionally with more general retail sales trends.

> *"[Growth online is] inherent in the number of people online and the availability of the marketplace… commercial end users who would typically drive down the road to a brick and mortar retail center are now searching online, at least to check pricing and if they have an easy way to transact and have it shipped."*

The second theory—that lighting-specific sales growth is due to the convenience of finding a specific type of hard-to-find lamp—was also a common thread among interviewees. All interviewees mentioned that a portion of customers purchasing lamps online sought less common lamps. Interviewees said that for these customers it was easier to search for a product code online than to call (or travel to) multiple stores to find the right lamp. One interviewee summed this up, saying, "How many stores are you going to call for a specific item versus just searching [online]?" Additionally, nearly universal access to the Internet means customers in rural communities can still access the full gamut of lighting products.

It is important to note that these theories are not mutually exclusive—the increase in lighting sales is likely due to a combination of the two.

Customer Profiles

As noted above, the interviewees identified two types of shoppers: those that use online retailers for convenience and those that go online for the wider selection of uncommon, harder-to-find lamps. One interviewee explained that online retail works particularly well for consumers that know exactly what they want (a.k.a. replacing a burned out lamp with the same lamp, also known as "like-for-like" replacement). They indicated that a traditional retailer might better serve customers that are less certain—or are looking for fixtures, not lamps.

Online customers hail from both the residential and non-residential sectors. To better understand the percentage of online lighting sales going to each sector, the research team asked all of the interviewees about their sector splits (i.e., the percentage of their total sales that are residential versus non-residential). However, none of the interviewees track this information as part of their standard practice. Additionally, all interviewees agreed that it may not be clear whether the given customer is residential or non-residential, especially because many of a retailer's lighting products can be installed in either a residential or non-residential application. While this information is important to the research team for regional modeling purposes, interviewees did not see much value in tracking sector type for their business operations.

Collectively, the interviewees envisioned three ways they could potentially determine whether a given sale went to a residential or non-residential customer:

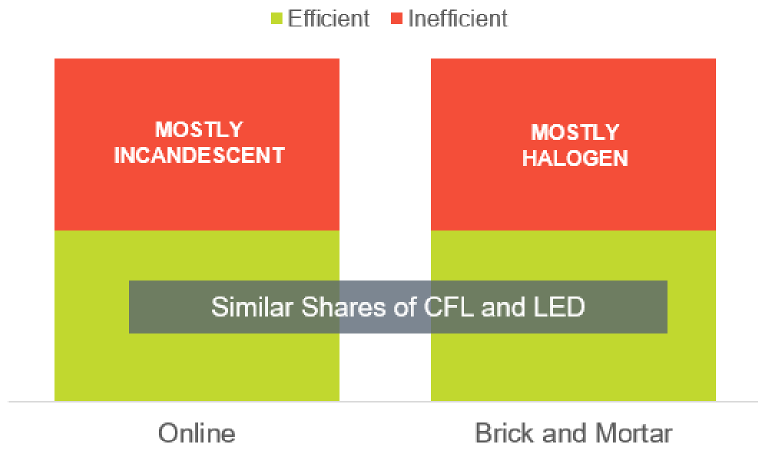
- **Quantity.** Residential customers purchase smaller quantities than non-residential customers (e.g., five lamps versus 500 lamps).
- **Shipping location.** Residential customers typically have lamps shipped to home addresses, whereas non-residential lamps typically go to commercial areas, such as business parks or retail areas.
- **Price.** Residential lamps are generally less expensive than non-residential lamps. One interviewee explained that non-residential decision makers better understand operating costs and seek the best return on their investment, which often translates into buying higher quality and products that are more expensive. The interviewee added that residential new construction builders and general contractors are typically only required to warranty a product for one year; thus, they look for products with a lower initial cost regardless of its longer-term performance.

Common Purchasing Behavior

According to one interviewee, the most common lamps purchased online were general purpose lamps (a standard, or traditional, light bulb shape that fits the vast majority of residential sockets) and linear fluorescent lamps. This indicates that, while a portion of customers are going online for harder-to-find lamps, the bulk of online purchases are the same applications most commonly sold through traditional retailers.

The research team compared the technology mixes (e.g., the percentage of total sales that were a specific technology) of online and traditional brick and mortar retailers (Figure I-1). The team found that the online channel sold a higher percentage of general purpose incandescent lamps in 2015 than traditional retail channel did. Interestingly, both market actors sell similar proportions of inefficient lighting overall (i.e., incandescent and halogen lamps as a share of total sales). The difference is that the majority of the online channel inefficient sales are incandescent lamps, while most of the traditional retailer channel inefficient sales are halogen lamps. The definitive cause for the disparity is unknown, but one possible explanation is that online retailers are able to maintain larger inventories than traditional brick and mortar stores. This means they can stock a wider array of legacy products such as incandescent lamps. While interesting, it is important to note that these trends may change as the online lighting channel grows and matures.

Figure I-1: Technology Mix at Online Versus Traditional Retail Stores (Illustrative Only)*



Intended to reflect general market trends only

The team also found that efficient lighting—CFLs and LEDs— sold by through the online channel tended to be ENERGY STAR-qualified less often than the CFLs and LEDs sold through traditional retail channels (mass merchandise, do-it-yourself, and small hardware retailers).

Figure I-2: Share of ENERGY STAR Lamps by Store Type (Illustrative Only)*

Intended to reflect general market trends only

Experience with Utility Programs

Two of out three interviewees recently began working with utility-sponsored lighting programs. Both interviewees indicated the programs follow a common online model, where shoppers confirm their eligibility for marked down prices by either entering their utility account number or their shipping address. They also noted the programs limit transaction quantities and restrict purchases to utility customers only.

All interviewees agreed that as the number of utility programs offered online grows, so too will the sophistication through which online retailers can deliver these programs. All interviewees mentioned how the utility program web interfaces had improved significantly in recent years, with one interviewee noting, "the functionality seems more robust, and the websites are nicer and easy to use."

For utilities not yet involved in online rebate options, one interviewee argued that if (for example) 10% of sales are online, 10% of incentives should go toward online retailers. He/she mentioned "utilities might budget about 10% of their budget to go towards a few of the biggest sites in the territory…it seems like something they don't want to ignore, because those savings go unclaimed."

"It seems silly to ignore [online sales] and we know that a portion is being sold through that channel, so those rebates should also be available through that channel as well."

Developed for the Bonneville Power Administration • www.bpa.gov

Developed by Navigant Consulting, Inc.

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