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# Luminaire Level Lighting Controls: Market Sizing for Exterior Parking Lot Applications

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# Luminaire Level Lighting Controls: Market Sizing for Exterior Parking Lot Applications

## Executive Summary

This literature review, conducted in late 2023, investigates the potential market size<sup>1</sup> for exterior Luminaire Level Lighting Controls (LLLC) in parking lots in the Northwest<sup>2</sup> to support refining its technical potential estimate for the Northwest Energy Efficiency Alliance (NEEA). Research methods included analysis of national and regional lighting data, a review of spatial data on parking lot coverage, review of county and municipal level outdoor lighting codes and ordinances, and a review of reported suitability and limitations of LLLC in parking lot settings. Different data sources and analyses yielded varied estimates of market size. Therefore, Cadeo's review indicates that the current number of exterior luminaires in Northwest parking lots is within the range of 860,000 luminaires (a low-end estimate) and 3.5 million luminaires (a high-end estimate). Further research to refine this estimate may be necessary.

This assessment determined that less than 1% of total existing luminaires in Northwest parking lots currently have LLLC installed. Most open-air parking lots are suitable applications for LLLC systems and may benefit from both energy savings and security improvements. There remain certain barriers to broader adoption, however, including cost and complexity factors, concerns over perceived safety due to dynamic lighting, and questions of suitability for low-traffic or infrequently used parking areas.

Analysis of historical geographical data shows that total parking lot coverage has been slowly expanding over the past decades. Cadeo forecasts that the total square foot coverage of parking lots in the Northwest will increase by approximately 3% over the next 20 years. This projected expansion of parking infrastructure indicates a similar growth pattern in exterior luminaires, and therefore a modest growth in the opportunity for LLLC systems and their associated energy savings over the next 20-year period.

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<sup>1</sup> In this report, we use 'market size' and 'potential market size' to reflect the same idea – the total number of luminaires possible to replace with LLLC. This is different from the likely amount of luminaires that would be replaced with the product's successful inclusion in a market transformation program, which would be created later by the NEEA LLLC program team.

<sup>2</sup> "Northwest" includes Idaho, Montana, Oregon, and Washington throughout this document.

This report summarizes the outcomes of Cadeo’s literature review investigating the market size for exterior Luminaire Level Lighting Control (LLLC) products in parking lots. The purpose of this investigation is to improve the Northwest Energy Efficiency Alliance’s (NEEA’s) understanding of the size of exterior LLLC in parking lots and identify possible program opportunities through a thorough and technical review of secondary research.

The NEEA team identified the following research questions:

**1) What is the current potential market size for exterior LLLC in parking lots?**

- i. How many luminaires are installed in uncovered parking lots today? Including 1) recent new construction, 2) natural replacement, and 3) already existing?
- ii. What portion of these luminaires may be affixed to poles higher than 26 feet tall? (Lighting on these poles trigger a different set of code requirements.)
- iii. What portion of these luminaires might not be applicable for LLLC? (What may or may not make a parking lot space a good match for LLLC?)
- iv. How many of these luminaires are already exterior LLLC?

**2) What is the projected market size for exterior LLLC in parking lots over the next twenty years?**

- i. Will the number of parking lots (in terms of individual lots, square footage, and total luminaires for these spaces) grow, shrink, or remain the same over the next 20 years? How does this translate to the number of luminaires?

To support this investigation, Cadeo conducted the following activities:

- Reviewed exterior lighting sales data to determine the existing number of luminaires installed today, and what proportion were already LLLC.
- Reviewed current and historical United States Geological Survey (USGS) data of parking lot coverage in Oregon, Washington, Idaho, and Montana to assess current parking lot coverage and forecast change in parking lot coverage over the next 20 years.
- Reviewed city and county level ordinances in Oregon, Washington, Idaho, and Montana to understand exterior lighting standards and requirements in the Northwest.
- Reviewed literature to find recommendations on best applications of LLLC in open-air parking lots in the Northwest.

The remaining sections of this memo provide high-level key takeaways, additional background on the LLLC market, and detailed findings from the Cadeo team’s research activities.

# Key Takeaways

Based on this review, the team identified the following key takeaways for further consideration by the LLLC program:

- Exterior LLLC can benefit most open-air parking lots by saving on energy, can increase safety and security, and help meet dark sky goals.
- Currently, Cadeo estimates that LLLC make up less than 1% of exterior parking lot luminaire stock in the Northwest.
- Open air parking lot coverage (i.e., square feet of parking lot) is estimated to grow by approximately 3% over the next 20 years, which will mean that the number of luminaires required to light them will grow, as well.
- There is considerable variation in municipal and county development codes and design standards for exterior lighting in the Northwest, especially around pole height for lighting mounts, but it is likely that up to a third of poles may be over 25 feet tall.
- There are additional future research questions that have been raised by this review, including how lighting manufacturers and distributors are thinking about safety and security in their LLLC product design and product offerings (particularly whether they target or avoid certain submarkets due to safety-related needs) and how end-users experience LLLC in parking lots. Understanding end-user needs and perspectives may help NEEA further develop expectations of market adoption as well as identify potential barriers and opportunities for program intervention.

## Background

Luminaire Level Lighting Controls (LLLC), as defined by NEEA, are a type of networked lighting control system with integrated sensors and controls in each luminaire that are wirelessly networked.<sup>3</sup> Unlike conventional systems, LLLC are embedded within individual fixtures, allowing sensing and control at a granular level. This enables LLLC systems to provide deeper energy savings, an improved lighting experience and data collection and connectivity to other systems.

In order to accelerate the adoption of advanced lighting controls in the northwest, NEEA has implemented an LLLC Program that seeks to increase adoption of LLLC as an energy-saving option for commercial new construction, renovation, and retrofits, and to bolster market capacity to implement this technology.

NEEA's LLLC Program is now considering adding exterior LLLC in uncovered parking lots to its overall program work. Through this literature review, NEEA seeks to understand the market size for exterior LLLC in parking lots.

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<sup>3</sup> [LLLC-Overview-for-Decision-Makers-V5-1.pdf \(betterbricks.com\)](#)

# Detailed Findings

The team investigated the following questions about exterior LLLC. Findings are presented for each research question below.

## What is the potential market size for exterior LLLC in parking lots?

To answer this question, Cadeo investigated four related questions.

### How many total luminaires (including LLLC and non-LLLC) are installed in parking lots (including residential and non-residential applications) today?

Estimating the number of non-residential parking lot luminaires installed in the region today involved analyzing diverse datasets including national Department of Energy (DOE) lighting data, regional lighting stock models, and spatial data from United States Geological Survey (USGS). Cadeo used different methodologies to calculate estimates for each dataset. All these approaches have strengths and weaknesses, and so Cadeo is presenting their findings as a wide range of possible estimates, spanning from 860,000 to 3.49 million parking lot luminaires.

The following sections will examine each method in greater detail to explain how the values in the range were calculated. Additional detail on data sources and calculations is also provided in an accompanying workbook.

#### *Method 1.*

Using Method 1, Cadeo estimated that the market size of exterior parking lot luminaires is roughly 860,000 in 2023 (see Table 1). Almost all of these (840,000), are assumed to be installed in non-residential parking lots. Cadeo calculated these numbers by first estimating the number of luminaires in non-residential parking lot stock by using regional lighting data. Then, using the total parking lot coverage from USGS data and estimated residential parking lot area based on RBSA data<sup>4</sup>, Cadeo was able to estimate the number of residential parking lot luminaires (20,000 luminaires). The calculations are summarized in the table below.

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<sup>4</sup> RBSA Multifamily Homes Report 2016-2017 <https://neea.org/img/documents/Residential-Building-Stock-Assessment-II-Multifamily-Homes-Report-2016-2017.pdf>

**Table 1. Total luminaires in NW parking lots in 2023 (Method 1)**

<b>2023 Parking Lot Luminaires</b>	<b>Calculation</b>	<b>Mathematical Total</b>	<b>Total Rounded to Nearest 10,000</b>
Non-residential	Forecasted # of luminaires in non-residential parking lots based on the BPA 2016-2021 Nonresidential Lighting Market Model	840,311	840,000
Residential	# of non-res luminaires per ft <sup>2</sup> X # total ft <sup>2</sup> of all parking lots X % of residential parking lots = # Res luminaires	19,329	20,000
Total 2023 Parking Lot Luminaires		859,825	860,000

Cadeo’s first step in reaching these estimates was to review lighting data from the Bonneville Power Administration (BPA) 2016-2021 Nonresidential Lighting Market Model. In the market model, most technologies are reported as lamps, not luminaires, so these measures needed to be converted to luminaires using an average 1.2 lamps per luminaire conversion.<sup>5</sup> Once completed, the 2023 luminaire stock was estimated by forecasting the luminaire amount based on the previous years’ stock data.

Next, Cadeo needed to determine the current estimated amount of parking lots in the Northwest. The United State Geological Survey (USGS) conducted a study estimating the presence of paved surface parking lots in the conterminous U.S. in 1974, 1982, 1992, 2002, and 2012. This data was presented in square miles, by county.<sup>6</sup> The table below summarizes these data by state for each year.

**Table 2: USGS Estimated parking lot coverage in square miles by state, over time**

<b>State</b>	<b>1974</b>	<b>1982</b>	<b>1992</b>	<b>2002</b>	<b>2012</b>
Idaho	180	177	180	184	185
Montana	298	299	303	307	309
Oregon	248	253	256	260	263
Washington	275	278	286	294	302
Regional Total	1002	1008	1025	1045	1060

<sup>5</sup> Average lamp per luminaire is used in BPA light modeling (2016-2021) and derived from CBSA 2019 <https://neea.org/resources/cbsa-4-2019-final-report>

<sup>6</sup> Estimating the presence of paved surface parking lots in the conterminous U.S. from land-use coefficients for 1974, 1982, 1992, 2002, and 2012: [https://www.sciencebase.gov/catalog/file/get/5c0ea593e4b0c53ecb2af59f?format=disk\\_6c%2Fa2%2F2b%2F6ca22ba184f53f9546e6d6493458bcec52657049&transform=1&allowOpen=true](https://www.sciencebase.gov/catalog/file/get/5c0ea593e4b0c53ecb2af59f?format=disk_6c%2Fa2%2F2b%2F6ca22ba184f53f9546e6d6493458bcec52657049&transform=1&allowOpen=true)

Cadeo used this historical data to inform a linear forecast of the regional parking lot coverage, in square miles, in 2023.

Total residential parking lot area was estimated by first calculating the square footage of parking required per residential unit in the Northwest. Using the RBSA 2016-2017<sup>7</sup> data on total number of residential units in multi-family buildings, and their estimated number of parking spots per unit, and the average parking lot size (according to the American Planning Association<sup>8</sup>) the average square foot per residential unit in the region was estimated. Assuming an additional 33% of square ft per parking lot for driving lanes and entrances gave us our final estimate for residential parking lot coverage.

This allowed us to estimate the amount of non-residential parking lot coverage, and, using the 2023 parking lot luminaire estimate, it also allowed us to calculate an average number of luminaires per square foot. Applying this to the total projected parking lot coverage gave us an estimated 860,000 total (residential and non-residential) open parking lot luminaires in the Northwest.

### *Method 2.*

Using Method 2, Cadeo estimated that the market size of exterior parking lot luminaires is roughly 2.32 million in 2023 (see Table 3). Almost all of these (2.27 million), are assumed to be installed in non-residential parking lots. Cadeo calculated these numbers by using the national DOE 2015 U.S. Lighting Market Characterization report.<sup>9</sup> The national estimate was then scaled down to the Northwest, and adjustments were applied to account for parking structure lighting, the estimated share of residential parking lot lighting, and growth over time. The calculations are summarized in the table below.

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<sup>7</sup> RBSA Multifamily Homes Report 2016-2017 <https://neea.org/img/documents/Residential-Building-Stock-Assessment-II-Multifamily-Homes-Report-2016-2017.pdf>

<sup>8</sup> American Planning Association: Site Design, Parking and Zoning for Shopping Centers <https://www.planning.org/pas/reports/report59.htm>

<sup>9</sup> [https://www.energy.gov/sites/prod/files/2017/12/f46/lmc2015\\_nov17.pdf](https://www.energy.gov/sites/prod/files/2017/12/f46/lmc2015_nov17.pdf)



**Table 3. Total luminaires in NW parking lots in 2023 (Method 2)**

<b>2023 Parking Lot Luminaires</b>	<b>Calculation</b>	<b>Mathematical Total</b>	<b>Total Rounded to Nearest 10,000</b>
Non-residential	Scaled down number of National estimates from 2015 DOE study.	2,273,068	2,270,000
Residential	# of non-res luminaires X % of residential parking lot = # Res luminaires	41,422	40,000
Total 2023 Parking Lot Luminaires		2,319,457	2,320,000

Cadeo’s first step in reaching these estimates was to review lighting data from the DOE 2015 U.S. Lighting Market Characterization report. In the report, lighting was again reported as lamps, not luminaires, so these measures were converted to luminaires using the same metrics as Method 1.

Once converted, the national estimates were scaled down to Northwest. The 2018 Commercial Building Energy Consumption Survey (CBECS) estimated total US commercial floorspace to be 96,243 million sq ft,<sup>10</sup> and the 2019 Commercial Building Stock Assessment (CBSA)<sup>11</sup> estimated Northwest commercial floor area to be approximately 3,400 million sq ft. Using these values, Cadeo estimates that the Northwest accounts for 3.5% of US commercial floor area. Additionally, Cadeo needed to remove parking garages and facilities from this estimate. The DOE report estimated that of the approximate 695 million parking spaces they estimated in the US, 85 million were parking garage spaces, or roughly 12.5%. Finally, Cadeo adjusted the estimated number of parking lot luminaires for growth over time: the DOE estimate was for 2015, so Cadeo leveraged the growth rate assumption from Method 1 to estimate approximately 2.32 million total parking lot luminaires for 2023.

Using the same data and process as Method 1., Cadeo estimated the amount of residential parking lot coverage (approximately 2% of the total). The 40,000 estimated residential parking lot luminaires were removed from the total, resulting in an estimated 2.27 million non-residential parking lot luminaires.

*Method 3.*

The final method used in this analysis, Method 3, provides Cadeo’s largest estimate of exterior parking lot luminaires at approximately 3.49 million in 2023 (see Table 4). Cadeo calculated these numbers by using the USGS data. Using total parking lot coverage for the region in 2023

<sup>10</sup> <https://www.eia.gov/consumption/commercial/>

<sup>11</sup> CBSA 2019 <https://neea.org/resources/cbsa-4-2019-final-report>

and calculating the amount of non-residential parking spaces this would accommodate, Cadeo estimated the number of lighting systems that would be required for this total by applying the DOE’s estimate of parking spaces per lighting system.

**Table 4. Total luminaires in NW parking lots in 2023 (Method 3)**

	<b>Calculation</b>	<b>Mathematical Total</b>	<b>Total Rounded to Nearest 10,000</b>
Estimated Non-residential Parking Lot Area (sq ft)	Total parking lot coverage in the NW from USGS data X 98% (removing residential)	29,336,335,820	29,336,340,000
Estimated Number of Parking Spaces	Non-res parking lot area X (0.67 (to remove driving aisles and walkways)) /350 (average parking space size)	56,158,129	56,160,000
<i>Average of 13 Parking Spaces per Lighting System</i>			
Total 2023 Parking Lot Luminaires		3,487,152	3,490,000

Cadeo first used the previously calculated total parking lot square footage in the Northwest according to the USGS<sup>12</sup>, and removed the estimated 2% of residential parking lot area. Cadeo then converted that area into parking lot spaces, using the assumptions from Method 1. Those assumptions were that a third of parking lot area is not used for parking, but for driving aisles and for walkways, and that the average parking lot size is 350 square feet.<sup>13</sup> This provided an estimated 56.1 million parking spaces.

To create their national estimate of parking lot lighting systems, the DOE estimated that there was roughly 1 lighting system per 13 parking spaces.<sup>14</sup> Using this estimate, Cadeo calculated that there would need to be approximately 4,320,000 lighting systems to account for this number of spaces. To convert this to luminaires from fixtures, Cadeo used the same CBSA metric from Methods 1 and 2 and estimates that there are 3.49 million nonresidential parking lot luminaires in the Northwest.

<sup>12</sup> Estimating the presence of paved surface parking lots in the conterminous U.S. from land-use coefficients for 1974, 1982, 1992, 2002, and 2012:  
[https://www.sciencebase.gov/catalog/file/get/5c0ea593e4b0c53ecb2af59f2f=disk\\_6c%2Fa2%2F2b%2F6ca22ba184f53f9546e6d6493458bcec52657049&transform=1&allowOpen=true](https://www.sciencebase.gov/catalog/file/get/5c0ea593e4b0c53ecb2af59f2f=disk_6c%2Fa2%2F2b%2F6ca22ba184f53f9546e6d6493458bcec52657049&transform=1&allowOpen=true)

<sup>13</sup> American Planning Association: Site Design, Parking and Zoning for Shopping Centers  
<https://www.planning.org/pas/reports/report59.htm>

<sup>14</sup> [https://www.energy.gov/sites/prod/files/2017/12/f46/lmc2015\\_nov17.pdf](https://www.energy.gov/sites/prod/files/2017/12/f46/lmc2015_nov17.pdf)

All 3 methods have gaps, and all rely on imperfect assumptions and generalizations. These uncertainties have resulted in this large range of possible estimates. With multiple credible estimation approaches yielding a wide range of results, it highlights the difficulty in narrowing down a definitive total of regional outdoor parking lot luminaires given currently available data.

### **What portion of these luminaires may be affixed to poles higher than 26 feet tall?**

Pole height standards for exterior lighting vary from state to state and are typically set at the municipal or county level. While Cadeo cannot give an exact number affixed to poles higher than 26ft, an analysis of local ordinances, described in detail below, suggests that only a third would be affixed to poles higher than 25ft. A table with exterior lighting regulations reviewed from across the Northwest is provided in Appendix A. Examples of standards from across the region include:

In Washington County, Oregon the fixture angle and illumination levels of the fixture determine height allowance: "The following standards are required of all exterior lighting ... Many uses have the option of providing a lower light post with a non-cutoff type luminaire or a higher pole, up to 40 feet, with a luminaire that totally cuts off light spillover at a cutoff angle smaller than 90 degrees. The maximum light post height permitted is dependent on the amount of cutoff provided." (Article IV- Development Standards/415 - Lighting).

In Seattle, Washington: "Exterior lighting on poles shall be permitted up to a maximum height of thirty (30) feet from finished grade. In MR/RC and HR/RC zones, exterior lighting on poles shall be permitted up to a height of forty (40) feet from finished grade, provided that ratio of watts to area is at least twenty (20) percent below the maximum exterior lighting level permitted by the Energy Code." (Land Use Code/Chapter 23.46)

In total, Cadeo reviewed 12 ordinances, three in each of the four Northwest states, to compare pole height restrictions. A third of all heights looked at could not exceed 25ft; an additional third could only exceed 20ft in certain circumstances (for example in one case, only industrial applications could permit a pole exceeding 20ft). The last third ranged in limits between 30 - 40ft. Half of the limits allowing between 30-40ft were in Washington, which had the second highest parking lot coverage. Half of the limits below 25ft were in Idaho, which had the least amount of parking lot coverage. Montana had the highest amount of parking lot coverage, and in all 3 ordinances reviewed, residential zones could not exceed 20 ft.<sup>15</sup>

### **What portion of these luminaires might not be applicable for LLLC?**

According to the US Department of Energy (DOE), most parking lots are lit for 13+ hours per day. LLLC can be used to save energy at times of infrequent use, especially in parking lots that are typically empty at night. The DOE estimates that control savings for most exterior

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<sup>15</sup> Estimating the presence of paved surface parking lots in the conterminous U.S. from land-use coefficients for 1974, 1982, 1992, 2002, and 2012:  
<https://www.sciencebase.gov/catalog/file/get/5c0ea593e4b0c53ecb2af59f?disk=6c%2Fa2%2F2b%2F6ca22ba184f53f9546e6d6493458bcec52657049&transform=1&allowOpen=true>

applications can easily be 30 to 50 percent, because most commercial sites are not open through the night.<sup>16</sup>

A major focus of exterior lighting is safety and security. In a previous investigation, Cadeo found that exterior LLLC offer improved flexibility to meet specific light level requirements and preferences to ensure safety and security.<sup>17</sup> During that investigation, the Cadeo team asked manufacturer representatives which markets they targeted for exterior LLLC. Their answers included:

- Car dealerships
- School and educational facilities
- Warehouses and distribution centers
- Secure sites that use fencing

According to the 2021 Northwest Power Plan<sup>18</sup> and the 2019 Commercial Building Stock Assessment (CBSA),<sup>19</sup> educational buildings, and warehouse and distribution centers make up more than a quarter of commercial building stock.

While LLLC generally promote security and offer enhanced lighting control, there are still scenarios where this technology might not be applicable.<sup>20</sup> The primary inhibitors for LLLC adoption, interior or exterior, are the luminaire's higher base cost, potential higher complexity of the project, insufficient value or savings for a given project, and uncertain owner interest in non-energy benefits generated by collecting data.

The following factors may make LLLC undesirable:

- 1 | **Cost and Complexity Factors:** In smaller parking lots with only a few lighting fixtures, the added cost and complexity of LLLC systems could outweigh their potential benefits.<sup>21, 22</sup>
- 2 | **Low-Traffic or Infrequently Used Spaces:** Parking lots with minimal traffic and infrequent use, such as remote or seasonal locations, might not fully leverage the energy-saving and control features of LLLC.<sup>23</sup>

**Perceived Safety in Late Night Lots:** Considering the perceived safety in parking lots where people may be leaving or returning late is important. While in many cases, LLLC can improve

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<sup>16</sup> Guide to FEMP-Designated Parking Lot Lighting: <https://www.energy.gov/femp/articles/guide-femp-designated-parking-lot-lighting#:~:text=Most%20parking%20lots%20are%20lighted,periods%20will%20help%20save%20energy>.

<sup>17</sup> Exterior Lighting LLLC Market Research (Investigation Conducted by Implementation Team), NEEA internal document

<sup>18</sup> NW PowerPlan 2021 Com- ExteriorLighting-2021P\_V10-C19 [https://www.nwcouncil.org/2021powerplan\\_commercial-ee-methodology/](https://www.nwcouncil.org/2021powerplan_commercial-ee-methodology/)

<sup>19</sup> CBSA 2019: <https://neea.org/data/commercial-building-stock-assessments>

<sup>20</sup> US DOE Exterior Lighting Scoping Study [https://www.pnnl.gov/main/publications/external/technical\\_reports/PNNL-20579.pdf](https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-20579.pdf)

<sup>21</sup> <https://www.lightnowblog.com/2023/10/street-lighting-control-systems-exploring-advantages-disadvantages-and-choosing-the-right-approach/>

<sup>22</sup> 2020 C&I Lighting Controls Market Study [https://ma-eeac.org/wp-content/uploads/MA20C11-E-LCR\\_Lighting-Controls-Final-Report\\_20210630.pdf](https://ma-eeac.org/wp-content/uploads/MA20C11-E-LCR_Lighting-Controls-Final-Report_20210630.pdf)

<sup>23</sup> IES Research Report: Lighting for Parking Facilities [IES Research Report: Lighting for Parking Facilities – The IES Webstore](https://www.ies.org/research-reports/lighting-for-parking-facilities)

security, the perception of safety is very important to end-users. An Illuminating Engineering Society (IES) research report found that lighting uniformity affected perceptions of parking lot safety. In some cases, the dynamic lighting control offered by LLLC may create concerns or confusion, affecting their sense of security. Careful consideration of user perceptions is essential in these settings. Additional research into how manufacturers and distributors are thinking about security, and how users feel about lighting controls in their building’s parking lot may help implementers better understand suitability.<sup>24</sup>NEEA should consider these factors when implementing their exterior LLLC program. The property and use times and frequencies will determine the suitability of LLLC application.

**How many of these luminaires are already exterior LLLC?**

To answer this question, Cadeo again reviewed lighting sales data from the BPA 2016-2021 Nonresidential Lighting Market Model and NEEA’s preliminary regional exterior LLLC sales data.<sup>25</sup> By reviewing the sales and stock data in the model and performing a few calculations, Cadeo was able to estimate that LLLC currently account for 0.32% of non-residential parking lot luminaire stock.

**What is the forecasted market size for exterior LLLC in parking lots over the next twenty years?**

**Will the number of parking lots grow, shrink, or remain the same over the next 20 years? How does this translate to the number of luminaires?**

Using the same USGS data, Cadeo forecasted the regional parking lot coverage, in square miles, in 2023 and in 20 years. The table below provides the resulting estimates for 2023 and 2043.

**Table 5: Estimated parking lot coverage in the Northwest in sq miles, over time**

	2023	2043
Regional Total	1,076	1,108

To determine how this forecasted increase in parking lot area translates to luminaires, Cadeo used an assumption that the number of luminaires per square foot of parking lot would remain constant over time. With that assumption, Cadeo estimates that the total luminaires will rise approximately 3% over this 20-year time horizon, in correlation with the forecast increase in parking lot area.

<sup>24</sup> Estimating the presence of paved surface parking lots in the conterminous U.S. from land-use coefficients for 1974, 1982, 1992, 2002, and 2012:

<sup>25</sup> Anonymized sales data from 2021.

**Table 6. Estimated nonresidential parking lot luminaires in 2043**

	<b>2023 (Calculated Totals)</b>	<b>2023 (Rounded to the nearest 10,000)</b>	<b>2043 (Calculated totals)</b>	<b>2043 (Rounded to the nearest 10,000)</b>
Method 1	840,311	840,000	865,263	870,000
Method 2	2,029,673	2,030,000	2,340,566	2,340,000
Method 3	3,487,152	3,490,000	3,590,702	3,590,000

This represents a possible range of 870,000 to 3.6 million estimated total luminaires in parking lots (including residential and non-residential) in 2043.

## Conclusion

This review provided several key findings and estimates that can help NEEA characterize the opportunity for exterior LLLC. It underscores the potential advantages of LLLC for some exterior applications, and the growth potential of the technology as parking lot coverage increases over time. It also estimates the current limited adoption rates of LLLCs, and market segments where their adoption may be inappropriate. To that end, this review also prompts additional research questions, about how to target LLLC applications for greater security and how end-user experience, comfort, and safety can be impacted and improved by LLLC. These insights will all be valuable in guiding the program’s strategies and decisions in promoting LLLC adoption in exterior applications in the Northwest.

# Appendix A. Exterior Lighting Codes and Ordinances Reviewed

City/County	State	Resource Name	Highest Height Permitted	Rules
Blaine County	Idaho	Blaine County, Idaho/ 9-29A-4: Outdoor Lighting Standards	17ft	Parking area luminaires shall be no higher than seventeen feet (17') in height as measured from the ground to the top of the highest light source.
Valley County	Idaho	Valley County, Idaho/ Lighting Ordinance Flyer, Outdoor Lighting	30ft	The height of any light fixture or illumination source shall not exceed thirty feet (30').
Boise	Idaho	Boise Zoning Code/ Chapter 11-04-011. Exterior Lighting/ 11-04-011.4 General Standards	20ft	Parking lot poles shall not exceed 20 ft in height.
Billings	Montana	Ordinances of City of Billings, Montana/ Ordinance No. 12-5571	20ft	Light pole standards must be 20 feet in height or less. For subdivisions and residential areas, parking areas must be 15 ft or less.

City/County	State	Resource Name	Highest Height Permitted	Rules
Great Falls	Montana	Great Falls , Montana - Code of Ordinances Title 17 - LAND DEVELOPMENT CODE Chapter 40 - OUTDOOR LIGHTING	30ft	Luminaires shall not be taller than twenty (20) feet in residential zoning districts or when placed within fifty (50) feet of a residential zoning district. In all other zoning districts, luminaires shall not be taller than thirty (30) feet.
Whitefish	Montana	Whitefish, MT Code of Ordinances/ 11-3-25: OUTDOOR LIGHTING STANDARDS:	30ft	<p>Parking Area Lights: Parking area lights are encouraged to be greater in number, lower in height and lower in light level, as opposed to fewer in number, higher in height and higher in light level:</p> <ul style="list-style-type: none"> <li>a. Parking area luminaires up to seventeen feet (17') in height are permitted subject to all other regulations in this section.</li> <li>b. Parking area luminaires between seventeen feet (17') and thirty feet (30') in height may be permitted, subject to the submittal of an illumination plan showing location, intensity and light trespass from all proposed fixtures. This illumination plan must be approved by the city before lighting may be installed.</li> </ul>
Canby	Oregon	Canby, Oregon Codes/ 16.43 OUTDOOR LIGHTING STANDARDS	37.5 ft	



City/County	State	Resource Name	Highest Height Permitted	Rules
Washington County	Oregon	Washington County, Oregon-Community Development Code/ Article IV- Development Standards	40 ft	[Complex rules related to angle of the fixtures shield, distance from residential area, and lamp wattage, most restrict well below 40ft]
Portland	Oregon	City of Portland Technical Manual	30ft	Residential and Commercial limited to 20ft; 30 ft allowed for large industrial uses of 50,000 sq ft or more
Seattle	Washington	Municipal Code/ Subtitle III- Land Use Regulation	40 ft	Exterior lighting on poles shall be permitted up to a maximum height of thirty (30) feet from finished grade. In MR/RC and HR/RC zones, exterior lighting on poles shall be permitted up to a height of forty (40) feet from finished grade, provided that ratio of watts to area is at least twenty (20) percent below the maximum exterior lighting level permitted by the Energy Code.
Duvall	Washington	Duvall, Washington - Code of Ordinances Chapter 14.46 - EXTERIOR LIGHTING STANDARDS 14.46.060 - Open-air parking lot lighting.	25 ft	The following mounting height regulations shall apply to open-air parking lot lighting: The maximum permissible mounting height of all other outside lighting shall be twenty-five (25) feet.

City/County	State	Resource Name	Highest Height Permitted	Rules
Pierce County	Washington	Pierce County Codes/ 18J.15.085 Exterior Illumination.	35 ft	Pole lights shall be no taller than 35 feet above a 36-inch base in parking lots and traffic areas and no taller than 12 feet in pedestrian areas.