Memorandum

To:	Jessica Aiona, Bonneville Power Administration
From:	Ethan Wilkes, Kate Bushman, Fred Schaefer, and Rob Carmichael, Cadeo
Date:	May 22, 2019
Subject:	Non-Residential Lighting Model Update

BPA engaged the Cadeo team (the research team or the team) to update the Non-Residential Lighting Model (the model) used to quantify Momentum Savings for the Northwest Power and Conservation Council's (the Council's) Seventh Power Plan action plan period (2016-2021). This update focused on integrating newly available data sources to calculate actual Pacific Northwest non-residential lighting savings in the first two years of the 7th Power Plan action plan period (2016 and 2017) and update the forecast for the rest of the action plan period based on the new data sources. In this memorandum, the team details the updates to model input data sources and development methodology, as well as model changes needed to accommodate the updated model inputs.

The memo is organized in the following sections:

- Summary of Model Input Updates
    - Program Savings
    - Sales Mix
    - Building Stock
    - Technical and Financial Parameters
    - Indoor Agriculture Adjustment
- Recommendations for Future Updates to Model
    - Theoretical Changes
    - Structural Changes
    - Data Changes

The *Summary of Model Input Updates* section highlights data input development. This section focuses on differences between the existing and updated model inputs and documents the market intelligence the team used to guide assumptions and methodological decisions, as well as mechanical model changes required to accommodate the new data.

The *Recommendations for Future Updates to Model* section discusses model improvements the team recommends BPA consider in future updates. The team makes these recommendations to ensure the model remains consistent with the changing lighting market and able to accommodate new data sources.

Supplementary data input documentation includes two input documentation workbooks.[1] Please see these workbooks for calculation detail.

Summary of Model Input Updates

The team updated several model inputs for which new data were available. Before the update, the model included actual data for the 6th Plan Period, along with forecasts from 2016 through 2020. The team added additional data to replace the 2016 and 2017 forecasts with actual data and update forecasts from 2018-2021 to reflect improved market intelligence. Data updates included program savings, sales mix, building stock, retrofit rates, retail rates, and technical specifications. The summaries in this section describe data sources and any calculations the team applied.

Program Savings

The team added actual 2016 and 2017 program savings to the model using data sources and methods consistent with past modeling efforts. Table 1, below, lists the program savings data sources with a brief description of each.

Table 1: Program Savings Data Sources

Data Source Name	Description
BPA Lighting Calculator Summary	This data source includes detailed internal BPA project-level lighting program savings. These data informed program technology mixes and program savings splits across different model dimensions.[2]
BPA BOOM Data	These data are less detailed (but more comprehensive) internal BPA project-level program savings. This report includes lighting calculator projects as well as custom projects that are unavailable in the lighting calculator summary.
Regional Conservation Progress (RCP) Report	The RCP contains aggregated Pacific Northwest program savings data. The Regional Technical Forum (RTF) publishes the RCP annually as a comprehensive account of all regional energy-efficiency program savings. This report includes BPA, NEEA, and investor-owned utility (IOU) program savings. The team used it to derive IOU program savings and remove program savings associated with lighting controls.
Northwest Energy Efficiency Alliance (NEEA) Data	NEEA provided internal 25W, 28W, and 32W T8 lamp counts from their Reduced Wattage Lamp Replacement initiative, as well as savings attributable to lighting code changes from their Commercial Code Enhancement initiative.

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[1] The first model input workbook, *TO14.002A Model inputs database and data descriptions_Part 1_2019-03-01* details updates to the market sales mix and program savings model inputs. *TO14.002A_Model Inputs Part_2 and TO14.002F Updated Tech Specs_2019-03-01* contains all other model inputs.

[2] Model requires program savings to be allocated to new or existing construction, sectors, and applications.

To begin updating the program savings inputs, the team added 2016 and 2017 annual program savings from BPA, NEEA, and non-BPA utilities. BPA BOOM data supplied annual BPA program savings. NEEA provided data on their Reduced Wattage Lamp Replacement (RWLR) initiative and non-residential lighting code savings. The team derived non-BPA utility savings by subtracting BPA savings and NEEA RWLR initiative savings from the RCP non-residential lighting program savings. For future years (2018–2021), the team assumed that savings would remain flat at the level reported in 2017.[3] The team added NEEA Code Enhancement savings estimates from 2016–2021 as a separate line item in the model. Code savings were not included as program savings in the previous model. The team discusses code savings in more detail below.

Next, the team updated inputs that the model uses to adjust program savings. There are three adjustments in the model: removing lighting controls savings, allocating program savings to more granular segments, and adjusting program baselines by comparing the model and program technology mixes.

The model removes lighting controls savings directly by applying a percentage adjustment to the overall program savings. Lighting controls are omitted in program savings because the model does not currently account for controls in its Momentum Savings estimates.[4] The team updated the methodology for finding the percentage of program savings attributable to controls. Previously, 7.5% of reported program savings were allocated to controls based on an internal communication with a subject matter expert from Energy Trust. The team updated the lighting control adjustment to reflect a more replicable and data-driven approach. The new adjustment is based on the percentage of non-residential lighting program savings in the Lighting Controls category in the RCP. Compared with the previous 7.5% assumption, the new approach results in a lower reduction in program savings due to controls—between 1% and 2% for 2016 and 2017. As the lighting market shifts towards LEDs, the lower controls adjustment appears reasonable. Controls save energy by reducing the amount of time lighting fixtures consume energy. As lighting technology gets more efficient, the same amount of time savings results in less energy savings.

The team used the lighting calculator to divide the program savings into new and existing construction, sectors, and applications. These splits are important because they inform the program savings baseline adjustments. New construction savings, as well as the *general purpose* and *ambient linear* application savings, use the same baseline as the model (i.e., a current practice baseline) and are not adjusted, but the remaining savings receive adjustments that vary by sector and application.[5] The team mapped lighting calculator information to model sectors and applications and used reported kWh savings to derive a sector-application mix. The model applies the mix to both the BPA and non-BPA savings from IOUs. The assumption that the BPA savings are similar to the non-BPA savings in terms of sector and application mix represents a significant model assumption. Because more descriptive information is unavailable for the non-BPA IOU savings, the lighting calculator provides the most reasonable allocations available.

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[3] This assumption may be conservative, since some programs expect declining savings over the next few years due to decreasing incentive amounts. However, future program years' data will be added to the model when they become available.

[4] The *Lighting Controls* section of this memo addresses the addition of control savings.

[5] The model uses the Council's Seventh Power Plan, or current practice, baseline.

Double Counting

Due to overlaps in each data source's reported savings and differences between program assumptions and the model's assumptions, the team took steps to ensure no savings were "double counted."

Latency in BPA Utility Savings Reporting

BPA customer utilities do not have a hard deadline to report to BPA; therefore, there may be late-reported savings missing from the BPA savings included in the RCP when the RCP is finalized. To ensure the most accurate available information is included in the model, the team used the most recent BPA BOOM report to calculate BPA savings, and a previous version of the report (that represents information known at the time the RCP was constructed) to subtract savings from the RCP and calculate non-BPA (IOU) savings. This accounting subtlety has a small impact on overall program savings.

NEEA-Reported Code Savings

The team updated the model to accommodate NEEA code savings to prevent double counting. Lighting codes influence the model's estimated market savings by impacting the sales mix. If the team did not subtract code savings from the total market savings, the model's Momentum Savings estimate would include code impacts on efficiency. NEEA claims code savings in the RCP. Therefore, failing to deduct code savings would result in reporting code savings twice, once by NEEA and once as Momentum Savings. To prevent this, the team deducted NEEA's reported code savings for non-residential lighting from the total market savings. Code savings are not allocated to specific applications in the same manner as other program savings. The team subtracted code savings as a separate line item due to uncertainty in the sector-application mix of code impacts.

Baseline Alignment

To prevent overcounting program savings, the team applied a baseline adjustment to program savings.[6] Many programs report savings based on an existing condition baseline (i.e., savings are determined based on the difference between what is being installed and the existing equipment). The model reports savings based on a current practice baseline (i.e. savings are determined based on the difference between what is being installed and what would have been installed, on average, in the baseline year). Because the model's baseline is generally more efficient than the program baseline, the program savings as-reported are misaligned with the model's methodology. To correct for this misalignment, the model uses the relative wattages of the program and model baselines to "true up" the program savings with the model, ensuring consistency between the program savings and model baseline. There is an example below for clarity.

Table 2 illustrates the baseline adjustment applied to the *parking lot* application in 2017. The program wattages are based on the lighting calculator technology mixes, while the model wattage is based on the modeled frozen baseline scenario technology mix. The pre-adjustment program savings are based on program savings inputs.

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[6] The team did not apply a baseline adjustment to new construction savings, or existing construction savings in the *general purpose* or *ambient linear* applications.

Table 2: 2017 Parking Lot Application Baseline Adjustment

Program Efficient Wattage	Program Baseline Wattage	Model Baseline Wattage	Baseline Adjustment	Pre-Adjustment Program Savings	Post-Adjustment Program Savings
80.9W	406.3W	245.9W	50.7%	1.54aMW	0.78aMW

$$\text{Baseline Adjustment} = \frac{\text{Model Baseline Wattage} - \text{Program Efficient Wattage}}{\text{Program Baseline Wattage} - \text{Program Efficient Wattage}} = \frac{245.9W - 80.9W}{406.3W - 80.9W} = 50.7\%$$

$$\text{Post-Adj. Program Savings} = \text{Baseline Adj.} \times \text{Pre-Adj. Program Savings} = 50.7\% \times 1.54aMW = 0.78aMW$$

Program Savings Sources of Uncertainty

The largest source of uncertainty in the program data is the allocation of non-BPA IOU program savings to applications, sectors and technologies. Because the non-BPA IOU program savings lack granularity to segment along those dimensions, the team used the BPA lighting calculator data to derive sector, application, and technology mixes, and assumed the non-BPA IOU program savings were similar to BPA lighting calculator savings. This assumption has a direct impact on the baseline adjustment applied to program savings. The team validated the assumption by conducting research on IOU program activity.[7] This assumption is unchanged from previous model iterations.

A lack of information on each program's baseline methodology also results in some uncertainty. In the model, the team assumed that *general purpose* and *ambient linear* applications are calculated against a current practice baseline and programs within other application are calculated against an existing condition baseline. The team ultimately applied assumptions that were consistent with the expert judgement of regional program subject matter experts. This assumption is unchanged from previous model iterations.

Sales Mix

The team updated sales mix model inputs with sales data developed as a work product BPA's annual lighting distributor sales data collection (Task Order 11). Under that effort, the team collected new sales data from 22 regional electrical distributors, which improved sales estimates for 2015 and 2016 as well as providing new estimates for 2017. (This dataset also included the results of the previous year's data collection effort, Task Order 46, which collected new data for 2016.) The team documented the sales data analysis and quality control processes in detail in the TO11 report and summary spreadsheet.

To align the Task Order 11 sales data with the sales mix model inputs, the team mapped sales data categories from the data collection effort (e.g. *25W T8 – High Performance 800 Series or Better*) to modeled technologies (e.g. *25W T8*) and calculated a market-wide sales mix, by technology.

The model determines the sales application mix using data from the Department of Energy (DOE) 2010 lighting market model and the 2014 Commercial Building Stock Assessment (CBSA) data. Due to a lack of LED luminaire information contained in those sources, the team derived the LED luminaire application mix

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[7] The team's research findings when validating the assumption that regional program savings are similar to BPA program savings resulted in the implementation of an indoor agriculture adjustment, discussed further in the *Indoor Agriculture Adjustment* section.

using the TO11 sales data. To calculate the LED luminaire application mix, the team mapped LED luminaire sales mix categories to model applications and calculated a percent application mix within the LED luminaire technology. The *TO14.002A Model inputs database and data descriptions_Part 1_2019-03-01* model input workbook, tab *LED Luminaire Mapping*¸ contains the sales mix category to application mappings and the results of the analysis.

Sales Mix Sources of Uncertainty

There is relatively little uncertainty in the sales mix update methodology, although the mappings from the sales mix categories to model input technologies are one source of potential uncertainty. The team mitigated this uncertainty by ensuring the mappings reflect the model definitions and sales mix variables as closely as possible. There is additional uncertainty in the sales data itself: it reflects only a subset of sales occurring in the region and includes some extrapolation and interpolation. The TO11 report describes these uncertainties in more detail.

Building Stock

Building stock updates included two model inputs: Industrial Building Stock and Agricultural stock. The team did not update *commercial* or *street and roadway* building stock model inputs because no new data sources were available.

Industrial Building Stock

The team updated industrial building stock using new data from the 2014 US Energy Information Administration (EIA) manufacturing energy consumption survey (MECS) and 2013–2015 manufacturing employment from the US Census.[8] The EIA last published the MECS in 2010, so the team updated the industrial floorspace estimates back to 2011 – impacting a portion of the 6th Plan Period (2011-2015) as well as the first two years of the 7th Plan action plan period (2016 and 2017). It was important to incorporate the most accurate information back to 2011 to ensure that the model characterized the 7th Plan baseline year (2015) as accurately as possible. The team calculated industrial building stock by multiplying the total amount of national manufacturing floorspace in the US from the EIA MECS report by the percentage of US manufacturing employees in the Pacific Northwest from the Census. The team used the percentage of US manufacturing *employees* in the Pacific Northwest as a proxy for the percentage of *floorspace* in the Pacific Northwest because region-specific floorspace estimates were not available. The team also used the new data to update industrial building stock projections through 2035. The calculation methodology is consistent with previous model updates—the addition of the new, more recent data was the only update.

Agricultural Building Stock

The model uses an agricultural scaling factor to scale the industrial building stock to account for agricultural building stock.[9] The team applied a calculation methodology consistent with past model iterations but used new lighting calculator data from 2016 and 2017 to adjust the calculation in the 7th Plan baseline and plan years. The relative lighting calculator savings in the industrial sector and agriculture

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[8] The US Census tracks establishments across years in the 1989-2015 business information tracking series.

[9] The agricultural scaling factor does not include indoor agriculture, which the model accounts for later, as described below.

sector are used as a proxy for relative floor space. The updated agricultural scaling factor is based on data from 2015-2017 and applied from 2015 on. The team decided to adjust the agricultural scaling factor because it is unlikely to change drastically from year-to-year and the previous scaling factor was based on a single year of data. The team added additional years to increase the number of observations and precision of the value, not reflect a change in the value.

Building Stock Sources of Uncertainty

The team used the best available data when calculating industrial building stock model inputs. Despite some uncertainty introduced by two primary assumptions, the impact of small estimation errors is unlikely to materially impact Momentum Savings due to the relatively small size of the industrial application.

The largest assumption embedded in the calculation methodology is the assumption that the Pacific Northwest's share of national manufacturing *employment* is a good proxy for the share of national industrial *building stock*. This assumption reflects the scarcity of Pacific Northwest industrial building stock data. The other assumption that has an impact on future industrial building stock is the usage of recent trends to linearly project industrial building stock into the future. This projection methodology is the best available low-cost method to estimate future industrial building stock. This assumption is unchanged from previous model iterations.

Inaccuracies in agricultural building stock are unlikely to have a meaningful impact on Momentum Savings because agricultural building stock is relatively small. Using the ratio of program savings in the industrial sector and agriculture sector is an imperfect method of estimating the ratio of industrial and agricultural building stock. To mitigate some of the uncertainty around this assumption, the team added program data from additional years to ensure variation in program savings would not result in inaccuracies. The methodology for this calculation was unchanged from previous models.

Technical and Financial Parameters

Retrofit Rates

Using data from the Council's Sixth and Seventh Power Plans, as well as 2015 fixture stocks from the model, the team developed building-type level fixture retrofit rates for the Seventh Power Plan action plan period. Model retrofit rates represent the percentage of non-LED fixtures that are replaced each year and vary by building type. Previously, the model used Sixth Power Plan retrofit rates as-is because the Plan reported retrofit rates at the building-type level. The Seventh Power Plan deviated from the building-type level retrofit rate reporting and reported aggregated fixture retrofit rates for all interior lighting. To convert the market-level Seventh Plan fixture retrofit rate to building-type fixture retrofit rates, the team used the overall magnitude of the Seventh Plan Rate, and the "shape" of the Sixth Plan retrofit rates (i.e. the relative building-type level retrofit rates). Because LED technology is exempt from turnover, the team adjusted the resulting retrofit rates to account for the prevalence of LEDs in each building type.[10]

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[10] The LED turnover exemption is an assumption that is currently supported by market actor interviews and is discussed in the *LED to LED Conversions* section.

The example below illustrates the team's methodology. This example shows the calculation of the Seventh Plan Hospital non-LED Fixture Retrofit Rate. The numbers are rounded for simplicity.[11] Variables are coded as such: blue denotes a Seventh Plan value, green denotes a Sixth Plan value, red denotes a modeled value, yellow denotes a model assumption, and dark grey shows a calculated value. Calculating the **Seventh Plan non-LED hospital turnover rate** is the goal of the calculations in this example and is shown in dark grey, bold type.

Knowns:

Seventh Plan Fixture Retrofit Rate for All Building Types ($\text{Turnover Rate}_{\text{7th Overall}}$): 6%
Sixth Plan Fixture Retrofit Rate for All Building Types ($\text{Turnover Rate}_{\text{6th Overall}}$): 8%
Sixth Plan Fixture Retrofit Rate for Hospitals ($\text{Turnover Rate}_{\text{6th Hospital}}$): 7%
LED Penetration in 2015 Hospitals ($\text{Saturation}_{\text{LED Hospital}}$): 10%
Non-LED Penetration in 2015 Hospitals ($\text{Saturation}_{\text{non-LED Hospital}}$): 90%
LED Turnover Rate ($\text{Turnover Rate}_{\text{LED Overall}}$): 0%

Unknowns:

Hospital Turnover Rate Including All Technologies ($\text{Turnover Rate}_{\text{7th Hospital}}$)

Objective:

Non-LED Hospital Turnover Rate (**$\text{Turnover Rate}_{\text{7th Hospital non-LED}}$**)

Calculations:

Step 1: Calculate the Seventh Plan Turnover Rate Including All Technologies ($\text{Turnover Rate}_{\text{7th Hospital}}$)

$$\text{Turnover Rate}_{\text{7th Hospital}} = \text{Turnover Rate}_{\text{6th Hospital}} \times \frac{\text{Turnover Rate 7th Overall}}{\text{Turnover Rate 6th Overall}} = 7\% \times \frac{6\%}{8\%} = 5.25\%$$

Step 2: Calculate the non-LED Seventh Plan Turnover Rate (**$\text{Turnover Rate}_{\text{7th Hospital non-LED}}$**)

$$\text{Turnover Rate}_{\text{7th Hospital}} = (\textbf{Turnover Rate}_{\textbf{7th Hospital non-LED}} \times \text{Saturation}_{\text{non-LED Hospital}}) + (\text{Turnover Rate}_{\text{LED Overall}} \times \text{Saturation}_{\text{LED Hospital}})$$

$$\textbf{Turnover Rate}_{\textbf{7th Hosp non-LED}} = \frac{\text{Turnover Rate 7th Hosp.} - (\text{Turnover Rate LED Overall} \times \text{Saturation LED Hosp.})}{\text{Saturation non} - \text{LED Hosp.}}$$

$$\textbf{Turnover Rate}_{\textbf{7th Hosp non-LED}} = \frac{5.25\% - (0\% \times 10\%)}{90\%} = \textbf{5.8\%}$$

The team weighed several options before deciding this methodology was most appropriate to preserve the building-level data while incorporating the newer retrofit rate data from the Seventh Power Plan.

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[11] For complete documentation on the retrofit rate calculation methodology, refer to *TO14.002A_Model Inputs Part_2_and TO14.002F Updated Tech Specs_2019-03-01,* Sheet: *Turnover Rates.*

Although this approach is more complex than other methodologies, it has a few strengths: it retains the market intelligence embedded in the Sixth Plan building type level rates, preserves the assumption that LEDs do not turn over, integrates the overall rates from the Seventh Plan, and there is sufficient data to perform the calculations.

Retail Rates

The team calculated electricity prices using the Seventh Power Plan 2009 to 2035 retail price forecast. To aggregate the Seventh Power Plan state-level retail rates, the team weighted the rates by state-level commercial building stock. The weight calculation only includes 57% of the Montana building stock (the percentage in Western Montana). The Seventh Power Plan prices are provided in $/MMBtu units, which the team converted to $/kWh to be compatible with the model. Projections beyond 2035 are based on the Seventh Power Plan growth rate from 2032–2035.

Technical Specifications

The previous approach to updating model technical specifications, such as wattage, efficacy, price, and lifetime operating hours relied on data from the Department of Energy (DOE) Solid State Lighting (SSL) Report.[12] DOE has not yet issued an updated SSL report at the time of this model update. Therefore, the team developed an alternative approach: the team leveraged its own database of technical data collected via web scraping. Strengths and weaknesses of the scraped data are shown in Table 3 below.

Table 3: Scraped Technical Specification Data Characterization

Strength	Weakness	Weakness Mitigation
Includes data from four lighting equipment distributors and three lighting equipment manufacturers.	The team attempted to collect data from a broader set of manufacturers and distributors, but some websites had limited information, making it impossible to collect the necessary data for additional companies beyond the seven the team successfully scraped.	The manufacturers and distributors included in the data are large and assumed to be representative of total market sales, although no quantitative validation could be done on this assumption.
The team matched scraped lamp information to sales data categories so sales data could be used to weight sales category-level average wattages.	Within sales categories, there is still some variation in lamp wattages. The team used a simple average within sales categories because more granular sales data was unavailable.	The team quality checked the category averages by comparing the calculations to individual observations and online product offerings. The team omitted outliers and non-representative products.

Bonneville and the research team agreed to limit the scope of the update to technical specifications that were both likely to impact Momentum Savings results and likely to have changed since the previous

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[12] Wattage, efficacy, and price information is not available from the sales data collection performed in Task Order 11. In the first model update, the 2014 CBSA provided other technical specifications, like ballasts and lamps per fixture.

iteration of the model. A sensitivity analysis revealed that LED wattage estimates (specified at the application-technology-sector-year level) were the only technical specifications that met those criteria.

LED products used for similar applications can still have substantial variability in wattage. The team broke down application-technology pairs into more granular segments to increase the calculation accuracy. The sales-mix-to-technology and sales-mix-to-application mappings developed earlier in the project were used to produce the more granular sales categories.[13] The team used the remaining variability in category-level wattages, due to variability in the internal database, to develop ranges of expected wattages for each application and technology.

The team compared the range of possible wattage values for each application and technology to the existing values in the model. There were three possible outcomes of the comparison, and the team took the following approach in each:

- The existing model wattage fell **within the range calculated** using the database. In those cases, the wattage was not updated.
- The existing model wattage was **greater than the calculated range**. In those cases, the wattage was reduced to the average wattage from the database.
- The existing model wattage was **less than the calculated range**. In those cases, the team held the wattage constant at the 2015 wattage level. The 2015 wattage represents the last known wattage. In the previous model update, a downward trend on LED wattage was applied. The update methodology the team applied acknowledges that the database does not support the previously assumed downward trend in wattage for some applications and technologies, while maintaining information from the last DOE SSL report.

In all the above scenarios, the team used the 2018 wattage level to project future years.

The results of this analysis, documented in the *TO14.002A_Model Inputs Part_2_and TO14.002F Updated Tech Specs_2019-03-01* workbook, resulted in a more conservative estimate of continued efficacy gains in LED technology, as compared to the previous model iteration. The team also determined that this change aligned with BPA's market intelligence on the lighting market. Market actors stated in recent interviews and at LightFair that LED technology was unlikely to get significantly more efficacious because it is no longer cost effective to make incremental improvements.

Busbar Factor

The team updated the busbar factor to convert site-level consumption to busbar-level consumption. BPA provided a system busbar factor, 1.0749, that the team entered directly into the model, beginning in 2016. The system busbar factor represents a weighted average busbar factor across all measures and end uses.

Technical and Financial Parameters Sources of Uncertainty

The team chose the retrofit rate development strategy that best reduced uncertainty in the presence of imperfect data. The team made a few assumptions when developing this methodology and reviewed each in detail. The first assumption is that each building type retained its level of fixture turnover relative to

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[13] The team developed the mappings when calculating the market sales mix.

other building types. The team determined the assumption that building type level non-LED lighting renovations would remain consistent over time is reasonable. Turnover occurs in different building types for different reasons – for example, in retail stores and restaurants turnover could occur to update the aesthetics, while in warehouses or industrial facilities turnover is more likely to occur as needed to reduce costs or due to fixture failure. The second assumption is that LED fixtures are exempt from fixture turnover. Market actor interviews informed this assumption – market actors stated that LED to LED fixture updates remain rare. Additionally, retrofitted LEDs are subject to the sales mix for the application in which they are installed (i.e. LEDs can be replaced with other technologies), which can lead to unlikely fixture downgrades. This is an opportunity for future model development—the *Recommendations for Future Updates* to Model section of this memo discusses updates to LED retrofit rates.

The impact of retail rates on Momentum Savings and uncertainty in retail rate calculations are minimal. There were two assumptions the team reviewed in the process of converting the Seventh Power Plan retail rates into useable model inputs. The team persisted an assumption that outdoor retail rates are similar to commercial retail rates—an assumption developed in a previous model. Commercial building stock was chosen as a proxy for state-wide commercial energy consumption when weighting the state-level retail rates. Both assumptions introduce minimal risk on Momentum Savings estimates.

As discussed above, the team mitigated uncertainty in technical specification updates by prioritizing important technical specifications, incorporating data variability into the update analysis, and utilizing market actor interviews to inform data trends. Despite this conservative approach, uncertainty remains in the estimates and the team will re-evaluate technical specifications when the next DOE SSL report is released.

Indoor Agriculture Adjustment

While conducting a program data analysis to validate model assumptions, the team identified indoor agriculture, driven by the recent legalization of recreational cannabis in Oregon and Washington, as a recent contributor to non-BPA program savings that was not captured in the model.[14] BPA and its public utility customers cannot provide incentives for cannabis efficiency improvements due to federal regulations. However, IOUs have invested incentive funding in lighting upgrades in cannabis facilities, resulting in substantial savings. To maintain comparability between total market savings and total program savings, and therefore maintain analytical accuracy, the team decided to add indoor agriculture load to the model. Using data from the Council, described below, the team developed an adjustment to industrial consumption that reflects the size of the Northwest indoor agriculture industry and updated model mechanics to accommodate the adjustment. The team validated assumptions using data from the Cannabis Business Times *State of the Market Lighting Report*.[15]

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[14] The team examined industrial building stock, hours of use, and technical specification input development methodologies to confirm indoor agriculture was not already being accounted for.

[15] The model adjustment calculation is included in *TO14.002A_Model Inputs Part_2_and TO14.002F Updated Tech Specs_2019-03-01,* Sheet: *Indoor Agriculture Adjustment*. The assumption validation is in the next sheet of the same workbook, *Indoor Ag. Assumption Evidence*, and sources for these calculations are in the *Ref - Indoor Ag. Sources*.

Ideally, the model would account for indoor agriculture through the development of a new application versus an adjustment to the existing applications.[16] However, due to current data and modeling limitations, it was not possible to develop a new indoor agriculture application in this model update. Instead the team developed an approach based on the best available data and assumptions, informed by industry market intelligence.

A 2017 Council study produced regional estimates of annual cannabis lighting load. The team used the ratio of the Council-estimated lighting cannabis load and overall actual industrial lighting consumption to calculate a percentage adjustment to total market consumption.[17] Actual lighting consumption was used in the calculation (rather than baseline lighting consumption) because, as of 2017, cannabis load is consistent with the forecast the Council originally made in 2015. The team applied this adjustment to both actual and baseline industrial energy consumption.

The most material assumption embedded in this methodology is that the indoor agriculture industry is becoming more efficient at a similar rate to the industrial sector. The team compared the change in wattage of the indoor agriculture technology mix from 2016 to 2017 (4.7% efficiency improvement) to the change in overall industrial wattage over the same time (4.9% efficiency improvement) to validate that assumption. The Cannabis Business Times *State of the Market Lighting Report* includes a technology mix and hours of use of the industry's lighting in 2016 and 2017. The Council report includes average wattage estimates of the equipment in the technology mix. The team derived the overall market wattage for the indoor agriculture industry by weighting each technology's wattage by the technology mix of cannabis industry lighting. Based on the results of that analysis, it appears that between 2016 and 2017 cannabis lighting became 4.7% more efficient. The output from the model indicates that in that same time period, industrial lighting became 4.9% more efficient. The similarity between the efficiency improvements provides evidence that the industrial sector and indoor agriculture industry are experiencing similar efficiency gains over time.

Indoor Agriculture Sources of Uncertainty

Due to limited data availability and the recent boom in cannabis cultivation, the indoor agriculture industry is a large source of uncertainty in the model. The adjustment is a simple, imperfect solution based on the best available information. The team validated the assumption that the indoor agriculture industry is changing at a similar pace as the industrial industry using recent research done by indoor agriculture experts; however, the technology mix data is not specific to the Pacific Northwest and is only available for 2015 and 2016.[18] The Council's projections of indoor agriculture consumption are also uncertain, which contributes to model uncertainty in upcoming years. The indoor agriculture assumption has a moderate impact on the model, resulting in between 70 and 80 aMW per year of energy consumption in the market scenario, with higher consumption in future plan years. Future updates could improve estimates of indoor agriculture and will be discussed further in the next section.

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[16] This option will be discussed further in the *Updating Application* section that details future update recommendations.

[17] The model estimates actual industrial consumption before the adjustment is applied.

[18] In 2016, Cannabis Business Times sampled 117 facilities, 42% of which were in the West/Pacific (Alaska, California, Hawaii, Oregon, or Washington). In 2017, they sampled 294 respondents, 46% of which were in the same region.

Recommendations for Future Updates to Model

During the process of updating the model, the team identified areas of improvement that should serve as the focal point of future model updates. The team's recommendations are split into three sections.

- **Theoretical Changes:** Changes to the model that require a fundamental change in model structure. Changes that fall into this category are necessitated by the changing lighting market.

- **Structural Changes:** Changes to the model that require updating model infrastructure but are not as sweeping or impactful as theoretical changes. Changes that fall into this category are recommended to increase model functionality or expand definitions to improve results.

- **Data Changes:** Changes to the model that are purely data updates. This section highlights important updates that will improve market intelligence and reduce model uncertainty.

Theoretical Changes

This section describes two potential model update recommendations that reflect recent changes in the lighting market – the increasing popularity of Full-Space Lighting Redesigns and the growing market for Lighting Controls.

Full-Space Lighting Redesigns

As LEDs penetrate the lighting market, full lighting redesigns are becoming more prevalent. Market actors stated that lighting redesigns are often based on replacing existing fixtures with an equivalent number of foot-candles (i.e. lumens per square foot) – rather than replacing fixtures with the same number of fixtures with similar lumen outputs. Based on market intelligence gathered in the model update process, the team suggests updating the model to turn over floorspace, rather than replacing fixtures on a 1-to-1 basis. The implementation of this strategy would require additional data and an update to model turnover mechanics.

Currently, the *fixtures per square foot* variable in the model varies by building type. The team can leverage the 2014 and upcoming 2019 commercial building stock assessments (CBSAs) to develop time and technology dimensions, in addition to the building type dimension, for this variable. Different technologies provide different foot-candles because of varying lumen output and directionality; therefore, new installations have different fixture densities. This trend is becoming more popular as LEDs gain market share, making time an important dimension to reflect changes in replacement practice. These added dimensions would allow the model to convert fixture retirements to the amount of floorspace that needs new lighting and fill that floorspace with new fixtures.

The model structure updates would include altering the sales mix to a per-ft basis, rather than a per-lamp basis (e.g. 50% of floorspace is lit by LEDs, rather than 50% of fixtures are LEDs). The team would need to add a couple additional steps in the turnover logic as well—an intermediate step where retiring fixtures are converted to floorspace and another step in which the space is filled with new fixtures.

Lighting Controls

Market actor interviews indicate that lighting controls are increasing in popularity. As long-living LEDs gain market share, manufacturers have recently focused on developing lighting control technology to

combat declining fixture and lamp sales. There is a substantial amount of data collection and mechanical model changes that need to be implemented to accommodate controls in the model.

The team has collected seven years of lighting control sales data in the annual data collection process. However, the sales data is lacking detail and will need to be supplemented with assumptions about how controls products are being installed in the field. Lighting control stock data that can inform application mapping is one area of uncertainty. Future stock assessments would likely inform the saturation of controls, by modeled applications and sufficient data is unlikely to be available until the next CBSA is completed. The team needs to research and develop lighting control technical specifications, such as the percentage of daily operating hours saved and equipment lifetimes.

Mechanical model changes are required to accommodate lighting controls. Lighting controls are different from other lighting technologies—they supplement other lighting equipment, rather than replace it. After stock accounting logic is developed, the impacts on other lighting equipment lifetimes and consumption must be derived and accounted for appropriately in the savings calculations.

Structural Changes

This section describes two potential model update recommendations that require updates to model definitions.

LED to LED Conversions

The team identified LED to LED conversions as an upcoming issue to be resolved in the model. Market actor interviews indicate that LED to LED conversions remain rare; however, as LEDs continue to age, LED fixtures will undoubtedly retire. Currently, the model permits LED lamps to burnout as they reach the end of their expected lifetime but prohibits LED fixtures from being replaced.[19] As LEDs continue to age, this assumption will lose validity. The team suggests allowing LED fixture turnover but requiring LEDs to be replaced with other LED technology.

Updating Application Definitions

As the lighting market has evolved, the model's defined applications need to be reviewed. The team recommends reviewing application definitions particularly for applications that include a wide range of products, technologies, wattages, and form factors. With the mainstream adoption of LED lighting, these applications may no longer have an adequate level of endogenous uniformity. Specifically, the team recommends reviewing and potentially updating the application definitions for: building exterior high/low and ambient linear. This review should entail comparing technologies and tech specifications for each application against up-to-date stock data (i.e., the forthcoming CBSA) to determine whether current definitions accurately reflect stock trends.

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[19] Lamp lifetimes are modelled using technology-application-level Weibull distributions.

Additionally, the team recommends adding an indoor agriculture application to the model to more accurately represent lighting load in the Pacific Northwest.[20] Cannabis lighting energy consumption has exploded along with the recreational cannabis industry in Oregon and Washington.[21] Some investor-owned utilities have claimed and reported energy efficiency savings from lighting conversions in the industry. Failing to model indoor agriculture and including program savings from regional IOUs would result in undercounting Momentum Savings. Indoor agriculture requires high-output lamps and many hours of use, making conversion projects especially successful. The implementation of an indoor agriculture application will require a non-trivial research effort. The upcoming CBSA and Outdoor Lighting Stock Assessment (OLSA) studies, the Council report on cannabis energy consumption, and industry-specific data sources will likely be required to facilitate the change.

Data Changes

This section briefly describes two potential model update recommendations that require updates to data collection methodology.

Retrofit Rates

The team recommends updating retrofit rates to incorporate economic indices. Currently, retrofit rates vary by plan period, but not year. Based on market intelligence the team gathered during the project, retrofit rates likely fluctuate based on economic conditions. The team recommends using the American Institute of Architects architecture billings index and NEMA lamp indices to develop annual retrofit rates.[22]

Exterior Applications

Due to relatively high uncertainty in exterior applications, the team recommends utilizing the upcoming CBSA and OLSA stock assessment studies to improve exterior application assumptions. Additional data informing the fixtures per interior square foot and technology mix assumptions will improve the model's characterization of the size and composition of these applications.[23]

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[20] The team applied an indoor agriculture adjustment in this iteration of the model, discussed in detail in the *Indoor Agriculture Adjustment* section of this memo.

[21] Recreational cannabis was legalized in Washington in 2012 and Oregon in 2014.

[22] The architecture billings index is an economic indicator for nonresidential construction activity published by the American Institute of Architects. The National Electrical Manufacturers Association publishes lamp indices that measure national shipments of a variety of lamp types.

[23] Exterior applications include the *parking lot, building exterior high, building exterior low, street and roadway high* and *street and roadway low* applications.