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2022 Review of Key Assumptions for Luminaire Level Lighting Controls

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Introduction

The Northwest Energy Efficiency Alliance (NEEA) contracted with Cadmus to review its approach to estimating potential energy savings from the Luminaire Level Lighting Controls (LLLC) program. Cadmus addressed three key research questions in its review:

1. Is NEEA's approach to estimating the control savings fraction (CSF) and hours of use (HOU) for commercial LLLC sales reasonable?

    Context: The LLLC sales data that NEEA currently has access to lacks the information on building types where fixtures are installed, so NEEA assumes the LLLC fixtures sold in the Northwest are installed in either Office or Warehouse building types and applies the CSF and the HOU assumptions in the Regional Technical Forum (RTF)'s Non-Residential Lighting Standard Protocols.

2. How can NEEA reconcile the changes in its assumptions used to estimate lighting power between those used in its early savings forecasts with those used for reporting savings now?

    Context: When the program began in 2015, LLLC sales data were not available and the lighting market was rapidly shifting to LEDs. NEEA forecasted savings using available information, which included Washington State Energy Code's (WSEC) lighting power density (LPD) allowance, floor area, and HOU. Now that NEEA has LLLC sales data and actual fixture wattage, it can report savings based on this information.

3. Is NEEA's approach to estimating the number of LLLC fixtures being sold in the Northwest region (including in Idaho, Montana, Oregon, and Washington) reasonable, given that NEEA's assumptions draw from a dataset that represents less than 50% of the market?

    Context: NEEA currently collects LLLC sales data from seven LLLC manufacturers, which are then used to estimate savings.

NEEA provided Cadmus with two materials: (1) a PowerPoint presentation documenting the current savings approach with links to the RTF lighting calculators used as key sources[1] and (2) an Excel spreadsheet showing the proposed extrapolation of total LLLC unit sales to the entire Northwest (including Idaho, Montana, Oregon and Washington) based on a subset of LLLC manufacturers who report their sales to NEEA through a third party. During the review of these materials, Cadmus and NEEA met multiple times to discuss interim findings and obtain clarifications on the research questions.

In addition to reviewing these materials, Cadmus conducted secondary research to determine whether relevant data were available from other studies and prioritized the most recent studies, listed in appendix A.

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[1] The scope of work does not include reviewing the values in the RTF, only the application of those values in NEEA's calculations.

Research Question 1: Control Savings Fraction and Hours of Use Assumptions

Control Savings Fraction

The control savings fraction (CSF) is the percentage change in lighting energy consumption from a lighting system with controls compared to one with a manual on/off switch. NEEA uses the LLLC CSF from the RTF's Nonresidential Lighting Code Compliant Protocol Calculator v2.2 for non-residential lighting in its modeling. The RTF's CSF is 0.60 for all interior building types, except warehouses, which have a CSF of 0.70. NEEA applies the CSF of 0.70 for high-bay fixtures reported in the manufacturer shipment data, assuming that most high-bay LLLC fixtures are installed in warehouses. According to the 2020-2022 sales data, NEEA estimated high-bay luminaires account for approximately 10% of total sales.

NEEA also removes baseline controls savings (namely occupancy sensors required in many commercial spaces by the 2015 WSEC) [2] for new construction, as it is accounted for in calculation of commercial code savings. NEEA currently does not have data on the proportion of LLLC fixtures installed in new construction versus retrofit applications, although its sales data indicate nearly 20% are retrofit kits (which would not be installed in new construction applications).

NEEA does not deduct baseline control savings for existing buildings, so Cadmus examined the penetration of controls in the commercial sector. Navigant's *2015 U.S. Lighting Market Characterization* report, released in November 2017, indicated 82% of commercial-sector lighting had no lighting controls, with 10% controlled by occupancy sensors. Navigant released another study in 2019 that estimated 66% of commercial lighting in 2017 had no lighting controls, with 6% using occupancy sensors. The CBSA 4 found most (68%) indoor lighting (connected wattage) was manually controlled, with occupancy sensors controlling 13% of lighting power for the Northwest and bi-level switches controlling 9% of connected wattage. Table 1 shows control penetration rates in commercial buildings from these three studies.

Table 1. Comparison of Control Penetration Rates in Commercial Buildings

Study	Datapoint Year	Percentage of commercial buildings with and without controls		
		No controls (on/off switches only)	Occupancy sensor controls	Other controls[3]
Navigant 2017	2015	82%	10%	8%
Navigant 2019	2017	66%	6%	28%
CBSA 4	2017-2019	68%	13%	19%

2 Washington State Energy Code Section C405.2.1 states occupant sensor controls must be installed in: classrooms/lecture/training rooms, conference/meeting/multipurpose rooms, copy/print rooms, lounge/breakrooms, enclosed offices, open plan office areas, restrooms, storage rooms, locker rooms, other spaces 300 square feet or less that are enclosed by floor-to-ceiling height partitions, warehouse storage areas, enclosed fire rated stairways, service corridors, covered parking areas

3 Includes dimmer, daylighting, timer, and Energy Management Systems.

Conclusion: Applying the RTF's CSF assumptions for office and warehouse building types to LLLC fixture sales in the Northwest seems reasonable. Below are recommendations on further refining the estimates for the high-bay LLLC fixtures and for accounting baseline lighting controls.

High-Bay Fixtures: High-bay LLLC fixtures could be installed in buildings other than warehouses, such as manufacturing facilities. Manufacturing was the most prevalent building type for LLLC installations[4] in the Energy Solutions study (2020). Investigate the building types where high-bay LLLC fixtures are installed by interviewing lighting installers or NEEA's utility partners. Weight estimates from utility partners or installers based on utility program activity or installation volume. See recommendation under the *Research Question 3: Market Size Estimation* section for more details on installer interviews. High-Level Recommendations include:

1. Develop a weighted CSF for high-bay units based on installations in warehouse and non-warehouse building types. Because high-bay fixtures account for only 10% of current sales, NEEA should use its current approximation that all high-bay units are installed in warehouses until it obtains data from utilities or installers.
2. If installers or utility partners indicate that LLLC fixtures are often installed in manufacturing or industrial buildings, add those building type(s) to the NEEA model.

Expected impact: For 10% of sales, CSF may decrease from 0.7 to a value between 0.6 and 0.7. There is no expected impact on CSF from adding manufacturing or industrial building type to the NEEA model, but it will impact HOU.

Baseline Lighting Controls: Proceed with plans to net out code-required control savings for new construction applications and also net out market penetration of controls in existing commercial buildings. For new construction, occupancy sensors are a good proxy for baseline controls because the WSEC requires occupancy sensors in many areas where LLLC fixtures are likely to be installed (e.g., enclosed and open office and warehouse storage spaces). Net out baseline controls using the occupancy sensor CSF as follows:

1. *Non-warehouse:* 25% CSF as a conservative baseline because most applicable spaces in the RTF have a CSF ranging from 15% to 25%.[5]
2. *Warehouse:* 50% CSF

Net out baseline control savings for retrofit applications to account for the fact that in 2015 (the start of NEEA's program) approximately 20% of existing lighting was controlled, and the most prevalent controls were occupancy sensors. Use the same baseline CSF recommendation for new construction as previously discussed, but only apply it to 20% of retrofit sales.

[4] The study did not specify whether LLLC fixtures were high-bay or low-bay fixtures.

[5] Applicable spaces do not include hallways, restrooms, or stairs, which have a much higher CSF for occupancy sensors.

While NEEA can identify retrofit kits in its data, installers can use non-retrofit kit fixtures in retrofit applications. This makes it more difficult to parse retrofit versus new construction sales in the current dataset. NEEA should independently estimate new construction and retrofit unit sales by interviewing utility partners or lighting installers. See recommendation under the *Research Question 3: Market Size Estimation* section for a complete list of installer questions. NEEA can use the retrofit kit market share as a proxy (80% new construction and 20% retrofit) until it obtains data from utilities and lighting installers.

Expected Impact: There is no expected impact on new construction applications; however, there may be a decrease in the retrofit CSF:

1. *Retrofit Original:* warehouse market share x warehouse CSF + non-warehouse market share x non-warehouse CSF = 10% x 0.7 + 90% x 0.6 = 0.61
2. *Retrofit Revised:* [80% x (10% x 0.7 + 90% x 0.6)] + 20% x [(10%)(0.7-0.5)+(90%)(0.6-.25)] = 0.555

Hours of Use

Hours of use (HOU) refers to the number of hours in a typical year that a lighting system controlled by an on/off switch is providing illumination. NEEA uses the RTF's HOU under the control of a manual on/off switch for warehouses (high-bay products) of 2,600 hours per year and the floor-area weighted average office HOU of 2,950 hours per year for all other LLLC sales as recommended by Energy 350 (2019).

For high-bay applications, the HOU for warehouses is 2,600, which is lower than the HOU for other building types that commonly utilize such fixtures (e.g., 5,500 for manufacturing or 6,000 for the average industrial building).

For non-high bay units, given the potential variation in HOU among the different types of buildings, Cadmus investigated whether average office HOU is representative by comparing this figure with the CBSA floor-area weighted HOU.

Table 2 shows the variation in HOU and percent difference from office HOU by building type. Of the other building types, the school category had the lowest HOU at 2,300 hours and retail/hospital had the highest HOU at 4,200 hours. The last column shows the building type as a percent of total floor area analyzed in CBSA 4. The CBSA floor area weighted average HOU is within 20% of the average office HOU. There is significant variance within the multiple types of office and retail building types. For example, a small retail boutique has an HOU of 2,500 while the largest big box stores have an HOU of 6,000.

Table 2. Average Lighting HOU and % Difference by Building Type

Building	HOU	% Difference from Office	CBSA 4 Floor Area %[a]
Office (Energy 350 recommendation)	2,950	0	13%
Retail (average)[b]	4,200	+42%	24%
School (average)[b]	2,300	-22%	10%
Hospital	4,200	+42%	1%
CBSA Weighted Average	**3,466**	+17%	-

[a] Does not sum to 100% because other building types in the CBSA 4 are not included in this table

[b] Simple average, not weighted

Conclusion: Applying the RTF's HOU assumptions for office and warehouse building types to LLLC fixture sales in the Northwest seems reasonable and conservative given the available data. Below are Cadmus' recommendations on further refinement of HOU estimates:

Low-Bay Fixtures: Interview installers or utility program partners to determine what building types LLLCs are installed in to develop a weighted HOU reflecting actual installations.

Estimated Impact: It is unclear if the new weighted HOU will be higher or lower than average office HOU.

High-Bay Fixtures: As discussed previously, high-bay fixtures may be installed in buildings other than warehouses. Investigate the percentage installed by building type through interviews with LLLC installers and develop a weighted HOU to apply going forward. Until that information is obtained, use warehouse HOU as a proxy.

Expected Impact: If LLLCs are found to be predominantly installed in industrial or manufacturing facilities, HOU could more than double from 2,600 up to 6,000 hours.

Research Question 2: Reconciling Lighting Power Assumptions Given Improved Data Sources

Prior to obtaining sales data, NEEA used a top-down approach to estimate the program's savings potential and to forecast annual energy savings, using lighting power density (LPD) estimates from the 2015 WSEC, along with the floor area being illuminated, HOU, LLLC market penetration, and relevant control savings fractions (see Figure 1). In this top-down approach, LPD affects lighting consumption estimates and is, in turn, affected by changes in fixture wattage and luminous efficiency, which has changed markedly during the 2010s with the introduction of affordable and high-quailty LEDs.

In the bottom-up model NEEA currently uses for reporting annual savings, it has access to regional LLLC unit sales information from seven manufacturers, which includes fixture wattage, fixture type (high-bay or not), the lumen bin, the area code/city sold, and if it is a retrofit kit. NEEA does not currently have a way to convert that information into LPD for reporting energy savings. Since control savings depend on fixture wattage, NEEA intended to quantify control savings relative to lighting energy consumption required in the 2015 WSEC. NEEA is concerned that today's LED fixture wattages are lower than what would have been a typical fixture wattage installed under the 2015 WSEC.[6]

Figure 1. NEEA's Savings Forecast versus Savings Reporting Approach[7]

Savings Forecast (Top-Down Approach) in Year i

Reported Savings (Bottom-up Approach) in Year i

Source: NEEA. September 22, 2022. "LLLC Model Overview." PowerPoint presentation.

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6 NEEA staff indicated the DesignLights Consortium's qualified product list for all lighting products only contain LED-based products today.

7 Some terms in NEEA's forecast modeling (Figure 1) require further definition. Year "i" denotes any year of savings in the program's lifecyle. "Annual Lighting Consumption" is based on LPD, HOU, and total floor area. "LLLC Market Penetration" is the estimated percentage of lighting in commercials buildings that is LLLC. "Control Savings from LLLC" refers to the CSF that applies the percentage of energy savings from LLLC fixtures in various spaces.

Analysis of WSEC LPD

Table 3 shows the interior LPD for office, retail, and warehouse building types over four versions of the WSEC and compared to the LPD requirements in ASHRAE 90.1-2019 (rightmost column). LED lighting started to dominate the market in 2015, which explains the drop in LPDs across all building types in the 2015 version of the WSEC. NEEA staff report that the 2015 WSEC LPDs imply “some presence of LED lighting in the building.” LPDs for warehouses and schools did not change over the last three versions of the WSEC, while office and retail LPDs declined since the 2015 version and have remained stable between the 2018 and 2021 versions of the code. According to a U.S. Department of Energy training prepared by Pacific Northwest National Laboratory, ASHRAE 90.1-2019 is based on a 100% LED baseline and is most similar to the 2018 (and 2021) WSEC LPDs.

Table 3. Comparison of LPD (Watts Per Square Foot) in WSEC and ASHRAE 90.1-2019

	WSEC LPDs				*ASHRAE 90.1 LPDS*
Building Type	**2012**	**2015**	**2018**	**2021**	***2019***
Office	0.90	0.66	0.64	0.64	*0.64*
Retail	1.33	1.01	0.84	0.84	*0.84*
School	0.99	0.70	0.70	0.70	*0.72*
Warehouse	0.50	0.40	0.40	0.40	*0.45*

Future Efficacy Improvements

NEEA is concerned that control savings have been and will continue to decline as fixture efficacy improves relative to the 2015 WSEC.

Cadmus estimates that most of the fixture wattage decline has already occurred for products on the market and that fixture wattage will not change dramatically going forward for two reasons: (1) most commercial lighting products are already solid-state lighting and (2) the Energy Solutions study (2020) found that high-end trim contributed a large share of savings, suggesting that rated fixture wattages are still higher than necessary even in LLLC systems. Cadmus hypothesizes that LLLC manufacturers offer products with a higher fixture wattage so they can be installed in more applications instead of offering more models.

Figure 2 shows Navigant’s 2019 forecast that most commercial lighting stock (luminaires) will transition to LED-based sources in the next 10 years. To achieve the forecasted stock mix, new sales will have to be primarily LED-based to rapidly replace conventional lighting technologies; as such, there is little room for the fixture wattage of products on the market to decline.

Figure 2. Commercial Building Sector Installed Stock Projections

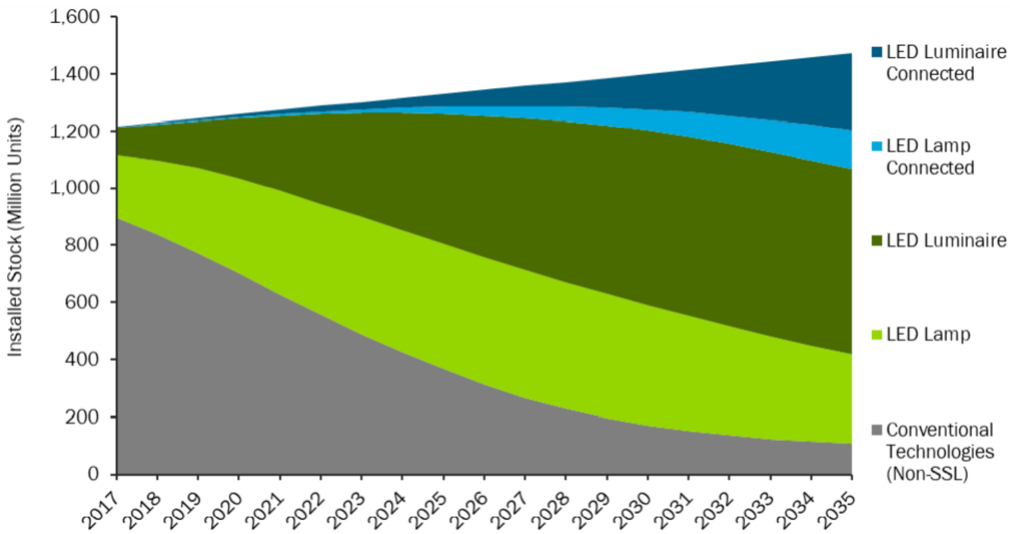


Figure 4.2 Commercial Building Sector Installed Stock Projections for the Current SSL Path Scenario. In this sector, the stock of non-connected LED lighting peaks in 2029, at which point connected lighting increases in prevalence through the end of the forecast period to 28% by 2035.

Source: Navigant 2019.

Conclusion: NEEA’s 2019 forecast lighting power assumptions and current reporting approach are not significantly different for most building types. The 2015 WSEC LPDs reflect usage of LED products in office, school, and warehouse building types. Future declines in fixture wattage are unlikely to be significant since LEDs are the predominant technology on the market.

Recommendation: Update the forecast for office and retail building types to use LPDs from the 2018 WSEC.

Expected Impact: There is no expected impact on school and warehouse building types; however, there may be a decrease in office and retail forecasted savings.

Recommendation: Through interviews with lighting and building code experts, confirm that 2021 WSEC and ASHRAE 90.1-2019 LPDs are based on all LED lighting. Alternatively, if NEEA has access to ASHRAE 90.1-2022 LPDs, which are likely based on all LED lighting, review those to determine if LPDs have changed compared to the 2021 WSEC.

Research Question 3: Market Size Estimation

NEEA currently has access to two sources of LLLC sales data: (1) a report covering sales to the region by seven LLLC manufacturers and (2) data on rebated LLLCs from utility partners. Since the sales data do not include all manufacturers on the Design Lights Consortium's qualified product list (DLC QPL), NEEA extrapolated the sales data using previously collected LLLC sales from lighting distributors and staff judgement about each manufacturer's market share to estimate the total market. NEEA's extrapolation approach resulted in 25,361 LLLC units for 2021, with reported sales (8,199 units) covering an estimated 32% of the market and extrapolation to the remaining 68% of the market.[8]

Cadmus independently estimated the market size for NLCs using a top-down approach, which resulted in a ceiling value, because LLLC systems are a subset of NLC technology. Starting with Navigant's 2019 forecast of the installed commercial stock of LED connected luminaires, we scaled down the national stock using the Northwest population as a percentage of the U.S. population (4.48% per the April 1, 2020 U.S. Census data).[9] Then, assuming that the change in stock represents all new system sales, we estimated the annual market size by dividing this change by the number of years between datapoints. Table 4 shows the calculation steps.

Table 4. Calculation of NLC Market Size

Calculation	2017	2020	2025	2030
Installed Commercial Stock (millions)	2	8	44	125
Northwest Stock (thousands)	90	358	1,971	5,599
Annual Increase (thousands)[a]	N/A	90	322	726

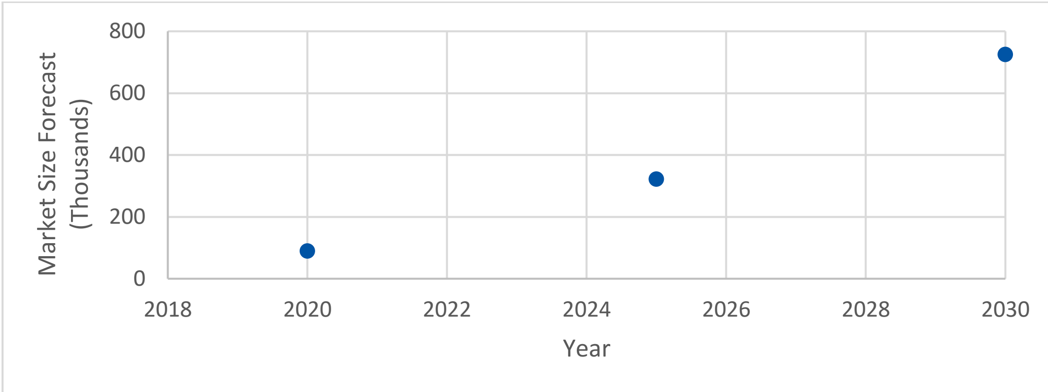
[a] Annual increase (thousands) row may differ slightly from change in stock per year due to rounding.

This estimate assumes that the Northwestern adoption rates will match the Navigant (2019) forecast for the entire U.S. Figure 3 shows the NLC annual market size is expected to increase rapidly from approximately 90,000 LED luminaires per year in 2020 to 322,000 systems per year in 2025 and 726,000 systems per year in 2035. Considering that LLLC systems are a fraction of NLCs, NEEA's extrapolated value of a little over twenty-five thousand units appears to be consistent with this analysis.

8 NEEA's extrapolation shared with Cadmus included data from six manufacturers. NEEA was recently able to obtain new information from Encentiv that included data from seven manufacturers in Q1 and Q2 of 2022.

9 Cadmus used population as a readily accessible proxy but commercial building square footage could also be used to scale down national numbers.

Figure 3. LED NLC Commercial Adoption Per Year in the Northwest



Conclusion: Overall, Cadmus found NEEA's extrapolation to be reasonable and supported by quantitative (distributor data) and qualitative (NEEA staff judgement) sources. NEEA's extrapolation approach starts with the DLC's QPL for a list of manufacturers, and through the judgement of the program team, NEEA determines the final list of manufacturers and estimates market shares for each manufacturer. NEEA's logic for assigning market shares is consistent with the facts provided (e.g., manufacturers just entering the market are expected to have smaller market shares than those that have been in the market for longer).

Reporting Manufacturers: Because extrapolation based on market shares under 50% may not be reliable, continue to pursue sales data reporting from additional manufacturers and triangulate results based on other methods. NEEA recently received data from an additional manufacturer and should revise the extrapolation to include new data as it becomes available.

Market Growth: The Navigant study (2019) forecasts that the market size for NLC systems will increase rapidly. Periodically recalculate the LLLC market size to account for this expected rapid growth. To avoid false precision, round the market size to the nearest thousand units.

Utility Rebate Data: As another way to estimate market size independently from the sales data extrapolation, consider using input from lighting installers on the incidence of LLLC systems receiving rebates. Divide the number of utility-reported units by the ratio of rebate/no rebate to estimate the total market size.

$$Annual\ Sales\ (LLLC\ in\ PNW) = \frac{Number\ Reported\ by\ Utility\ Incentive\ Programs}{\%\ of\ Installations\ Receiving\ Rebates}$$

If Cadmus assumes a 50% rebate incidence, the number of extrapolated LLLC systems is equal to about 19,500 units (9,786 ÷ 50%). Conduct research with lighting installers to improve the rebate incidence estimate.

Lighting Installer Data Collection: Survey lighting installers to determine several details:

1. Whether they install LLLC systems or other types of luminaires
2. How many LLLC and non-LLLC luminaires they install annually
3. The types of buildings and spaces where they install LLLC systems
4. Building types where high-bay and non–high-bay LLLC fixtures are most often installed (e.g., warehouse, big box retail, industrial)
5. The number of luminaires installed in new construction versus retrofit applications
6. How many LLLC units get a rebate versus the units that receive no rebate
7. Which LLLC manufacturer(s) sell them the products they install, and an estimate of that manufacturer's market share

Conclusion

Cadmus was tasked with reviewing NEEA's assumptions and approach to forecasting and reporting energy savings associated with the LLLC program's influence on the market. Given currently available information, our review yielded three major findings: (1) NEEA's CSF and HOU assumptions are reasonable, (2) NEEA's lighting power assumptions in its forecast and current reporting approach are not significantly different for most building types, and (3) NEEA's market size estimation is reasonable and supported quantitatively and qualitatively.

We recommend that NEEA conducts additional research with lighting installers and utility partners to characterize real-life LLLC installations and apply those assumptions to their model.

Our research found NLCs are expected to grow rapidly, and as such, NEEA should regularly reassess the market size for LLLCs.

Appendix A. List of References

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