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Reduced Watt Lamp Replacement Market Characterization and Baseline

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Executive Summary

As part of its Reduced Wattage Lamp Replacement (RWLR) commercial lighting initiative to transform the Northwest market, the Northwest Energy Efficiency Alliance (NEEA) commissioned Cadeo Group to provide two elements necessary for the execution of a successful initiative:

1) An analysis characterizing the commercial lighting market supply chain, key players, market segments, and technologies at play. The lighting market brief will help NEEA make more informed decisions in rolling out the Initiative.
2) A twenty-year baseline forecast—defined as the market share of reduced-wattage four-foot T8 lamps sold annually in the Northwest, absent market intervention. The baseline will also include an estimate of the absolute number of reduced-wattage four-foot T8 lamps sold annually. Reduced-wattage lamps are defined as 25-watt and 28-watt lamps. The baseline will be used to estimate future energy savings of the initiative.

The primary source for Market Characterization is the Bonneville Power Administration's (BPA) Non-Residential Lighting Market Characterization (estimated to be published in April 2014). The focus of that study was the general service fluorescent lamp (GSFL) market and the impact of the new Department of Energy (DOE) standards (which took effect in 2012). The study relied heavily on interviews with key decision makers in the Northwest lighting market supply chain. Among the interviewees were nineteen distributors, eight regional lighting experts, one lamp manufacturer, two fixture manufactures, and one major retailer. The research team also conducted fifteen interviews with lighting maintenance contractors at a network event hosted by BPA and NEEA in the fall of 2013. In addition to the market actor interviews, regional sales data was collected from eleven of the nineteen distributors, which provided Navigant with a comprehensive understanding of the technologies used in the market and how those are trending due to natural market progression, utility programs, and DOE standards.

A twenty-year baseline forecast that will be used to estimate future energy savings of the Initiative. The Initiative currently gives incentives to lighting distributors in the region based on their sales of reduced-wattage (28 watt and 25 watt) T8 lamps. This forecast estimates the market share of reduced-wattage four-foot T8 lamps sold annually in the Northwest without market intervention. The baseline also includes an estimate of the absolute number of reduced-wattage four-foot T8 lamps sold annually.

The primary source for baseline development is also the Bonneville Power Administration's (BPA) Lighting Model, which was built using data from four main sources: BPA's Non-residential Lighting Market Characterization, Department of Energy's (DOE) 2010 US Lighting Market Characterization, DOE's Energy Savings Potential of Solid State Lighting in General Lighting Applications, and DOE's 2011 Solid State Lighting Multiyear Program Plan.

Cadeo updated and adapted the model to NEEA's specific needs: namely, enabling NEEA to estimate the impact of the Initiative by modeling a forecast of reduced-wattage lamps.

1 Market Characterization

1.1 Purchase Events

Lamp "purchase events"—defined as instances that trigger the need to purchase a lamp—are typically grouped into three categories:

1) New construction or renovations;
2) Maintenance;
3) Upgrades or retrofits.

The distinctions among these categories are important because they affect the economics of the choice a given purchaser or installer faces when selecting a lamp or system for installation.

New Construction or Renovations: Renovations are categorized as new construction and differentiated from retrofits because the decision to renovate is not driven by the lighting system whereas retrofits or upgrades are. The primary decision maker is the building owner or tenant who is paying for the new construction or renovation, but they are often influenced by other stakeholders, such as architects and contractors. In larger or high-end projects, architects and lighting designers will provide input into the purchase decision. Depending on the size of the project and importance of lighting, manufacturer representatives or distributors may also be involved in the decision making process. Distributors reported that they consider guidance on lighting specification in such instances as a value-added service they provide their contractor customers.

Maintenance: One of the major findings from BPA's research was that the maintenance market accounts for the majority of lamp sales. This market is relatively large as lamps typically burn out at a faster rate than buildings (or building spaces) turn over. The higher burnout rate is due to the long operating hours of the commercial sector. The replacement of failed lamps and ballasts is typically completed in two ways:

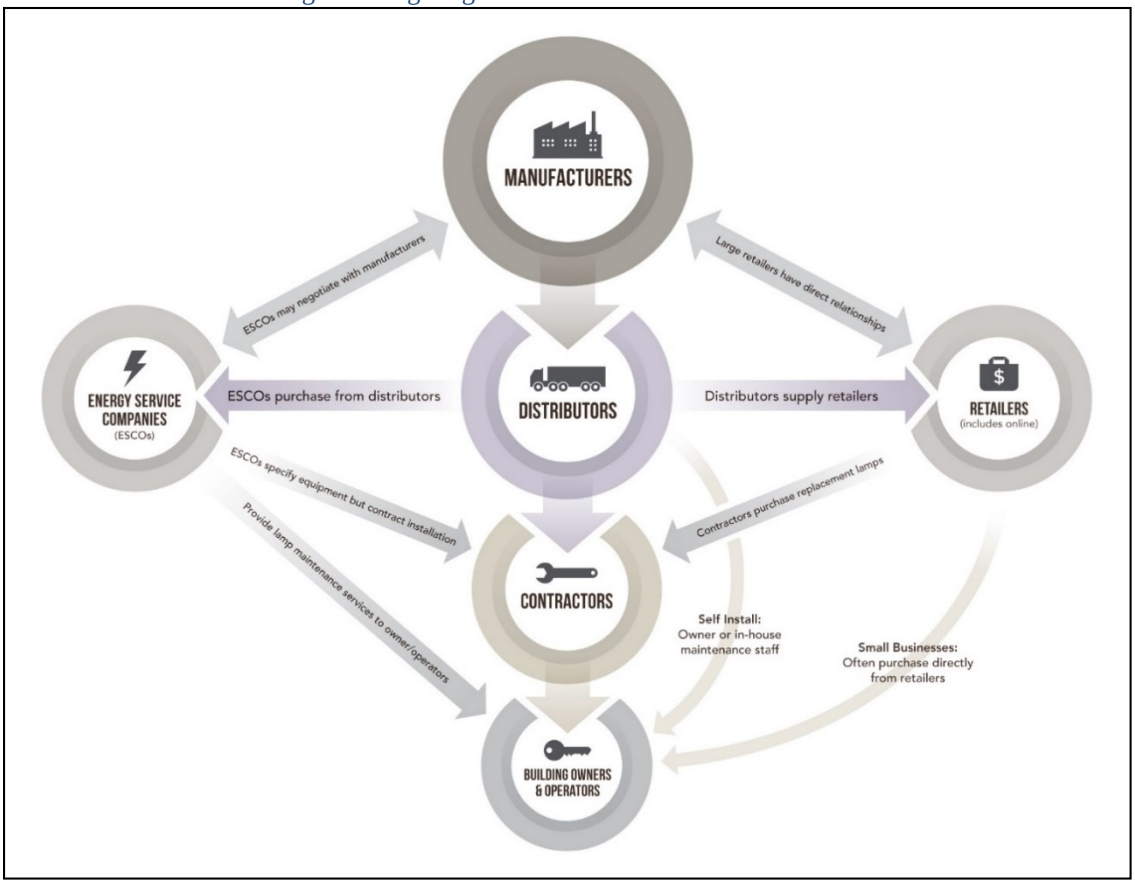
1) Spot replacement. This occurs when an individual lamp in a system burns out and is replaced one-for-one. Spot replacement is probably the most common type of maintenance activity, and certainly is in buildings with a significant diversity of technologies installed, with small buildings, or where the primary decision marker is a small business owner.
2) Group replacement. This occurs when a building owner, tenant or maintenance manager determines to replace all the lamps in a building or floor at one time, typically near the end of the expected useful life (seventy percent-eighty-five percent). Usually, only large businesses will follow a group replacement schedule, and even then some still favor individual lamp replacement (perhaps by default). The motivation for group replacement is savings on maintenance costs. For example, it is a common practice in high-bay applications, in order to avoid bringing in a lift every time a single lamp fails.

Retrofit: The retrofit purchase event occurs when a given lamp is purchased in order to improve the efficiency (and/or reduce energy consumption) of a given lighting system. The primary decision makers are the end-user and, potentially, the contractor who may have sold the retrofit job, but similar to new construction, several other players, including energy service companies (ESCOs), may influence the final decision on exactly what is installed.

1.2 Distribution Chain

The commercial lighting sector, shown below in Figure 1, illustrates several paths to market. Path to market varies based on technology and purchase events. For mature technologies, such as GSFL and High Intensity Discharge (HID), major manufacturers (GE, Osram Sylvania, Philips) control the bulk of the market. For emerging technologies such as light emitting diode (LEDs) the market is still fragmented and evolving quickly, but consolidation is expected as the technology matures. In addition to the channels contained in Figure 1, LEDs are often integrated with fixtures and sold through fixture manufacturers. Further down the distribution channels leads to a more fragmented market with more players at each stage. All of whom have their own priorities and motivations.

Figure 1: Lighting Market Channels and Stakeholders



Notes: Figure from Navigant (2014).

Manufacturers: Being the first step in any distribution channel gives the manufacturers enormous power to influence the rest of the market. They are focused on producing the lamps in a profitable manner to maintain their margins and also to push lamps through the distribution channels to avoid the build-up of inventory and associated working capital investment at their plants. The major lamp manufacturers prefer to sell direct to distributors and major retailers. Manufacturers often try to incentivize distributors to move higher margin items to help increase their profits. For GSFL, the majority of sales are negotiated between the manufacturer and distributors. Major retailers also have deals with the large manufacturers, but the product will often still flow through distributors, who, in such situations, may receive a fixed mark-up on the product. Very rarely, large end-users can work directly with a manufacturer. This market structure argues for an upstream approach for market intervention.

Distributors: The distributors are by far the most important step in the chain after the manufacturers because they usually "touch" the lamps regardless of the purchase event or who influenced the purchase decision. Distributors have a unique role in that they are the only market actor capable of holding large inventory across the market. They will often employ a regional hub and spoke model with a central warehouse that moves product to branches and directly to customers. The branch footprint enables direct interaction with customers (typically contractors) and affords the ability to gain local market knowledge and influence customer decisions. This local knowledge is important for individual distributors to differentiate themselves within the market. There are low barriers to entry in distribution—ultimately, distributors are "middlemen"—and brand loyalty among distributors' customers is low, which tends to lead to price competition. Beyond the physical distribution of the product, distributors also serve as a "bank" of sorts for the working capital invested in the inventory. Therefore, minimizing the time between paying for the product and getting paid by their customers for selling it is paramount to their financial success. Distributors are challenged to continually optimize the balance between having the products their customers want in stock and not having excess inventory to maximize profitability.

Energy Service Companies: The term ESCO is inconsistently applied to various businesses in the commercial lighting sector. We use it here to mean a company focused on retrofit activities, selling energy savings as a key value proposition and typically through the use of some contractual credit arrangement. Their projects typically involve energy efficiency programs and ESCOS are motivated to save the most energy for their investment. They will usually work with distributors to move the lamps so they don't have the inventory or distribution fleet expenses. They will often either perform the installation or work with contractors who provide the labor to complete the retrofit.

Retailers: Big box retailers such as Home Depot or Lowe's primarily serve the maintenance market. For GSFL, roughly half of sales are to contractors and half to end-users (namely, homeowners). Similar to the distributors they are concerned with minimizing inventory and also moving volume through as quickly as possible to boost profitability. Large retailers typically

negotiate directly with the manufacturers at the corporate level, leveraging their scale to obtain better prices. For commercial sector products, retailers do little to upsell. They sell, for instance, a negligible share of reduced-wattage T8 lamps. Their influence on downstream customers is limited largely to what is offered on their shelves.

Contractors: Contractors are often the market actors who actually make decisions about which lamps are purchased and installed, particularly in maintenance situations. Building owners or management firms often contract out for the maintenance of the building. Contractors will generally buy lamps from retailers or distributors and will pass along any price disruptions to the customer. Most contractors make their money on their labor, not on the small mark-up they apply to the product—so they have little incentive to push higher priced products in maintenance situations. When the customer is a small business owner, contractors can influence the decision significantly because they are often viewed as the expert by the building owner/operator.

Building Owners & Operators: These 'end-users' constitute the demand side of the equation; they ultimately have the authority to make the decision about what lamp type to purchase. Larger businesses or buildings often either have in-house staff dedicated to maintenance or will subcontract maintenance to a lighting contractor. More sophisticated building operators (typically larger organizations or buildings) or large spaces will group replace lamps rather than spot replace lamps—to save on maintenance costs (as noted above) and ensure even lighting in a space.

For small businesses and buildings, the owner or lessee with lighting responsibility, will often have a service contract with a lighting maintenance contractor. The contractor makes scheduled site visits and is available as needed to replace failed lamps. Smaller contractors and mom-and-pop business owners are the most likely actors to utilize a DIY retailer for commercial lighting applications.

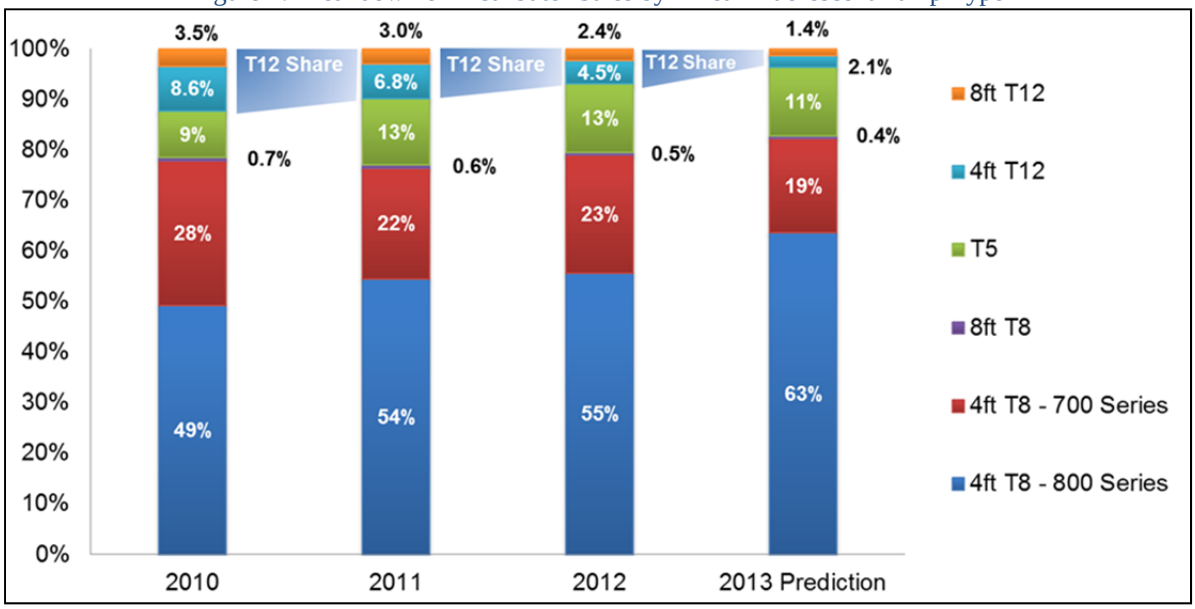
1.3 Technology Mix

DOE lighting standards announced in 2009 were expected to eliminate the manufacture of T12 lamps in July 2012, but manufacturers were able to produce T12 lamps that met the standard. Additionally, high Color Rendering Index (CRI) T12s are exempt from the standard, providing a loophole for T12s to remain on the market. Consequently, the market share of these products and their effect on T12 retrofits was unclear before BPA conducted their extensive lighting market characterization.

Figure 2 contains a breakdown of distributor linear fluorescent lamp sales data and indicates that the previously mentioned T12s are not having a significant influence on sales and are phasing out. Several distributors also noted that they would discontinue stocking and phased out T12s. Sales data indicates that the transition from T12s to T8s is continuing and also that eight-foot lamp sales are falling dramatically. Four-foot T8s are expected to account for more than eighty percent of sales in 2013, while eight-foot T8s account for less than one percent. Surprisingly,

four-foot T8 800 series lamps were more common than the standard 700 series, which were given a two-year exemption by DOE. These four-foot T8 700 series lamps will no longer be compliant in July 2014.

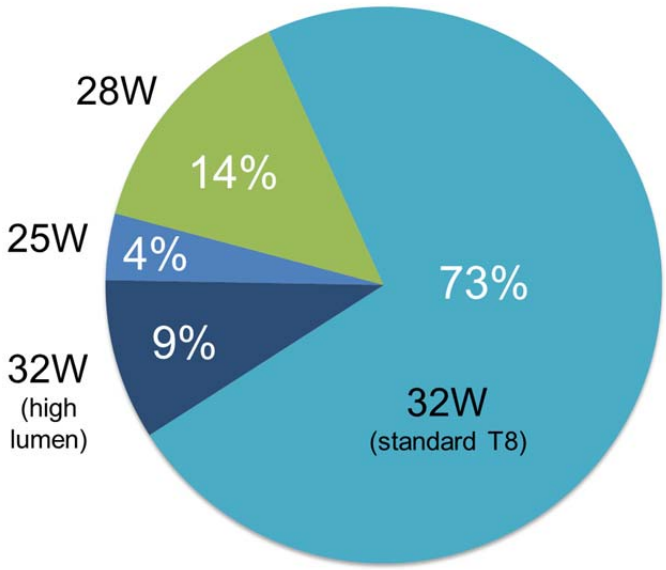
Figure 2: Breakdown of Distributor Sales by Linear Fluorescent Lamp Type



Notes: Figure from Navigant (2014).

Figure 3 illustrates that the majority of four-foot T8 lamp sales are of the 32-watt variety. Reduced-wattage lamps currently account for less than twenty-percent of distributor sales.

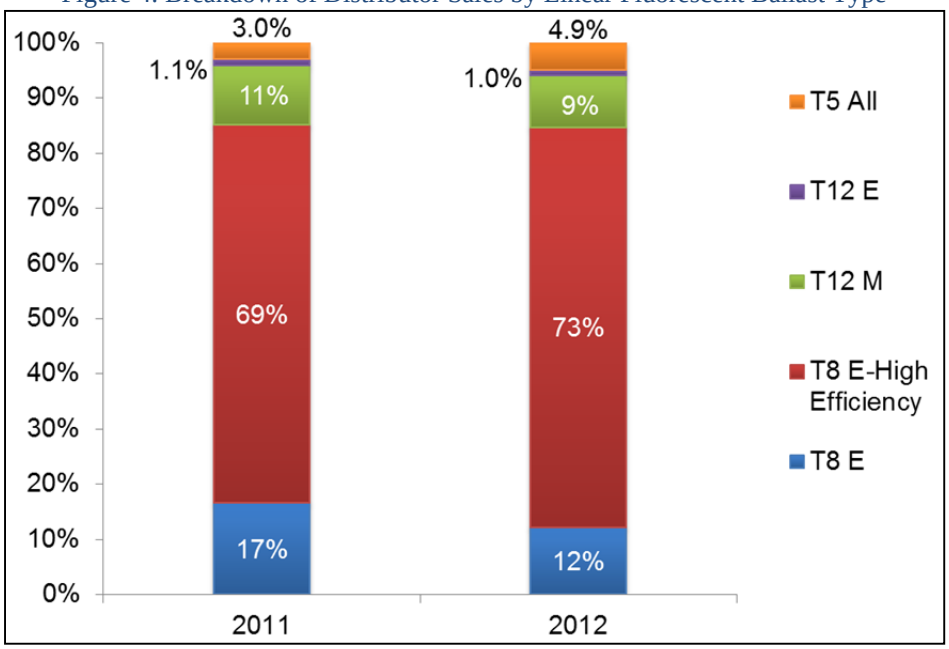
Figure 3: Breakdown of Four Foot T8 Distributor Sales



Notes: Figure from Navigant (2014).

As expected, sales data for linear fluorescent ballasts mirrors that for lamps with T8s accounting for the vast majority of sales. While the data shows high-efficiency ballasts as making up the majority of T8 ballast sales, this should be interpreted with caution because many market actors call any electronic ballast a "high-efficiency" ballast. While a still small part of the overall market, sales of T5 ballasts exhibited significant growth from 2011 to 2012. T5 lamp sales didn't have the same trends and remained constant from 2011 to 2012. This suggests the first generation of T5 ballasts are beginning to fail, leading to an uptick in replacement ballasts.

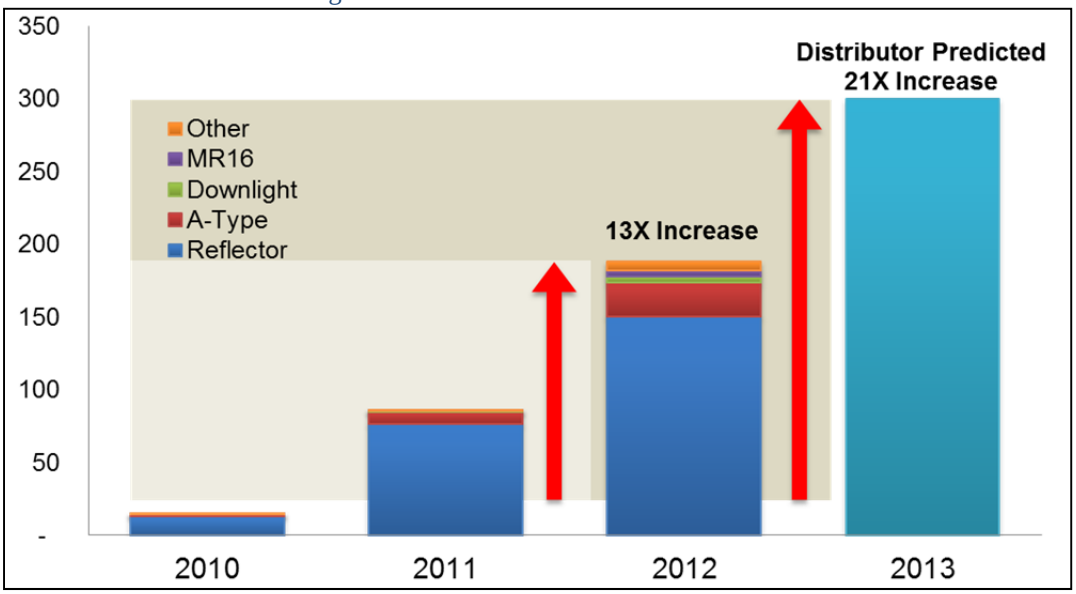
Figure 4: Breakdown of Distributor Sales by Linear Fluorescent Ballast Type



Notes: Figure from Navigant (2014).

LED systems have shown tremendous growth in all market actors reported that they expected this to continue over the next several years. The majority of reported sales are reflector LEDs that account for eighty percent of sales followed by A-Types with twelve percent of sales.

Figure 5: LED Sales in Thousands of Units



Notes: Figure from Navigant (2014).

In addition to a large percentage growth in LED sales, distributors noted that the LED market is still extremely fragmented with new market entrants still rushing in. Partly as a consequence of the fragmentation, internet retail distributors expected internet retail to grow as a channel for LEDs. The diversity of LED applications makes standardization difficult, which in turn mitigates the would-be advantages of mass production. Therefore, smaller players and foreign manufacturers will be better able to compete as the market emerges: these players are more likely to rely on the internet channel as a means of low-cost distribution.

Unlike LEDs, HID systems are declining in use. Mercury vapor lamps are nearly gone from the market, with the mercury vapor ballast ban from several years ago driving the decline. High pressure sodium lamps have experienced a steady decline both in absolute terms and as a share of the market. Metal halide lamps are also declining in absolute terms but growing as a share of the HID lamp category.

Table 1: HID Market Share

Type	2010 Market Share (%)	2011 Market Share (%)	2012 Market Share (%)	Expected Decrease in 2013 Sales (%)
Metal Halide	69	76	78	42
High Pressure Sodium	30	23	21	22
Mercury Vapor	2	2	1	13

Notes: Data from Navigant (2014). Share may not sum to one hundred percent due to rounding

2 Baseline Model Overview

In contrast to other approaches, the BPA model is appropriate for the task of modeling reduced-wattage T8 lamps because it models the entire lighting market (as opposed to a simple extrapolation of reduced-wattage T8 lamps in isolation). This is important because in the lighting market, particularly the non-residential sector, many different technologies "compete" for selection by the consumer at any given time. The model is also capable of accounting for significant changes in the marketplace, with the rapid growth of Light Emitting Diodes (LEDs) being the most prominent change. The dynamic cost and performance characteristics of one technology (i.e., LEDs, etc.) affect the likelihood of a consumer choosing one system over another (both in the real world and in the model). At its core, the BPA model evaluates this consumer decision making based on cost and performance specifications.

2.1 Model Structure

Sectors analyzed. The model investigates four sectors (residential, commercial, industrial, and outdoor). Reduced-wattage T8s are found almost entirely in the commercial and industrial sectors.

Lighting drivers. In each sector, the model examines four different components of the annual lighting market:

1. **New construction**: units added to the market due to new construction growth
2. **Retrofits**: installations to replace existing lamps, ballasts, or fixtures retired during renovation or remodeling
3. **Lamp replacements**: installations to replace lamps that reach their end of life
4. **Ballast replacements**: installations to replace ballasts that reach their end of life

Submarkets. Within each sector, five different submarkets, or groups of technologies suited for similar applications, are analyzed independently. Table 2 shows the specific lighting technologies that "compete" within each submarket, as analyzed in the model. Not all submarkets are assumed to be active in all sectors. For example, there is a very limited role of high intensity discharge lamps in the residential sector.

Table 2: Lamp Submarket Groupings

Submarket Group	Lighting Products in Submarket
General Service - Medium Screw Base	Incandescent, Halogen, CFL, LED
Directional	Incandescent, Halogen, CFL, LED
Linear Fluorescent	T12, T8 (32W, 28W, 25W), T5, LED
High Intensity Discharge	Mercury Vapor, High Pressure Sodium, Metal Halide, LED
Miscellaneous	Others

Note: Data from BPA 2014

2.2 Model Operation

Initial installed stock. The model is initialized with a 2010 lighting inventory (or total installed stock in 2010) in the Northwest. The Northwest stock was developed by scaling the lighting inventory developed by DOE in the 2010 U.S. Lighting Market Characterization to the Northwest region based on the ratio of floor space in the Northwest compared to the country as a whole (DOE 2010). T12 and T8 lamp quantities were modified to align with distributor sales data collected from the BPA lighting market characterization study (BPA 2014), as well as the Commercial Building Stock Assessment (CBSA) (NEEA 2009).

This installed base is then converted to *installed lumen-hours* by incorporating the average lamp wattage, efficacy, and operating hours. Lumen-hours are simply the service provided by lamps—that is, they provide lumens over time. The lumen-hour is a useful unit of analysis for the lighting market because it accommodates the longer product lifetimes and higher efficiencies entering the market due to the emergence of LEDs as well as new federal lighting standards.

Annual market. The model then generates an annual market through 2035 and predicts market share based on consumer purchasing decisions. The annual market is determined by calculating the demand in lumen-hours for each sector and submarket group. Market demand is driven by the four events listed above: new construction, retrofit, ballast replacement, and lamp replacement. To portray the new construction market, the model uses the residential and commercial sector forecast from the Sixth Northwest Conservation and Electric Power Plan (Sixth Plan) (Northwest Power and Conservation Council 2010). The building renovation or fixture replacement rate is assumed to be the average lighting turnover rate assumed in the Sixth Plan, while the lamps and ballasts are replaced based on their operating hours and rate lifetime.

Competition. The next step is to "compete"—within in each sector and each submarket—a set of technologies against one another for the available market that was generated as discussed above. In other words, the next step is estimate the market share of lamps and ballasts sales in

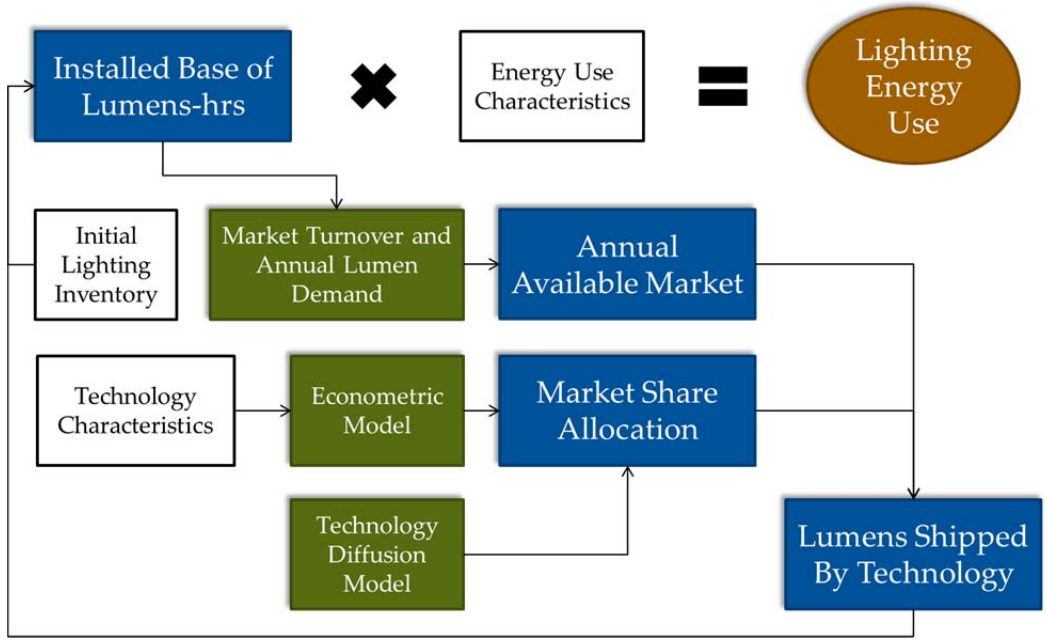
each submarket. To model the market share allocated to each technology, three different factors are considered:

- An econometrics model that accounts for different economic factors such as purchase cost and annual maintenance cost
- A technology acceptance factor that uses historical data to calibrate market share
- A technology diffusion curve to consider how prevalent a technology is in the market

The resulting market share distribution is then applied to the total available market to yield the total lumens shipped per technology.

The model recalculates the next year's installed base by applying the turnover rates. Figure 6**Error! Reference source not found.** summarizes the overall lighting model structure:

Figure 6: Lighting Model Structure



Source: BPA 2014

Scenarios. The lighting model has both a "frozen efficiency" and a "technology shift" scenario. Under the "frozen efficiency" scenario, which is more conservative in terms of market improvement, the technology market shares are essentially fixed; under the "technology shift" scenario, they can vary. Following discussions with NEEA staff, Cadeo decided to use the technology shift scenario as the baseline scenario because it represented the best estimate of the underlying dynamics in the lighting market.

Removing programmatic sales from the historical data and forecast. The only historical sales data in the region (from the BPA report) included all sales irrespective of whether they were driven by utility programs. To model the market without utility intervention, Cadeo needed

to estimate and remove from historical sales, the number of RWT8 lamps attributable to utility programs. There is no complete data on the number of RWT8 lamps that flow through utility programs; the best option was to approximate this volume based on a variety of sources.

First, the team queried a large sample (2,500+) of lighting projects conducted through BPA Option 1 programs between 2012 and 2013. Cadeo calculated the number of 32W, 28W, and 25W lamps sold during those jobs (which included many other types of lighting technologies).

This number then had to be annualized and scaled up to the region. The total energy savings from the sample of lighting jobs was 8.1 aMW. From its work with BPA, Cadeo also knew the total annual lighting energy savings generated through all regional commercial lighting programs (49.9 aMW in 2012). Using the ratio of the BPA sample savings to the total regional savings (8.1/49.9), Cadeo scaled up the total shipments of the three T8 lamp types. This method, of course, requires the assumption that the sample of BPA program data was representative with respect to technology mix of all regional commercial lighting programs in aggregate.

Table 1 shows the number of reduced-wattage lamps incentivized through utility-driven lighting projects in the Northwest in 2012. For comparison, 1.7 million reduced-wattage lamps were sold in total that year. Cadeo then shifted these lamps to the 32-watt category in the model to remove the effect of the programs:

Table 3: Lamps Sales Due to Regional Programs

Lamp Wattage	Number of Lamps
28 Watt	331,737
25 Watt	28,691
Total	360,428

2.3 Key Assumptions

Several key assumptions were made about inputs to the model to update it for NEEA's needs and to ensure that the model is using the most up-to-date data:

1) LED cost and efficacy data came from DOE's Solid State Lighting Multiyear Program Plan (DOE 2011). Lifetime projection data comes from DOE's Energy Savings Potential of Solid State Lighting in General Illumination Applications (DOE 2012).
2) The T8 lamp category in the model was disaggregated into 32 watt, 28 watt, and 25 watt lamps (shown in Table 4) based on regional distributor sales data from 2010-2012 that was collected in the aforementioned BPA Lighting Market Characterization study.
3) Prices for the T8 lamps, also shown in Table 4, are meant to reflect representative costs to the final end-users of the lamps and are based on information provided by NEEA.

Table 4: T8 Lamp Market Share and Prices

Lamp Wattage (W)	T8 Market Share (%)	Price ($)
32	82	4.11
28	14	5.77
25	4	5.70

Notes: Data from BPA 2014 and Cadeo research

4) Based on manufacturer and lighting contractor interviews, as well as other secondary research, Cadeo identified a reluctance in some portions of the market to install RWT8 lamps. One concern relates to their performance in cold environments, or near HVAC vents, where they can be susceptible to striation (due to the krypton gas), causing customer call backs. Another concern, particularly with 25W lamps, relates to their ability to perform in dimming applications. To account for these non-economic concerns and the pre-disposition most contractors have to replace lamps "like-for-like" in the maintenance market, Cadeo set the "lamp acceptance factor" at 30% for 28 watt T8s and 5% for 25 watt T8s. The lamp acceptance factor is an input that constrains the diffusion of a given technology based on non-economic factors. This acceptance factor increases by 1% per year for the 28 watt and 25 watt categories to account for the assumption that the market would naturally become more comfortable with them over time.

2.4 Baseline Forecast Results

Figure 7 and Table 5 below illustrate projected sales by count as well as by share of the T8 lamp market in the region, as forecast in the model.

Figure 7: T8 Lamp Sales

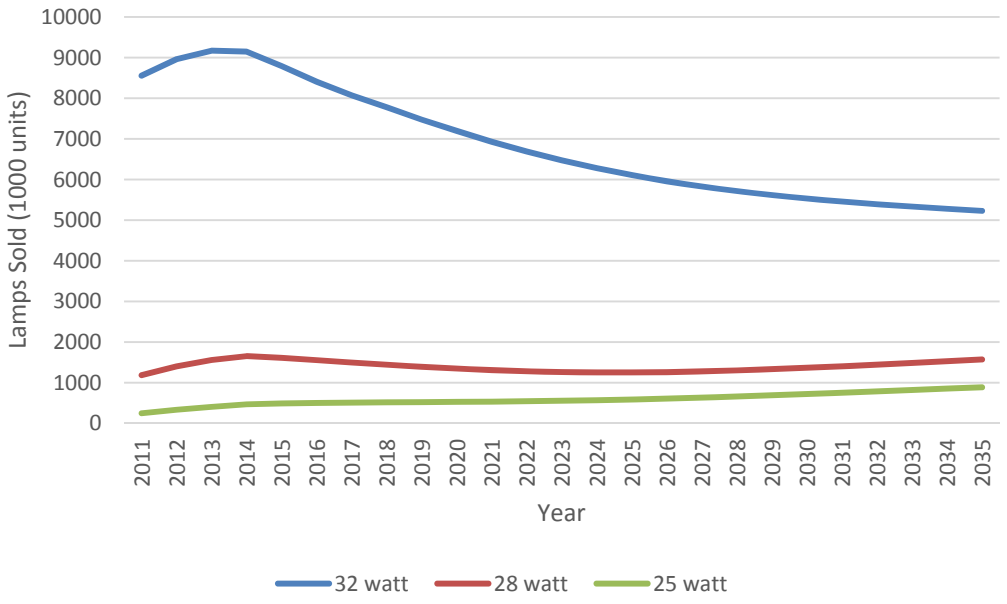


Table 5: Share of T8 Lamp Sales by Wattage

	2011	2016	2021	2026	2031	2035
32 watt	86%	80%	79%	76%	72%	68%
28 watt	12%	15%	15%	16%	18%	20%
25 watt	2%	5%	6%	8%	10%	12%

3 Additional Research Opportunities

Due to the rapid growth of LEDs and lingering uncertainty regarding the effects of DOE's federal minimum standards for general service fluorescent lamps, areas for additional research and analysis exist:

1) Currently, there is little understanding of what drives or influences the "demand-side" (e.g. building owners, maintenance firms), particularly with respect to the maintenance market and how choices on lighting systems are made. Deeper knowledge about this demand-side decision making process will assist in program design and evaluation as well as boost overall program effectiveness by allowing more targeted messaging efforts.
2) LEDs will have a significant impact on the commercial lighting market in the next five years, but the evolving marketplace remained extremely fragmented and ill-defined. A study of the LED market supply chain, which is likely significantly different than the GSFL market, would provide valuable insights into how programs and NEEA could influence this market. It would also provide insights to how NEEA and others can work to control quality issues.
3) Distributors reported that other channels including internet could account for up to ten percent of sales. The online channel was particularly strong for LEDs, and given the growth of LEDs, further investigation of the online channel could strengthen the analysis.

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