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Luminaire Level Lighting Controls (LLLC) Market Characterization and Baseline Report

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Executive Summary

The Northwest Energy Efficiency Alliance (NEEA) is developing its Luminaire Level Lighting Control (LLLC) Initiative to accelerate the adoption of advanced lighting controls in office buildings and warehouses. Unlike conventional systems that control a group of fixtures through a centralized processor, LLLCs are embedded within individual fixtures. They control the lighting output of individual luminaires and can provide autonomous communication and energy reporting. In addition to reducing energy use by providing light only when, where, and at the level it is needed, LLLCs offer non-energy benefits such as improved worker productivity, reduced worker health costs, HVAC system optimization, and reduced cost of space redesigns.

In 2015, NEEA contracted with Research Into Action and its subcontractor, Energy 350, to perform a market characterization of LLLC systems, update LLLC baseline assumptions, and forecast LLLC adoption for the next 20 years. Over the course of the project, NEEA continued working with the DesignLights Consortium (DLC) to influence and support development of the 2016 advanced lighting controls specification. NEEA also restructured the LLLC initiative so that it aligned with the final advanced lighting control specifications developed with the DLC. This restructuring enabled NEEA to rely on the DLC's qualified products list (QPL), using that list to identify the products with the characteristics NEEA plans to promote.

Market Characterization

The Research Into Action team conducted in-depth interviews with NEEA staff, regional nonresidential lighting experts, LLLC manufacturers, lighting distributors, and building owners to inform the market characterization. This research resulted in the key findings and recommendations presented below.

Key Finding #1: The shortage of experienced installers poses a barrier to LLLC adoption in the Northwest. Many of these installers over-bid jobs involving LLLCs to compensate for installation processes that they are uncertain of. In fact, manufacturers, distributors, and regional experts all stated that addressing this barrier should take precedence over addressing first cost and market fragmentation barriers. The market actors thought that training the market of lighting installation contractors is critical to increasing the adoption of LLLC systems in the Northwest.

> **Recommendation: Include LLLC systems in NXT Level training.** Although the promise of LLLC systems is that they become easier to install over time compared with traditional lighting controls, NEEA should include topics covering LLLC systems in the NXT Level training curriculum to ensure system acceptability and persistence. NEEA should also explore conducting pre-bid training with distributors and local trade associations that interact directly with lighting installers. Both training types will benefit the market by helping to ensure that LLLC systems are installed correctly and that end-users are satisfied with the product. In addition, once installers become more familiar with LLLC technology, they are less likely to overstate the cost of LLLC installation, thereby rendering LLLC systems more cost-competitive with traditional lighting controls.

Key Finding #2: Manufacturers agree with NEEA that energy codes present an opportunity to promote the adoption of LLLCs in the market. As NEEA pursues code-related work, energy codes that include exceptions for using advanced networked lighting controls or include requirements that those controls may satisfy (such as demand response enablement) represent the greatest opportunity.

> **Recommendation: Continue promoting advanced lighting controls in commercial energy codes.** NEEA should continue to push for the inclusion of advanced lighting controls in regional commercial energy codes through its Commercial Code Enhancement (CCE) initiative. Since many manufacturers integrate energy reporting capabilities within the LLLC system, the organization should also develop case studies and conduct pilot demonstrations that focus on the energy- and capacity-saving features of LLLC systems to make the case for including these technologies in energy codes.

Key Finding #3: Although the LLLC initiative did not initially target lighting designers, regional lighting experts and distributors report that designers play an important role in LLLC system adoption in the new construction and major renovation markets. Regional experts and distributors have both observed that designers are increasingly knowledgeable about advanced lighting controls and often promote these systems during the specification and bidding phases of construction.

> **Recommendation: Engage with lighting designers.** NEEA should interview a sample of lighting designers to identify: the channels through which they currently receive LLLC system information; the training opportunities they are aware of and participate in; the techniques they use to prevent LLLC systems from being taken out of designs; and the barriers they perceive limiting wider LLLC adoption. NEEA should also consider attending and making presentations at local lighting designer trade organization meetings (e.g., American Institute for Architecture (AIA) meetings) to share LLLC information with designers and to further increase designers' awareness.

Key Finding #4: All of the market actors who contributed to this research observed that LLLC systems are most commonly provided via traditional lighting and lighting controls delivery channels. The bulk of LLLC sales—made to all but the largest customers—go through the traditional pathway of manufacturer→ distributor→ lighting installer. Almost all manufacturers reported selling LLLC systems directly to their largest customers.

> **Recommendation: Rely on existing market contacts and leverage points.** Since LLLCs typically reach end-use customers through traditional lighting distribution channels, NEEA should leverage its other initiatives' efforts that target these same distribution channels to influence the supply chain of LLLCs. Similar techniques aimed at increasing distribution of Reduced Wattage lighting or high performance T8's at in the same market channel may also be applied to LLLCs.

Key Finding #5: Several manufacturers said they were skeptical that "lighting as a service"—which has not yet caught on in the marketplace—will ever replace or compete with traditional

market channels. However, several manufacturers and regional experts perceive "energy management as a service" as a potential supply chain disruptor.

> **Recommendation: Consider further research to explore the potential for "lighting as a service."** Although key market actors do not currently view "lighting as a service" as a potential market disruptor, the concept has the potential to fundamentally alter traditional LLLC delivery channels for several reasons. For example, because lighting fixtures are ubiquitous in commercial buildings, increased adoption of LLLC systems with reporting capabilities would allow unparalleled access to information about utilization and conditions (such as temperature, or comfort) of each space. This information could seamlessly integrate with other IT-based building energy management solutions to deliver "energy management as a service" more cost-effectively. NEEA should therefore consider further research on how lighting may fit into the broader "energy management as a service" category and explore the potential for increased use of "lighting as a service."

Key Finding #6: Examination of thousands of recent U.S. patents identified powered low-voltage grid systems as the most likely technology with potential to disrupt and/or enhance the market adoption of LLLC systems. This technology offers benefits similar to those of LLLCs: reduced wiring costs, space re-configurability, and potential integration with other whole building systems.

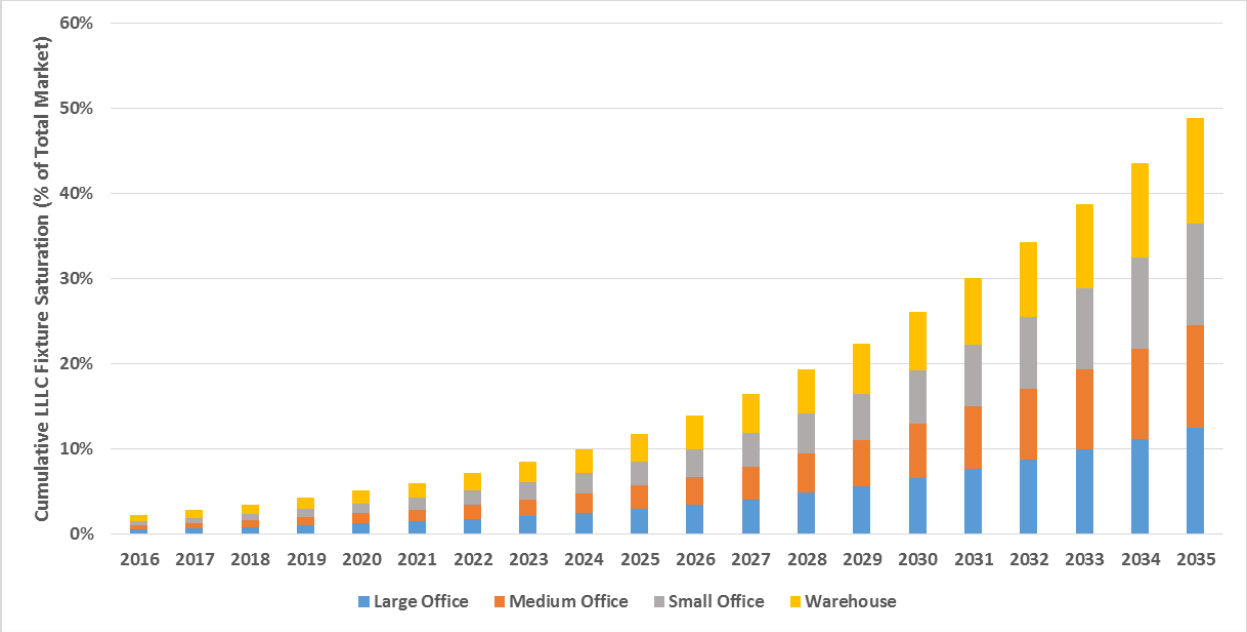
> **Recommendation: Conduct research on powered low-voltage grid system benefits and market awareness.** NEEA should investigate the cost, contractor and end-user awareness, end user benefits, and market uptake of powered low-voltage grid systems to determine if such systems are likely to complement and/or compete with LLLC systems in the new construction and major renovation markets in the near future.

Baseline and 20-Year Adoption Forecasts

The team used information from the market actor interviews, as well as secondary sources—including earlier market actor interviews, the 2014 Market Baseline report from Navigant Consulting, the 2014 Commercial Buildings Stock Assessment (CBSA) dataset, and lighting and lighting controls supply curves recently developed for Northwest Power Planning Council's 7th Power Plan—to update the LLLC baseline assumptions and develop the LLLC adoption forecast.

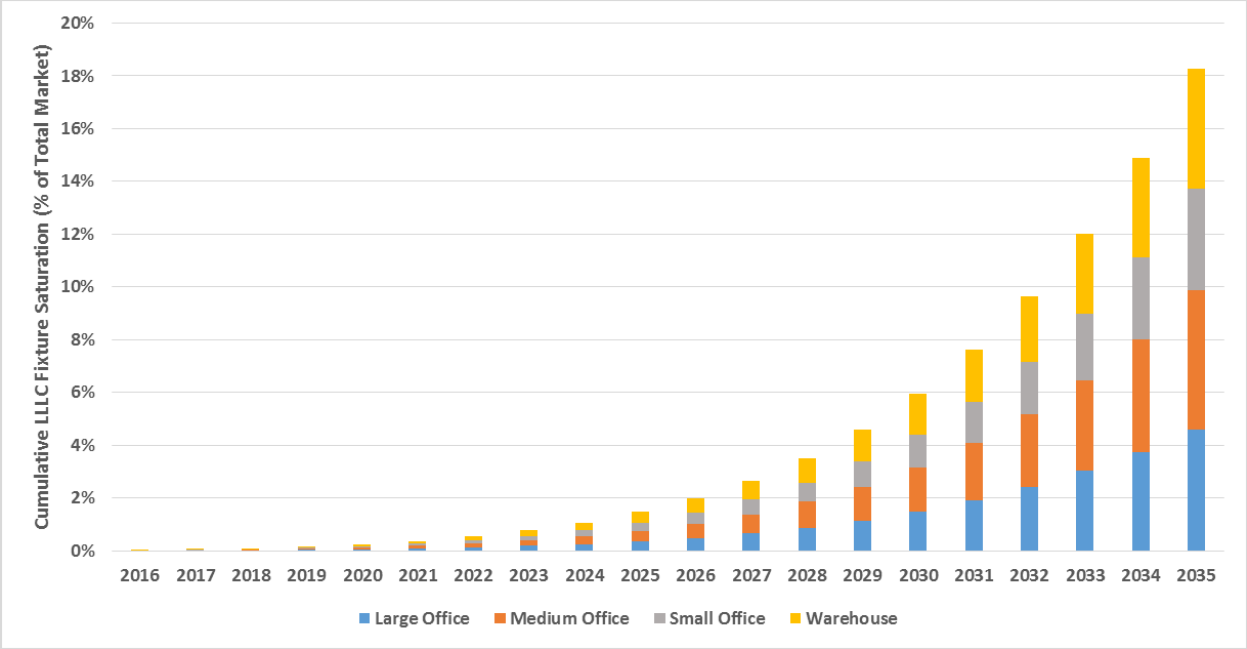
The baseline analysis found the 2016 saturation of LLLC systems is 0.5% of fixtures in offices (large, medium, and small) and 0.8% in warehouses. The 20-year forecast, spanning the years 2016 to 2035, shows a steady increase in LLLC saturation in new construction and major renovations over time, as LLLC systems become increasingly popular and their first costs decrease. Figure 1 depicts the forecast of LLLC saturation in the new construction and major renovation markets.

Figure 1. LLLC Fixture Saturation – Percent of Total New Construction and Major Renovation Regional Stock



The extensive stock of fixtures in existing buildings presents a substantial opportunity for LLLC retrofit installations. Figure 2 shows the forecasted saturation of LLLC systems in retrofits as a percent of the total retrofit market. The forecasted LLLC saturation in the retrofit market is smaller than that of new construction/major renovation market since LLLCs are not compatible with all lighting retrofits.

Figure 2. LLLC Fixture Saturation – Percent of Total Retrofit Regional Stock



1. Introduction

The Northwest Energy Efficiency Alliance (NEEA) is developing its Luminaire Level Lighting Control (LLLC) Initiative to accelerate the adoption of advanced lighting controls in office buildings and warehouses. Unlike conventional systems that control a group of fixtures through a centralized processor, LLLCs are embedded within individual fixtures. They control the lighting output of individual luminaires and can provide autonomous communication and energy reporting. In addition to reducing energy use by providing light only when, where, and at the level needed, LLLCs offer non-energy benefits such as improved worker productivity, reduced worker health costs, HVAC system optimization, and reduced cost of space redesigns.

Development of the LLLC initiative began after a 2013 strategy meeting held to inform the direction of NEEA's two other nonresidential lighting initiatives: Top Tier Trade Ally (TTTA) advanced training, and Reduced Wattage Lamp Replacement (RWLR). Stakeholders who attended the meeting expressed a need to focus on lighting controls which had become—and remain—an important part of the region's overall lighting strategy. At the time, stakeholders were not sure how best to shape an initiative targeting advanced controls, nor how such an initiative could integrate with other nonresidential lighting programs. NEEA developed the LLLC Initiative based on this identified need.

Following a preliminary effort in 2014 to perform a market characterization, NEEA contracted with Research Into Action and its subcontractor, Energy 350, in 2015 to perform a market characterization of LLLC systems using an updated product definition. The research included updating the LLLC baseline assumptions using the new product definition and forecasting LLLC adoption for the next 20 years. As a result of its concurrent work with the DesignLights Consortium (DLC), NEEA restructured the LLLC initiative during the course of this research so that the DLC advanced lighting control specifications and NEEA's product definition align. This restructuring enabled NEEA to rely on DLC's qualified products list (QPL) to identify products with the characteristics NEEA plans to promote.

1.1. LLLC Initiative Status

NEEA staff observed that the initiative is very early in its development. While staff have prepared a thorough logic model that incorporates LLLC's long-term market objectives, staff have yet to completely finalize the initiative's design and its implementation plan.

The initiative currently focuses on addressing these critical barriers to broader LLLC market adoption:

1. **Product Readiness:** LLLC product feature sets are not standardized and are expanding quickly in terms of both options and complexity. The dynamic LLLC market can make it challenging for end users to understand and compare options and to make informed purchasing decisions. Furthermore, while NEEA expects to influence LLLC systems to become easier to install than traditional controls over time, the current generation of

systems require additional training as they differ with complexity for installation and operation.

2. **First Cost:** The higher cost of LLLC systems that offer capabilities comparable to standard one-off lighting controls hinders customer adoption.

3. **Value Proposition:** Due to the limited number of products available on the market, little information or real-world case studies attesting to the potential benefits of LLLCs exist.

NEEA recently collaborated with the DLC to create an advanced lighting controls specification and QPL to standardize LLLC product offerings. At the outset of our research, NEEA was working with a logic model premised on products that exceeded DLC's initial advanced lighting control specification. The DLC-NEEA collaboration helped unify the advanced controls program market. NEEA directly influenced adjustments DLC made to its initial specification, and NEEA restructured its definition of LLLCs. The updated DLC specification now aligns with NEEA's revised logic model and restructured product definition.[1]

1.2. Overall Approach to Market Characterization and Baseline

Our NEEA-approved market characterization and baseline plan for the LLLC initiative consisted of the following activities:

- Interviewing NEEA program staff to gain an understanding of the program.

- Interviewing regional nonresidential lighting experts, LLLC manufacturers, lighting distributors, and a small sample of building owners to: identify and characterize LLLC manufacturers, gain insight into the opportunities and barriers to LLLC adoption, define and characterize the LLLC target market, clarify assumptions about LLLC adoption forecasts, and understand the planned LLLC marketing activities.

- Scanning and analyzing recent U.S. patents to identify technologies that may complement or disrupt LLLC adoption.

- Reviewing secondary data—including market actor interviews Research Into Action conducted in 2014, the 2014 Market Baseline report prepared by Navigant Consulting, 2014 Commercial Building Stock Assessment (CBSA) data, and the Northwest Power and Conservation Council's (NWPCC) recently-developed lighting supply curves—to update the LLLC baseline assumptions and develop the LLLC adoption forecasts that are aligned with NEEA's current LLLC product definition.

[1] Revisions to the logic model occurred mid-way through this market characterization. References to the logic model throughout this report reference the most recent version, which was last revised in May 2016.

1.3. Summary of Accomplishments to Date

As of this report, Research Into Action and Energy 350 had completed the following activities:

- Interviewed four NEEA and implementer staff involved about the planning, management, expected implementation, and marketing of the LLLC Initiative;
- Interviewed seven regional lighting experts;
- Interviewed ten LLLC manufacturers;
- Interviewed nine regional lighting distributors;
- Interviewed four building owners;
- Scanned and conducted a cluster analysis of thousands of recent LLLC-related patents; assessed the likelihood that the 20 patents most closely associated with LLLCs would affect LLLC market adoption;
- Developed updated LLLC baseline assumptions and 20-year LLLC adoption forecasts.

Section 2 of this report describes the team's methodology in greater detail. Section 3 uses the market actor interview findings to describe the LLLC market in terms of product availability, supply chain delivery channels, installations by building type, other market characteristics, barriers and drivers to LLLC adoption, and new technologies that may affect LLLC uptake. Section 4 provides updates to the baseline assumptions and LLLC adoption forecasts, and the final chapter presents the key findings and recommendations from this research.

Appendices to this report include:

- Appendix A: the market actor interview guides used in this research.
- Appendix B: DLC's final Advanced Lighting Control Specification
- Appendix C: the team's interim market characterization memorandum to NEEA.

2. Market Characterization and Baseline Methods

2.1. NEEA Staff Interviews

From September 23 through October 26, 2015, the Research Into Action team ("the team") interviewed four individuals involved in the planning, management, direction, and marketing of the NEEA LLLC initiative. These interviewees included the Program Manager (who has since left NEEA), the Senior Product Manager for Lighting (who has since left NEEA), NEEA's Strategic Market Manager, and NEEA's Senior Marketing Manager.[2] The team interviewed each staff member individually.

These staff interviews sought to:

- Understand the LLLC Initiative's design and status
- Understand the LLLC Initiative's vision, plans, and progress achieved to date
- Examine opportunities and barriers
- Identify and characterize LLLC manufacturers
- Define the LLLC target market and clarify the assumptions used for market penetration, market growth, market size, and market characteristics
- Understand the planned LLLC marketing activities

2.2. Market Actor Interviews

From January 19, 2015 through March 14, 2016, the team interviewed individuals with in-depth knowledge about LLLCs from four distinct market actor groups: manufacturers, distributors, regional lighting experts, and building owners. The market actor interviews sought to:

- Understand the availability of LLLC products in the market and the current sales volume of LLLCs
- Determine whether the currently installed base of LLLC products varies by geography and/or by building type
- Gain an understanding of who installs LLLC products
- Determine if LLLC systems follow traditional lighting supply chain delivery channels

[2] The team only included information from former NEEA staff that is still relevant to the initiative.

- Define market actors' target market for LLLC products in the near term, including LLLC's current market penetration and near-term growth
- Determine the barriers, drivers, and Non-Energy Benefits (NEBs) market actors associate with the installation and adoption of LLLC systems, and determine if NEEA's LLLC initiative appropriately addresses these barriers, drivers, and benefits
- Determine whether manufacturers agree with the DLC specification approach
- Identify whether LLLCs fit in with regional strategies aimed at using open-communication standards instead of relying on individual manufacturers' proprietary communication standards.

Table 1 shows targeted sample sizes and the final number of individuals we interviewed in each category:

Table 1. Market Actor Interview Sample

Market Actor	Target Sample	Achieved Sample	Notes
Manufacturers	10	10	Interviews covered large manufacturers as well as smaller, controls-only manufacturers
Distributors	10	9	Due to other regional efforts involving lighting distributors, the team ceased interviewing distributors to avoid interview fatigue
Regional Experts	3-5	6	Interviewed more than the original target sample, as NEEA required more information from regional experts than was obtained from original sample
Building Owners	0*	4	Building owners are a difficult group of market actors to reach. The LLLC respondents were interviewed as part of the RWLR ongoing market assessment

* Although interviews with building owners were not part of the initial LLLC evaluation scope, interviews conducted through the RWLR evaluation captured information pertinent to LLLCs.

The team developed the manufacturer sample from two data sources:

- The list of manufacturers involved with relevant, prior DLC meetings who also had a history of involvement in utility efficiency programs
- LLLC contacts NEEA provided.

The LLLC, TTTA, and RWLR evaluation teams, all planning to interview lighting distributors during the same time period, collaboratively decided that the RWLR researchers would take the lead with these interviews. Bearing in mind other ongoing regional efforts involving lighting distributors, the RWLR team carefully selected the sample of distributors to be interviewed for the RWLR, LLLC, and TTTA Initiatives. The RWLR team also incorporated the LLLC (and

TTTA) questions into a joint RWLR-LLLC-TTTA interview guide, and led the distributor interview process.[3]

For the LLLC regional expert sample, the team began by reviewing a list of LLLC contacts NEEA had compiled over several years. The evaluators developed the sample by identifying the individuals still actively involved in and knowledgeable about LLLC products, and who could contribute relevant insights into the market. This group was comprised of regional lighting program delivery contractors, utility program representatives, national lab personnel, and individuals involved with the DLC specification and QPL development.

The RWLR team also took the lead with building owner interviews: they selected the building owner sample frame--including both RWLR participants and nonparticipants—based on discussions with NEEA program managers.

2.3. Secondary Research

As part of the baseline and forecasting task, the team reviewed the data sources used in NEEA's prior (2014) LLLC baseline development. Most notably, this entailed reviewing market actor interviews Research Into Action conducted in 2014, and the 2014 Market Baseline report prepared by Navigant Consulting. Both sources included interviews with manufacturers developing or distributing products that met the then-current LLLC specification.

In addition, the team examined and incorporated the 2014 CBSA dataset, which had not been completed in time for the 2014 LLLC baseline estimation analyses. The now-completed CBSA provides updated regional baselines and forecasts of regional building stock and lighting power densities for office and warehouse spaces. The team also reviewed and incorporated the commercial lighting and lighting controls supply curves recently developed for NWPCC 7th Power Plan. These latter two sources provided the team with current market conditions and 20-year estimates of forecasted growth of the installed base of advanced lighting controls.

[3] In some cases, for example when distributor interviewees faced time constraints or were not knowledgeable about all three initiatives, the LLLC and/or TTTA teams conducted separate, initiative-specific interviews.

3. Market Characterization

The market actor interviews resulted in several key findings that confirm the barriers identified in NEEA's revised logic model. Namely, product complexity and availability, first cost, and the overarching value proposition for LLLCs all inhibit LLLC adoption. The interviews also identified a critical need for training for lighting installers, which was not previously identified in NEEA's logic model. Table 2, below, lists the top findings from our market characterization research.

Table 2. Summary of Key Market Characterization Findings

Topic	Finding
Product Availability, Lamp Compatibility, and Sales	All major manufacturers plan to meet the finalized DLC specification for advanced lighting controls by the end of 2016.
	Eight of ten LLLC manufacturers currently offer solutions that work with fluorescent luminaires. These solutions, however, are not installed at the time of manufacture and are likely to be phased out over the next five years as LED costs continue to decline.
	Though LLLC systems are currently a small percentage of overall lighting sales (for all but two of the manufacturers we interviewed), their share of overall lighting sales are expected to grow over the next five years as manufacturers produce more solutions to fit varying customer needs and as LLLC prices continue to decline.
Supply Chain Deliver Channels	In retrofit applications, most LLLC manufacturers use manufacturer reps and regional distributors to sell products to end users. In the new construction and major renovation markets, lighting designers play a key role in LLLC sales.
Installations by Building Type	Market actors agreed with NEEA that offices and warehouses show the greatest potential for LLLC installations. Market actors also suggested educational facilities, and exterior lighting in all building types, as markets with a good deal of LLLC potential.
Target Market Characteristics	Most LLLC systems are now installed using licensed electricians; these are the same market actors who typically install traditional standalone lighting controls.
	Since LLLC manufacturers generally target the niche markets where their systems are most applicable, LLLC there is much less competition in the LLLC market than in the broader lighting controls market.
Adoption Barriers and Drivers	Although manufacturers have different approaches to training and commissioning, manufacturers agree that a lack of training on the installation and commissioning of LLLC systems is a critical barrier to adoption; they report it is more important than NEEA's initial barriers of reducing first cost and addressing market fragmentation.
	According to manufacturers and distributors, code can be an important driver of LLLC system adoption, especially when code requires features such as demand response that LLLC systems can easily accommodate.
	NEBs are important to the promotion of LLLC systems, though they are rarely monetized and included in financial calculations. Once performance metering is regularly included with most LLLC systems, the reduction in program evaluation costs will likely become an important NEB to utilities.

3.1. Product Availability, Lamp Compatibility, and Sales

Interviews with NEEA staff indicated most of the predominant lighting manufacturers already have LLLC systems either ready for market or in development. When NEEA engaged 18 manufacturers during the spring of 2015, over 90% said they were offering advanced lighting controls and the majority were working specifically on LLLC systems.

Though many manufacturers are currently developing LLLC systems, only a few have begun to develop systems that include features beyond those required by the DLC specification. Building automation companies are producing some of the more advanced products, and NEEA staff speculated that market research firms specializing in data collection (such as Jones Lang LaSalle) may soon look to acquire or partner with fixture or controls manufacturers to get marketable data.

In addition to conducting interviews with NEEA staff, the team interviewed manufacturers and distributors and reviewed manufacturers' websites. The team used findings from this research to gauge the availability of LLLC products in the market, their compatibility with light-emitting diode (LED) and fluorescent lamps, and their current sales volumes.

3.1.1. Product Availability

The manufacturer website review confirmed that all ten of the manufacturers in the sample offer a product line considered to be an advanced lighting control system with embedded sensors capable of networked communication. Interviews, however, revealed that only seven of the ten manufacturers have products available that completely meet DLC's final advanced lighting controls specifications.[4] The other three manufacturers offer LLLC products that do not meet the DLC specification for two-way communication and high-end trim, and one of these manufacturers also did not meet software-based reconfigurable zoning. These three manufacturers did, however, anticipate offering products that meet the DLC specification by the third quarter of 2016.

Table 3 lists the DLC specifications' requirements and the numbers of manufacturers who indicated they met those requirements at the time of the interviews.

[4] The DesignLights Consortium has created a specification and qualified products list on advanced lighting controls which can be found here: *https://www.designlights.org/content/CALC/SpecificationAndQPL*.

Table 3. Manufacturers Offering Products in Compliance with DLC Specifications (n=10)

DLC Required Capability	Meet	Do Not Meet
Networking of Luminaires & Devices	7	3
Occupancy Setting	10	0
High-End Trim (aka Task Tuning)	7	3
Software Reconfigurable Zoning	9	1
Continuous Dimming	10	0

Regional distributors provided information only for the products they represent. None of the nine distributor respondents mentioned supply chain issues as a barrier to adoption. Six of the nine distributor respondents carry products from more than one LLLC manufacturer.

3.1.2. LED and Fluorescent Luminaire Compatibility with LLLC Systems

All of the manufacturer respondents who currently have market-ready LLLC products offer LED luminaires that are embedded with LLLC sensors at the time of manufacture. Manufacturers' production of these systems is driven by the popularity of LEDs in the marketplace: distributors and contractors—and their customers—value LEDs' continuous dimming capabilities. In addition, distributors reported that LEDs' lower energy use (than traditional fluorescent luminaires), coupled with their comparable light output, is a selling point.

Eight of the ten manufacturers also offer fluorescent luminaires that can be enabled with LLLCs, though none of these manufacturers embed sensors within their fluorescent luminaires at the time of manufacture. Instead, the luminaires must be retrofitted in the field to install LLLC sensors that work with fluorescents lamps. Two distributors noted a drawback to this retrofit-kit approach: namely that it resulted in added project costs and, in most cases, longer product lead times for the add-on sensors. Furthermore, the current DLC specification states that eligible luminaires must include continuous dimming functionality, which is not a feature inherent to most fluorescent luminaires. Enabling continuous dimming sometimes requires the use of two ballasts, which also increases the cost of LLLC-capable fluorescent luminaires. The eight manufacturers who currently offer fluorescent luminaire products with add-on sensors commented that they are likely to be phased out over the next five years as the penetration of LEDs increases in the market and the cost of LEDs becomes comparable to, or less than, the cost of fluorescents.

3.1.3. Current LLLC Sales

Two of the ten manufacturers reported that 100% of their sales are LLLC systems, though both are newer, smaller companies whose brands are almost exclusively focused on wireless lighting control. Another three manufacturers did not have market-ready LLLC products at the time of the interviews and were therefore unable to comment.

The other five manufacturer respondents were unable or unwilling to estimate their sales of LLLC systems as a percentage of their total lighting sales. These respondents were wary that the percentages they would provide could be linked to their overall sales values, which are proprietary. Several manufacturers also explained that LLLC sales are difficult to estimate because LLLC systems are packaged in many different ways. While some are stand-alone products, others are add-ons to flagship product lines. Further, respondents said that because LLLC systems are sometimes used in just a few locations on larger projects, they were not able to easily separate LLLC system costs from overall project costs during the course of the interview. While they were unable to give a precise number, four manufacturers did state that sales of LLLC systems were a very small percentage of their overall sales.

These five manufacturers all expect their LLLC product lines to expand in the coming months so they can accommodate a greater range of customer needs. As a result, they anticipated their sales of LLLC systems as a percentage of their overall sales would rise as well. One predicted its LLLC sales for the current calendar year would reach 30% of its total sales if they counted luminaries that shipped with sensors already installed, regardless of whether the luminaires were used in a networked LLLC system or not.

The team asked manufacturers whether their LLLC sales differed by geography, both by region of the country and by urban versus rural locations. Three of the ten manufacturers reported that, within the Northwest, greater numbers of their LLLC products have been installed in Oregon and Washington than in Idaho and Montana. Four manufacturers said the majority of their LLLC installations sites are in California, and attributed this to California's recent code changes favoring LLLC systems in new construction and major renovation projects. All four of these manufacturers added that their LLLC sales are greater on the east coast and California, where the incentives for lighting controls are richer than they are in the Pacific Northwest.

Manufacturers provided less information about differences in sales between urban and rural areas: seven of the ten manufacturers said they did not have sufficient sales data to comment on differences between urban and rural areas. While two manufacturers reported greater LLLC sales in metropolitan areas than in rural areas, these two manufacturers focus primarily on office retrofit spaces which are concentrated in more urban areas. Another manufacturer that specializes in lighting for warehouse and manufacturing facilities observed that their LLLC installations vary geographically based on where these building types are located, rather than on whether customer sites are in urban or rural areas.

During the course of our conversations with distributors, they commented that the uptake of LLLC systems is likely to increase over the next three years due to the increasing ease of installation, user friendliness of the product, and availability of utility incentives for controls.

3.2. Supply Chain Delivery Channels

The LLLC retrofit supply chain is evolving much more quickly than anticipated. When NEEA discussed the supply chain with LLLC manufacturers in the spring of 2015, NEEA learned that, due to the complexity of LLLC systems at the time, manufacturers commonly owned and managed the entire supply chain--from system production to sales and installation.

Recognizing that the one-off, highly customized nature of LLLCs prevented LLLC systems from growing beyond a niche market, NEEA staff focused on developing LLLC standards that would enable the products to be sold more broadly through traditional lighting sales channels, going from manufacturer representatives, to distributors, to installation contractors.

When NEEA staff were interviewed in 2016 for this study, they reported that LLLC system supply chains varied by manufacturer size. The largest manufacturers sold LLLC products through traditional distribution channels while most small controls manufacturers, on the other hand, commonly partnered with larger, established luminaire manufacturers and automation companies: through these arrangements, the smaller companies had their controls installed into the larger companies' luminaires. Based on these conversations, NEEA expected it would be several years before LLLC systems from all but the largest manufacturers would be sold through traditional distribution channels.

However, the Research Into Action team's interviews—conducted just one year after NEEA's discussions with manufacturers—suggest that the LLLC retrofit supply chain has changed a great deal over a relatively short time period. Nine of the ten manufacturers interviewed in 2016 reported that the bulk of their LLLC systems now find their way to end users through traditional market channels. That is, they generally rely on manufacturer representatives working with electrical distributors to provide products to end users.

While this supply chain channel is a primary source of sales, the nine manufacturers also reported that they still sell LLLC systems directly to large accounts (e.g., Fortune 500 companies), and many of these manufacturers offer these customers tailored full-service solutions. The one manufacturer that does not follow this pattern offers end users a turnkey solution or sells their products through Energy Service Companies (ESCOs).

Both manufacturers and distributors reported that, unlike in the retrofit market—where a manufacturer representative or electrical distributor may specify or promote a LLLC system—in the new construction and major renovation markets, lighting system designers act as one of the primary LLLC product specifiers. (lighting system designers are also the primary specifiers for traditional, standalone lighting controls in the new construction market). Manufacturer representatives and distributors act as sales agents to lighting system designers: they promote the products they understand to be most appropriate for the project.

One distributor elaborated on the lighting system designers' role in new construction and major renovation projects. He explained that his organization commonly finds multiple sensor options specified at the outset of a project so that the project can qualify for utility rebates. Moreover, the distributor said the lighting system designer must be involved in all cost-cutting decisions regarding the lighting and control system. **This finding suggests that lighting system designers play a large role both in specifying LLLC systems during a project's design phase, and in preventing LLLC systems from being removed from the design during the construction phase.**

3.2.1. Supply Chain Evolution

In the future, and especially with the advent of more advanced products, NEEA staff predicted that manufacturers of LLLC systems are likely to offer lighting-as-a-service in addition to a commoditized product. Staff agreed that the data acquisition possibilities offered through advanced LLLC systems coupled with lighting-as-a-service may advance products faster than traditional development cycles. While this is not expected to be an immediate shift for all products, it is happening already with several notable manufacturers.

Interviews with manufacturers confirmed that lighting-as-a-service is indeed occurring already, but only one manufacturer indicated that it would make up a significant percentage of the lighting market sales in the future. Two manufacturers questioned the added value that lighting-as-a-service offers, indicating that energy management-as-a-service made more sense, and that lighting may become a component of that, but not necessarily as a standalone service offering. Another manufacturer commented that, while it is tough to predict the future, the traditional path to market has been a multi-billion-dollar industry, which presents a significant challenge to introducing a new market channel model.

3.3. Installations by Building Type

When asked about the types of buildings where LLLC systems have been installed most often, the market actors most frequently named commercial offices. Table 4 summarizes the building types where manufacturers, distributors, and regional experts think LLLC systems have been installed most often. Furthermore, among the eight manufacturers who said commercial office space has been biggest target for LLLC installations, six expounded by saying there is more potential for LLLC installations in the new construction/major renovation market than in the office retrofit market. The other two thought the retrofit market holds greater LLLC potential.

Table 4. Building Types where LLLCs Have Been Installed Most Often

Building Type	Manufacturers (n=10)	Distributors (n=9)	Regional Experts (n=6)	Manufacturers NC/MR: Retrofit*
Commercial Offices	8	5	3	6:2
Warehouse/Distribution	3	4	4	1:2
Education	5	1	1	3:2
Industrial/Manufacturing	2	2	3	1:1
Retail	2	2		1:1
Hospitals/Healthcare	3	1		1:2
Parking Lots/Garages	1		1	0:1
Cold Storage	1		1	0:1
Stadiums	1			0:1
Convention Centers	1			1:0
Government/Municipal	1			1:0

* NC/MR means new construction or major renovation.

Since the manufacturers we interviewed offered a range of products with varying features and benefits targeted at distinctive markets, they offered differing views about the size of offices with the greatest potential for LLLCs. One specifically stated there is greater potential in large offices, while another thought there is great potential in offices more generally, regardless of size. Nonetheless, all of the manufacturers mentioned that because larger installations produce better returns on investment (ROI), LLLC systems are less likely to be "engineered out" during a large project's construction phase. That is, LLLCs are more likely to actually get installed in larger spaces. Manufacturers also explained that systems using wireless communication are good candidates for major renovations because their installation:

- Does not require moving power systems, and thus eliminates the need for new wiring;
- Does not require work above the ceiling grid, and therefore keeps asbestos and other unknown substances in the ceiling contained; and
- Enables simple one-for-one change-outs while still maintaining acceptable light levels, rather than requiring layout changes.

Among the interviewed market actors, regional experts also noted that LLLC systems have great potential when retrofitted into warehouses and industrial facilities. The low occupancy rates and high-wattage luminaires in these types of facilities result in high ROIs, making LLLC systems an attractive option.

Several manufacturers also saw good potential for LLLCs in warehouses and industrial facilities. They explained that warehouses are often interested in installing LLLC systems to eliminate the need for control wiring routing over long spans through high-bays. The manufacturers elaborated

that LLLC systems coupled with LEDs yields the additional benefit of reducing bulb replacement maintenance, a significant value proposition to facilities with high-bay spaces.

Five manufacturers also stated that education facilities may offer good potential for LLLCs. Because these facilities have predictable hours of operation, they are a natural fit for the expanded feature sets of LLLC systems (for example, color tuning can be focused to keep students awake after lunch and to quiet them down after recess). These manufacturers recommended they be considered as a target for the LLLC initiative.

Manufacturers said they have seen more LLLC systems in the new construction market for several building types (namely offices, education facilities, convention centers, and government facilities) as designers become increasingly comfortable with wireless technology. In fact, they noted that designers often act as specifiers for these products. Similar to the major renovation market, manufacturers reported that large cost savings can be realized for the majority of luminaires in the new construction market by installing LLLCs and thereby eliminating the need for installers to pull large amounts of electrical wire.[5]

3.4. LLLC Target Market Characteristics

NEEA staff explained, during interviews we conducted in late-2015, that while a large portion of the commercial lighting efficiency activity was in the retrofit market, due to the high first cost and system complexity associated with LLLCs, decision-makers were considering LLLC products for inclusion only in major renovation and new construction projects. LLLCs were, and generally still are, cost and resource prohibitive when simple lamp change-outs are all that are being considered. Thus, NEEA initially focused the LLLC Initiative on the new construction (NC) and major renovation (MR) markets, specifically in office and warehouse spaces. The staff elaborated on their reasoning for targeting these markets:

- LLLC products in NC and MR are relatively easy to install and commission; LLLC products in retrofit settings can be considerably more difficult to install and commission, especially with the myriad of existing fixtures and lamp types that may exist.

- Given the larger budgets and broader scopes of NC and MR projects, the integration of lighting with other building systems—an advantageous capability of LLLCs—is more feasible in the NC and MR markets. From a lighting design perspective, an entire office or facility should be viewed as one entity to ensure overall project cost-effectiveness.

- Since cost-effectiveness is a major criterion when considering whether to install LLLCs, spaces with higher lighting power densities (LPDs) have greater savings potential than spaces with lower LPDs. Thus, even with code advances, past demonstration projects through NEEA and several utility efficiency programs in California have identified office

[5] Electrical codes in the Northwest still require a wire to run from a manual wall switch to the primary lighting luminaire in a space, therefore not all wiring costs can be eliminated.

(especially open office) and warehouse spaces as having the greatest energy-savings potential for LLLC applications. For example, one interviewee noted that because code requires only the simplest of automated control for open offices, savings from LLLCs in those spaces could be 40% or greater.

Over the course of our research, NEEA staff reported that LLLC retrofit products had matured to the point that the retrofit market would become part of the LLLC Initiative's target market. While NEEA staff expected early adoption of LLLCs to occur in office and warehouse major renovation and new construction projects, they also anticipated that forthcoming retrofit kits would allow retrofit projects in offices, warehouses, and other types of buildings to adopt LLLCs in the near term. **The findings from the market actor interviews corroborate that the retrofit market is maturing at a much faster pace than NEEA initially expected.** The team gleaned information about the retrofit, new construction, and major renovation markets through our discussions with market actors about:

- Key commercial lighting decision makers
- The installer base for commercial lighting
- The installation and commissioning of LLLC systems
- The communication protocols currently employed by LLLC systems and the rationale for their selection
- The types of lighting systems on which LLLC systems are currently and projected to be installed

We present our findings on each of these topics, in turn, below.

3.4.1. Key Decision Makers

Though five of the six the manufacturers who answered questions about LLLC decision makers said that facility managers contribute to those decisions, they gave varying answers about the other market actors who are involved and the reasons for those actors' involvement. Only one manufacturer reported that LLLC decisions makers are largely the same as the decision makers involved with stand-alone lighting controls, namely facility managers or owners/property managers. Table 5 shows the responses from all six manufacturers.

Table 5. Key Decision Makers Involved with Lighting and Controls System Selection (n=6)

Manufacturer	Manufacturer Focus	Decision Maker	Reason Why Involved
C	NC & Retrofit Warehouse & Office	Facility Manager	LLLC systems are more expensive than standard controls and many people use them. Also, facility managers are able to compare energy use across multiple facilities and make decisions.
D	Retrofit Warehouse	Facility Manager and Operations department	These actors have a strong interest in facility operational information for their line of business (e.g., utilization of process machinery or product layout).
G	NC Office & Education	General Contractor & Design Team	In new construction, the project "driver" is the key LLLC decision maker, except where the building owner opts to involve himself/herself. In the retrofit market, building owners are more typically engaged.
H	Retrofit Office & Retail	All (Facility Manager, Property Manager, Owner, Architect, Designer, Engineer)	None given.
J	Retrofit Office	Facility Manager, General Contractor, Owner	Same decision makers as traditional standalone controls.
K	Retrofit Office, Education, Healthcare	Facility Manager, Property Manager	Whichever market actor has a vested interest in the health of the building.

Responding to a similar line of questioning, one distributor commented that **the Northwest is generally a designer/specifier market—as opposed to a general contractor market**— so designers/specifiers naturally play key roles in making decisions about energy-efficient lighting options. Four manufacturers and two distributors independently supported this claim, stating that they have witnessed lighting designers play a critical role in LLLC system installations.

With such a small sample, the team cannot confidently conclude that the key decision makers who opt for LLLC systems are different from those who opt for traditional standalone controls. Nonetheless, because the market actors listed in NEEA's logic model closely match those the LLLC manufacturers identified as key decision makers, the team believes that NEEA is pursuing an appropriate set of market actors through the LLLC initiative.

3.4.2. Installer Base, Training, and Commissioning

Similar to the findings regarding the supply chain delivery channels, nine of the ten manufacturers said traditional lighting market actors, primarily licensed electricians, generally install their LLLC products. The remaining manufacturer offers a turnkey solution and therefore rarely relies on traditional lighting installers.

Although most manufacturers reported that the contractors who install their LLLC systems are the same people who install standalone lighting controls, the manufacturers' commissioning and training requirements vary substantially from one another. Eight of the ten manufacturers typically use their own trained staff or manufacturer's representatives to commission LLLCs, though four of the eight also permit third-parties to commission their systems. Of the four who permit third-party commissioners, only two provide training for third-party commissioning staff and end users:

- One requires third-party staff to attend a two-day training course that includes a pre-qualification quiz and mockup jobsite walk
- The other requires third-party staff to be manufacturer certified and trained on their LLLC system

The remaining two manufacturers in that group do not currently open their training to third-party commissioning staff. Both manufacturers, however, believe that training is a key to successful adoption of their product and plan to be involved with the DLC's open training program in the future.

Several manufacturers who do not use third-parties to commission their products explained they do not need to do so because the **ease of commissioning is a key feature** of their LLLC systems. (Distributors and regional experts also thought that user-friendly products that are simple to commission are more likely to be adopted in the future.) These manufacturers intentionally designed their LLLC products to be easier to install and use than traditional lighting controls. Three of the ten manufacturers stated that commissioning was a minor endeavor involving only 15-20 minutes of setup once installed, or that the product comes pre-commissioned and requires almost no intervention on the part of the installer or end user once connected. The manufacturers who focused on the ease of commissioning stated that they generally offer training only when installers or end users specifically request it after an installation is complete.

Table 6 shows the varying commissioning and training services offered by the ten manufacturers we interviewed.

Table 6. Manufacturers' LLLC Commissioning and Training Offerings (n=10)

Manufacturer	Self-Perform / Field Rep Commissioning	Use 3rd Party Commissioning	Minimal Commissioning Required	Offers Training
A	X	X		X
B			X	X
C	X	X		X
D	X			X
E	X			
F	X	X		
G	X			X
H	X		X	
J			X	
K	X	X		

Although LLLC products are often easier to use and install than other types of lighting controls, NEEA staff interviewees stressed the need for increased training aimed at LLLC installation professionals. As LLLC products mature and as lighting shifts to more networked systems, lighting contractors will find they need additional IT expertise to interface more and more with building IT staff. To acquire such expertise, NEEA staff indicated that contractors will need advanced training that is outside the traditional lighting training regimen. **Distributors, manufacturers, and regional experts agree with NEEA's assessment that training of the lighting installer base is a critical component to widespread market acceptance and adoption of LLLCs.**

Staff from NEEA indicated that they intend to integrate LLLC systems into other ongoing NEEA initiatives. In particular, training for LLLC systems is a key barrier to increased adoption, and the lighting installer workforce will eventually need training on how to install these systems. Integrating the LLLC systems into established training programs, such as NXT Level training program, would provide a wider skillset to trade allies and increase the overall awareness of the product.

Integrating LLLCs into the existing NEEA training program may speed market adoption and help address the market barrier discussed in the following section. LLLCs may also be highlighted through other non-training initiatives, such as Commercial Real Estate (CRE), through incorporation into literature that informs building owners of potential savings opportunities.

3.4.3. Target Market

The team asked manufacturers about the types of customers they pursue and how they persuade customer key decision makers to install LLLC systems in lieu of traditional stand-alone controls. The interviews revealed that, while many manufacturers have systems that could compete with one another, almost all of the manufacturers **target specific niche markets with their respective flagship products**. As a result, the LLLC manufacturers generally do not compete for the same end users. This is especially true of smaller LLLC manufacturers who only have one product offering to satisfy a particular target market. This finding indicates that the LLLC market is highly fragmented. The interviews also revealed that the tactics manufacturers use to sell LLLCs vary based on their customers' primary interests. Some customers, for example, primarily pursue LLLCs as a means of improving the lighting in their space, while others pursue LLLCs to provide increased business intelligence.

For example, although eight of the ten manufacturers target commercial offices, each of the manufacturers interviewed targets a different set of commercial office end users with their flagship product line, each with its own specific needs. One manufacturer primarily focuses on offices looking for a simple, pre-packaged solution that requires little commissioning, comes programmed with typical set-points for dimming based on previous installation feedback, and allows for very limited user control. This manufacturer's system is competitively priced with standard controls packages. While the manufacturer does offer other controls solutions, its primary LLLC system is intended for use in open office areas where clients prefer systems with limited individual control so as to minimize disruptions in the shared space.

In contrast, another manufacturer that also targets commercial offices sells a higher-end product that aims to not only improve a space's lighting and energy usage, but also provides a great deal of user control and integrates lighting with other building systems. The manufacturer explained that its target market includes end users interested in data acquisition who think about business intelligence and view lighting as one possible solution. The end users in this manufacturers' target market, therefore, are unlikely to be interested in the same line-up of LLLC systems as the end users in the previous manufacturers' target market who seek relatively simple LLLC solutions.

Similarly, the manufacturers that target warehouse spaces offer LLLC systems designed for specific types of end users. One such manufacturer promotes its product to customers by explaining that the warehouse's relatively long hours of operation and low occupancy rates, coupled with the LLLC product's reduced maintenance costs, renders the LLLC system very cost-effective. In addition, the manufacturer describes its value proposition to prospective customers by explaining that its product offers not only overall light reduction and energy savings, but also a wealth of information about safety and productivity that customers can use to benefit their businesses. This manufacturer has found a niche customer base that values the increased business intelligence its product provides, enabling its customers to remain competitive in their specific lines of business.

Conversely, two other manufacturers that sell LLLC systems for warehouses offer pre-packaged solutions similar to the open-office solution described above. One of these two manufacturers

also offer a more holistic system that compares energy use and business intelligence across a portfolio of facilities. Since these products address customers with specific needs, the target markets for these manufacturers are quite different from the markets targeted by manufacturers whose products focus primarily on lighting energy savings.

Our findings also suggest that several manufacturers are targeting their products to end users whose information needs match the LLLC system's data acquisition and reporting capabilities, more so than to end users seeking a particular type of control system.

3.5. Adoption Barriers and Drivers—Including Non-Energy Benefits

In its logic model for the LLLC Initiative, NEEA identified nine primary barriers to LLLC adoption shown in Figure 3.

Figure 3. Key Barriers to LLLC Adoption

While the revised logic model addresses High Cost, Value Proposition, and Lack of Awareness as the key barriers being targeted as part of LLLC product development, NEEA staff interviewees indicated that the additional barriers listed above will be addressed over time once DLC has a significant number of products listed in its QPL.

To confirm the significance of these key barriers, the team interviewed with manufacturers, distributors, and regional experts about the barriers and drivers currently influencing adoption of LLLC systems. Researchers segmented interview questions into three different barrier sets: Adoption, Installation, and Utility Engagement. The interviewees also provided insight into the NEBs most valued by end users, as well as the NEBs promoted during the sale of LLLC systems.

3.5.1. Adoption Barriers

The team used the barriers identified in NEEA's original LLLC logic model as a starting point to discussions about market barriers and market drivers. Researchers asked manufacturers to rate, on a scale of 1 to 5 (with 1 being "not important" and 5 being "very important"), the importance

they placed on addressing each barrier. The results are shown in Table 7. Note that the table reports the mode of each response, rather than the average, to clearly illustrate the importance the majority of (the small sample of) respondents placed on each barrier.

Table 7. Barriers Manufacturers Perceive to LLLC Adoption (n=9)

NEEA Identified Barrier	Mode
Limited understanding of the capability, viability, and availability of LLLC products	5.0
LLLC systems appear too complex to be installed and commissioned correctly	5.0
Limited trained support network established for installers, building IT, & facilities	5.0
A lack of a clearly defined business value for LLLC products	5.0
High first costs for LLLC products & installation, making payback untenable	3.0
Perception of poor product persistence, serviceability, or re-configurability	1.0
Market fragmentation in terms of networking standards, communication protocols, and what even constitutes an advanced lighting control	1.0
Concerns over LLLC aesthetics, complexity, and possible user impact	1.0

NEEA staff interviewees stated that the initiative will primarily seek to reduce market fragmentation, and subsequently explore opportunities to bring down the first cost of the product through upstream and mid-stream incentive design. On a parallel path, participating in demonstration projects to develop case studies that showcase the value proposition of LLLC systems will aid in setting up the market for increased adoption.

While all of the manufacturers agreed that NEEA addressed important barriers to LLLC adoption, they remarked that several of the barriers identified as critical in the original LLLC logic model were not as important as others. As an example, all but one manufacturer noted that the fragmented market, identified as a critical barrier in NEEA's logic model, was not influential to the future adoption of LLLC systems.

The fact that eight of the ten manufacturers operate with proprietary communication protocols and do not perceive open-source communication systems as a significant benefit to the end user may support this perspective. Furthermore, when regional experts were also asked about the importance of addressing the fragmented market, none mentioned the lack of an open-source communication protocol as a significant barrier. Instead, both manufacturers and regional experts stated that open-source end-to-end communication (that is, between the lighting system and the building management system) was more important than open-source point-to-point communication between luminaires.

Manufacturers stated their preference for a proprietary communication was because manufacturers typically "own the system" once it is installed, and they would not be able to guarantee that an ecosystem of third-party sensors and luminaires would interact correctly with their system if it were developed as open-source. They added that commissioning also becomes more complex once a variety of third-party sensors are used, even if the protocol is open-source.

Many manufacturers also explained that current open-source standards do not have sufficient bandwidth to take advantage of all of the features offered with their LLLC systems, and that removing those features to comply with open-communication standards would remove the competitive edge of LLLCs over traditional controls. While two of the eight manufacturers said they might move to a non-proprietary communication protocol if standards advanced to accommodate their systems requirements, many were wary of open-source communication security issues. Only one manufacturer currently offers a system that uses open-source communications and noted that the primary benefits are price and customization for the end user.

3.5.2. Installation Barriers

Researchers also asked interviewees to discuss installation barriers, such as the difficulties of LLLC systems to be specified, installed, and set up correctly. Eight manufacturers stated that there is inadequate training on system installation and that this lack of training is a key barrier to adoption. One manufacturer added that **the evolution of these systems over the next five to ten years will require advanced installer and end user training to ensure LLLCs are properly integrated into other building systems.** Only the two manufacturers who focus on ease of commissioning and perform their own system commissioning did not view inadequate training as a barrier.

All of the NEEA staff interviewees indicated that first cost is a considerable barrier that needs to be addressed. Staff generally agreed that because electronics and networking capabilities are the chief differentiators of LLLC systems compared to traditional lighting controls, these products are likely to follow the faster-moving consumer electronics trends in terms of product advancement and commoditization. Furthermore, competition from manufacturers engaged in this faster-moving product development cycle will help drive down product costs at a faster rate than has been seen in previous lighting technology changes.

Our market actor interviews found that while six out of ten manufacturers mentioned first cost as a barrier, they did not think it was as important as other barriers. Both regional experts and manufacturers stated that the first cost of LLLC systems was declining, and the payback was already in a financially viable range for many end users.

However, several manufacturers commented **that installers commonly overestimate the costs of LLLC systems in their bids**, explaining that the over-stated bids are due to installers' lack of familiarity with LLLC products and their wariness about the amount of time required to correctly commission the systems. With the increased labor costs for installation and commissioning, end users often conclude that the first cost of LLLC systems is too great to create a financially viable payback. Distributors and manufacturers stated that this significantly limits the adoption of LLLCs since **many LLLC systems get value-engineered out of the design.**[6] Both

[6] Value-engineering is the process of removing design elements deemed "non-essential" by the contractor, design team, and/or owner in an effort to save on construction or operating costs.

manufacturers and distributors therefore perceive installers as key market actors in furthering the adoption of LLLC systems, especially as LLLC feature-sets continue to expand.

3.5.3. Efficiency Program Barriers

The third key barrier dealt with utility efficiency programs and barriers that exist for manufacturers trying to incorporate their system into utility incentive programs. Three manufacturers see the Northwest utilities' current LED incentives as one of the greatest barriers to LLLC adoption. Because the region's LED incentives are so robust, the manufacturers thought that the value proposition for adding an LLLC system gets marginalized, and it becomes much easier to value-engineer LLLCs out of a lighting upgrade if costs and timeline are a concern for the end user. Three regional experts and four manufacturers agreed that, due to the long life of LEDs, once an LED system gets installed it becomes a missed opportunity for installing controls.

NEEA staff explained that the current trend of rapidly increasing LED adoption may present a barrier as well as an opportunity. Specifically, while the surge in LED installations may enable LLLC systems to gain a foothold if the two technologies are installed at the same time, LEDs that are installed with either stand-alone controls, or no controls at all, may remain in service as-is for 20 or more years. Without a need to replace or update these lighting systems for many years, the opportunity to embed sensors into existing fixtures will either be lost or accomplished only through less cost-effective add-on products.

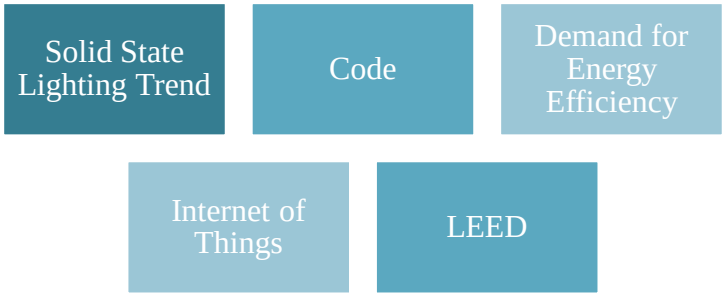
One regional expert and one manufacturer offered different perspectives. The expert opined that manufacturing a device that lasts for 20 or more years is not sustainable from a business perspective unless the manufacturer shifts to a different model or owns an extremely large share of the overall market. Along similar lines, one manufacturer said that due to their customers' changing demand, their company is transforming from a lighting-only company into an information services company.

As noted above, the barriers listed in Table 7 are based on the original LLLC logic model. The revised logic model includes barriers focused on increasing awareness, lowering first costs, and reducing the complexity of LLLC systems. This closely aligns with the team's findings from the market actor interviews.

3.5.4. Adoption Drivers

Along with barriers, NEEA's initial logic model identified several opportunities for LLLC. These are shown in Figure 4.

Figure 4. Key LLLC Opportunities



The current LLLC strategy strives to capitalize on the trend of increasing SSL installations and incorporating LLLC systems into regional energy codes. NEEA staff thought that once designers and specifiers can meet energy code requirements by incorporating LLLC systems, they will be more likely to choose LLLC products for new construction and major renovation projects in the future. This strategy has already realized some success: LLLC systems are listed as an alternate compliance option to meet automated lighting controls requirements in the 2016 Washington State Building Energy Code.

In line with capitalizing on rapidly evolving trends, commercial lighting efficiency programs are increasingly targeting the replacement of linear fluorescents with LEDs across all building types. All interviewees said they expect the SSL trend to serve as an entrée to increased adoption of LLLC systems. SSL has introduced the potential for the devices that control task lighting to also control other end uses such as plug loads. In this way, the first LLLC products can pave the way for more advanced LLLC systems that will interface and potentially drive whole-building systems.

NEEA staff also agreed that the benefits of LLLC depend on space type, and that recognition of, and interest in, those benefits ultimately depend on the end user. They noted that in all spaces, LLLCs that rely on a mesh network communication are significantly easier to install and to use than other centralized advanced lighting controls. In offices, for example, the versatility afforded by LLLCs in redefining fixture zones can eliminate the need for rewiring when office setups are changed. In warehouses, LLLC installations reduce forklift traffic accidents because workers can better see when forklifts were coming.

3.5.5. Code Integration

A second tenet of the LLLC initiative's design is through the integration with energy codes. NEEA's regional lighting strategy deals with codes and adoption and the design of the initiative is aimed at standardizing the definition of LLLC products so that integration into regional energy codes can be obtained in the future.

For commercial office spaces specifically, all ten manufacturers included code requirements as an important driver to adoption. They cited the example of California, where a recent change in the state's Title 24 code requires automated demand response capabilities for lighting in new construction and major renovations. Four of the ten manufacturers noted that California's code changes have led to a large increase in LLLC adoption in that state. Furthermore, they reported that Title 24 requires a third-party agent to commission the building's systems (in order for the building to receive a certificate of occupancy). This requirement has led to the development of LLLC systems that can be easily commissioned because manufacturers want to ensure the commissioning process is not the cause for a delay in a building's occupancy.

On the other hand, one manufacturer commented that energy codes can be a double-edged sword. While more controls may be installed as a result of the code, if the code is not enforced, installers and end users will seek—and find—loopholes. Two manufacturers noted that building codes for the retrofit market can also be barriers—rather than drivers—to LLLC adoption. They described recent experiences in California where building owners who may have considered installing lighting controls opted instead to forego the retrofits altogether, fearing that the upgrade might require them to pull a permit which would increase the expense and duration of the retrofit.

3.5.6. Non-Energy Benefits

NEEA staff unanimously agreed that the NEBs of LLLC systems are likely to play a large role in the successful adoption of LLLCs, and in many cases will be more important to market acceptance than LLLCs' energy reduction benefits. NEEA staff said building owners and occupants see improved worker productivity and reduced health costs as one of the largest potential NEBs of LLLC systems. Similarly important is the reduced cost of space reorganization made possible by the lack of having to re-wire fixtures. Farther down the list of importance to building owners and occupants are building efficiencies such as space, maintenance, and HVAC system optimization. Several NEEA staff reported that energy savings are of lesser importance.

When asked about their customers' reasons for choosing to install LLLC systems, six of nine manufacturers stated that energy savings were the primary driver. When coupled with utility rebates, they find that the large energy savings that result from low-cost sensor integration—offering daylight harvesting, occupancy control, and dimming—render LLLCs an attractive option to end users.

One manufacturer, however, noted that dollar value of energy savings is typically small relative to an end user's rent, and smaller still relative to the end user's wages. This manufacturer felt that **to provide value to the end user, LLLC systems need to do much more than save energy**; they need to tie lighting controls to the people in the space and provide information on how that space is used.

Another manufacturer stated that the lighting market is primarily driven by cost and a manufacturer's ability to offer different solutions to meet each end user's needs. Since low-end, commodity luminaires still comprise the bulk of sales, this respondent thought that integrating

inexpensive, efficient lighting with controls meets end users' desires for low-cost tailored solutions, and is therefore key to increasing LLLC adoption.

NEEA staff reported that they may promote the value proposition of LLLC systems, at least initially, largely based on the NEBs associated with them. The NEBs of some products are on the micro-zone level (for example, sensors that adjust light levels to better suit individual user needs, therefore reducing complaints and increasing productivity). More advanced products are data-driven (for example, offering data on space utilization and possible improved security that stems from networked occupancy sensors). Due to the many and varied NEBs of LLLCs, several NEEA staff also believe that LLLCs are likely to eventually be offered as a service—rather than a product—by lighting companies, IT providers, utilities, and others.

Staff interviewees also understood that LLLC systems may not be cost-effective from an energy efficiency standpoint at the onset. Part of the long-term vision is to develop a clear business case for LLLC and to focus on many of the NEBs that these systems can provide. Over time, as more systems get installed and case studies are generated, the NEBs will help increase the value proposition of the product as well as make it a more cost-effective resource for utilities to invest in.

The team asked manufacturers, distributors, and regional experts, which NEBs they promote most often and which NEBs are most frequently requested by end users. Most manufacturers promoted and heard requests for a variety of NEBs, and all were in agreement that the importance of NEBs is highly dependent on each customer's specific needs. Table 8 shows the NEBs mentioned by all sets of three market actors.

Table 8. Non-Energy Benefits of LLLCs

Non-Energy Benefit	Industry
Gunshot detection to dispatch emergency response	Municipal
Room occupancy tracking	Hospital
Ad targeting using Bluetooth sensing	Retail
Color temperature adjustment to stimulate activity	Office, Education
Space re-configurability without re-wiring	Office
Asset tracking with Radio Frequency Identification (RFID) tag integration	Hospital
Comfort level from dimming instead of on/off	Office
Space planning based on daily activity	Warehouse
Security and communication between teachers during crisis	School

None of the manufactures offered methodologies for quantifying the value of these NEBs for use in utility efficiency program financial calculations. While they do promote the NEBs of their systems and describe how they help meet their customers' needs, the manufacturers explained that aside from quantifying reductions in maintenance for longer lasting equipment, they do not include NEBs in payback calculations or incentive applications.

Several regional experts noted that one of the largest NEBs they see contributing to the future adoption of LLLCs will benefit utility efficiency programs rather than end users: once onboard energy performance metering becomes commonplace for LLLC systems, utility programs will be able to rely on the information from these systems in lieu of costly site evaluations and project verification. One expert also noted that the creation of an industry performance metering protocol will provide defensibility to utility programs, reduce the economic burden of performing evaluations, and increase trust among regulators.

3.6. Disruptive Technologies

The Research Into Action team examined recent patent filings to determine whether there are technologies likely to emerge in the next several years that may disrupt or complement the adoption of LLLC systems. The team employed the services of Professor Tugrul Daim, director of Technology Management at Portland State University's (PSUs) Engineering and Technology Management Department for this task. Professor Daim specializes in Social Network Analysis (SNA)—a general approach for investigating social structures or networks and the relationships between them.

To begin, the team provided PSU with a list of key terms to use as indicators in PSU's patent/technology scanning process. Though the team considers basic lighting controls, such as dimming, occupancy sensing, and daylight harvesting to be standard lighting control systems, the team included them in the product scan to learn whether they appear in technologies other than luminaires and traditional standalone lighting controls. Table 9 lists key terms that are associated with advanced lighting controls—which may be either complimentary and/or competitive with LLLC systems–and can be used to identify patents that reference similar terms.

Table 9. Key Indicators for Complimentary or Competitive LLLC Technologies

Keyword	Significance
Light Fidelity (LiFi)	Visible light communication embedded within luminaries is understood to be complimentary to WiFi and may offer faster connection speeds
Power over Ethernet (PoE)	A way to provide wiring between luminaries to allow for low-cost autonomous communication and networking
Asset Tracking	A significant non-energy benefit currently touted by many LLLC manufacturers
Color Shifting or Circadian Health	Viewed as one of the next big benefits to LLLC systems
Space Sensing or Space Tracking and Utilization	Mentioned by one manufacturer as a next-step feature for many LLLC systems (beyond simple occupancy sensing)
Organic Light Emitting Diode (OLED)	Likely the next technology to enter the luminaire market; expected to offer greater benefits than traditional LEDs
Performance Metering	A significant benefit to utilities and likely LLLC users
Energy Reporting	A significant benefit to utilities and likely LLC users
Application Program Interface (API)	Development of unique feature sets is likely to require an API on the embedded chipset
BACNet or HVAC Energy Management	Primary communication protocol for HVAC systems and indicator of potential to tie-in with building systems.
Wide Area Network (WAN)	Capability to tie-in with buildings over long distances; could link portfolio of buildings together
Dimming Occupancy sensing Light level scheduling Daylight harvesting Scheduling	Standard control features available on most current LLLC products and standalone lighting controls
Demand Response	Integration with utility to schedule lights off during grid peak periods
Personal Control	User-level control over light levels, presets, ability to follow user to different office environment
High-end trim	Ability to tune full output of fixture to lower light levels without noticeable difference by occupant
Internet of Things (IoT)	Indicates ability to tie in with multiple non-lighting devices for control over other aspects of potential energy use
Zigbee	Primary legacy open-source protocol used to communicate between many wireless devices in place today
IPv6	Most recent version of internet protocol that allows adequate headroom for communication of advanced LLLC features
THREAD network protocol or IEEE 802.15.4 or 6LoWPAN	Potential future open-source communication protocol for future Internet of Things; THREAD is potential standardization of open-source protocol

PSU assembled the keywords related to advanced lighting controls into a searchable order, then scanned thousands of patents registered through the US Patent and Trademark Office for these keywords. Table 10 lists the patent options the team searched and the associations between individual keywords included in the search.

Table 10. Keyword Combination Options

Options	Keywords
Option 1	Wireless lighting control OR Luminaire mesh network OR Programmable lighting control system OR Lighting zone control OR Programmable lighting control system OR Mesh network intelligent devices OR Wireless lighting control wide area network AND energy efficiency OR LED OR Led lighting OR lighting OR wireless network OR dimming OR ipv6 OR 6lowpan OR personal OR WiFi OR energy reporting OR POE
Option 2	Wireless lighting OR Programmable lighting OR Luminaire mesh network OR Lighting zone OR Mesh network intelligent device AND control wide area network OR control OR system
Option 3	TITLE (lighting OR luminaire OR “intelligent device”) AND TITLE (wireless OR programmable OR zone OR “mesh network” or wire) AND TITLE (“control wide area network” OR control OR system or LED or dimming or sensor or software or lamp) sensor OR Thermal camera OR Micro radar
Optional	energy efficiency OR LED OR Led lighting OR lighting OR wireless network OR dimming OR ipv6 OR 6lowpan OR personal OR WiFi OR energy reporting OR POE OR Occupancy OR Infrared OR light-level OR LED OR Bluetooth OR Voltage regulation OR WiFi OR Energy metering OR Networking OR Algorithm OR Trim OR Ultrasonic OR Motion-detecting OR Heating-sensing OR Sound-sensing OR optical camera OR Infrared motion OR Optical trip wire OR Door contact

Once PSU had run a keyword search on all current and recently filed patents, the Research Into Action team identified several notable clusters of patents containing large numbers of citations. As the keywords developed in Table 10 were chosen to represent features of LLLC systems, the more citations to a particular patent containing these keywords, the more applicable to LLLC systems the team deemed a patent to be.

Research Into Action and Energy 350 used this information to identify the most common patent filing clusters where advanced lighting technologies appeared. Using these groupings, the team identified the patents for the 20 technologies most likely to disrupt or complement LLLC market adoption using two criteria: the relevance each patent had to others (referred to as “betweenness”), and the number of citations for each patent within published journals.[7]

[7] Since older patents tend to have higher citation rates than newer patents, the team did not base the importance of a patent solely on the number of times it had been cited.

Table 11 shows these 20 patents, listed from most to least important based on the combined rating of relevance and total number of citations.

Table 11. Patents Most Closely Linked to LLLC Systems

Patent Number/Appl. Number	Filing Date	Assignee/Patentee	Disruptive/ Complimentary	Notes on technology
Usp5668446	9/23/1996	Negawatt Technologies Inc.	Complimentary	LLLC system with full building integration for fluorescent lamps
Usp7075254	12/14/2004	Lutron Electronics Co., Inc.	Complimentary	Dimmable ballast by major manufacturer
Usp6683419	6/24/2002	Dialight Corporation	Complimentary	LED dimming
Usp5498931	10/3/1994	TLG PLC	Complimentary	LLLC system with occupancy sensing, daylight harvesting, and dimming
Usp5581158	4/3/1995	ETTA Industries Inc.	Complimentary	Potential LLLC system with fluorescent light dimming control
Usp8344665	9/29/2008	Orion Energy Systems Inc.	Complimentary	Potential LLLC system with DR control
Usp8492987	6/11/2010	Lutron Electronics Co., Inc.	Complimentary	Load control for LEDs
Usp5293097	11/27/1991	Novitas Inc.	Complimentary	Automated occupancy sensing control
Usp5473202	6/5/1992	Platner Brian	Complimentary	Occupancy sensor control unit
Us13/212556	8/18/2011	Lutron Electronics Co., Inc.	Complimentary	Fault detection in lighting
US 20120043900				
Us13/212773	8/18/2011	Lutron Electronics Co., Inc.	Complimentary	Stepped dimming control for fluorescent ballasts
US 8593076				
Usp4434388	9/3/1981	N/A	Complimentary	Linear dimming for High-intensity discharge lamps (HID) and fluorescent fixtures
Us11/536356	9/28/2006	Worthington Armstrong Venture	Disruptive	Powered ceiling grid for lighting
US 7679222				
Us12/694353	1/27/2010	Koninklijke Philips Electronics, N.V.	Complimentary	Linear dimming for fluorescent fixtures
US 7986103				
Us11/570944	6/28/2005	Koninklijke Philips Electronics, N.V.	Complimentary	Linear dimming for fluorescent fixtures
US 7667409				

The analysis found that 19 of the 20 most relevant patents are for features that are complementary to—rather than a disruptor of—LLLC systems. Examples include a linear dimming feature for HID or fluorescent lamp ballasts, and an automated occupancy sensing control.

The analysis identified only one patent as potentially disruptive for the new construction and major renovation commercial office sector: a powered grid for lighting, which utilizes the drop-in ceiling grid to provide an electrified low-voltage framework for power and signal distribution. Like LLLC systems, powered grids require less wiring and therefore lower labor costs than traditional systems. Furthermore, powered grid lighting fixtures can be easily reconfigured without the need for extensive re-wiring, and the low-voltage framework can interact with other building systems, such as security and HVAC controls. Powered grids also benefit from the increased market presence of LEDs and solar power, since both use low-voltage power that is more efficiently delivered through integrated powered grid networks.

However, unlike LLLCs—which are designed to be installed with common lighting infrastructure—the installation of a powered grid, and the light fixtures that operate with it, is vastly different from a traditional commercial lighting installation. In addition, the proper installation of powered grid systems requires specially trained installation contractors, and powered grid systems can cost significantly more than traditional ceiling grid and lighting fixture installations.

Despite these drawbacks, powered grids may present a unique and attractive solution for new construction and major renovation projects interested in efficient lighting solutions. Powered grids can also complement LLLCs in new construction or major renovation settings: they may enable LLLC systems to communicate more easily with one another and enable the integration of LLLCs with other building systems at a reduced cost. The team suggests NEEA investigate the cost and viability of powered grid systems in the new construction and major renovation markets further. The team does not foresee wide adoption of powered grids in the retrofit market for the foreseeable future due to the high cost of replacing an entire ceiling grid.

4. Baseline Assessment and 20-Year LLLC Adoption Forecasts

The Research Into Action team developed an LLLC market baseline and a 20-year forecast of LLLC adoption for the four Northwest states in the new construction, major renovation, and retrofit markets. The team focused on two building types for this analysis—commercial offices (broken down into large, medium, and small size categories) and warehouses.

To establish the LLLC market baseline and 20-year forecasts, researchers used findings from the market actor interviews conducted in 2016, the NWPCC interior lighting and lighting controls supply curve data, and the 2014 LLLC Market Baseline report prepared by Navigant Consulting (NEEA Report #E14-301).

The team utilized the 2014 CBSA data to develop the baseline and forecast of office and warehouse area (in millions of sq. ft.) for new construction, major renovation, and retrofit projects. This building stock forecast broken down by state (OR, WA, ID and MT) and building type (large office – above 50,000 sq. ft.; medium office – between 5,000 sq. ft. and 50,000 sq. ft.; small office – below 5,000 sq. ft.; and warehouse); it spans the years 2016 through 2035.

4.1. Existing Building Stock Area and Forecasts

The NWPCC collated building stock assessment data from CBSA for use in the 7th Power Plan. Since the Research Into Action team used these data without making any modifications for this analysis, the 20-year forecast of buildings projected to have LLLC system installations aligns with the NWPCC building stock forecasts. Figure 5 and Figure 6 show the forecasts of regional large office, medium office, small office, and warehouse building stock (in millions of sq. ft.) for new buildings and existing buildings, respectively.

Figure 5 illustrates fluctuations in new commercial floor space over time that are due to the Council's employment projections, as well as to forecasted changes in the stock of other building types that, while not represented in these graphics, affect office and warehouse stocks. For example, increasing amounts of e-commerce in the retail sector may drive warehouse construction. Figure 6 shows a steady decline in the stock of existing buildings as more existing buildings are demolished over time; the replacement of these buildings with new structures is incorporated into Figure 5.

Figure 5. New Construction Forecast – Total Regional Stock

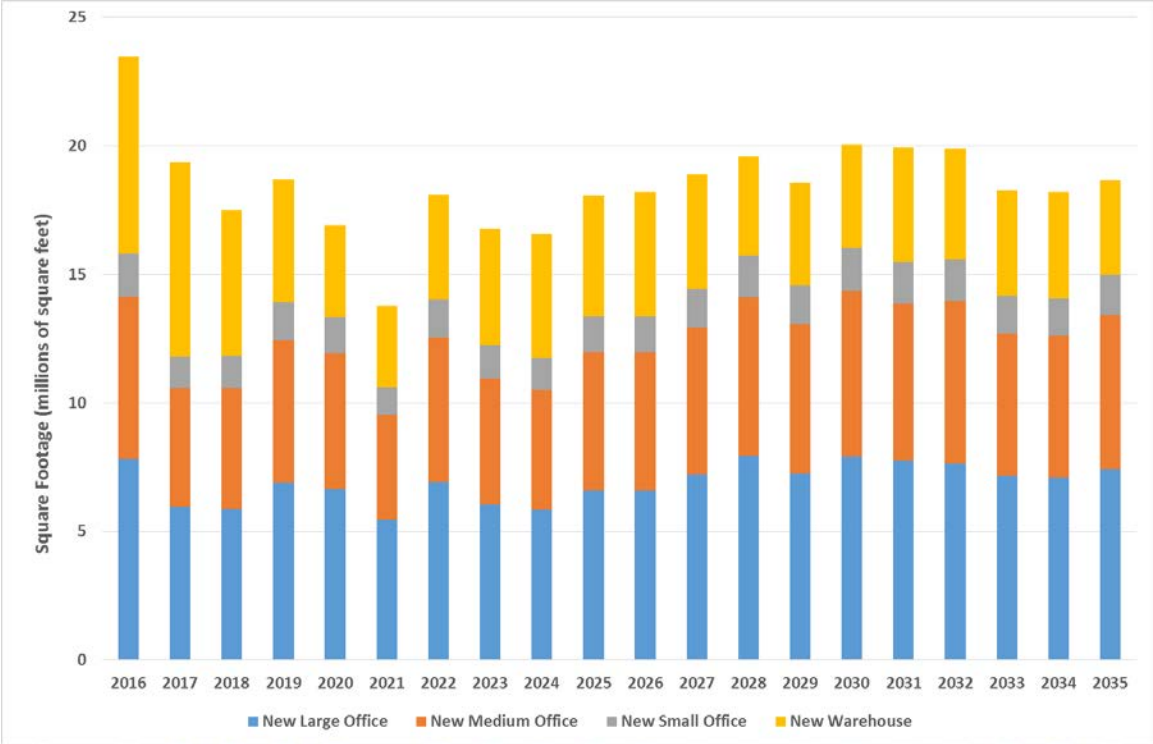
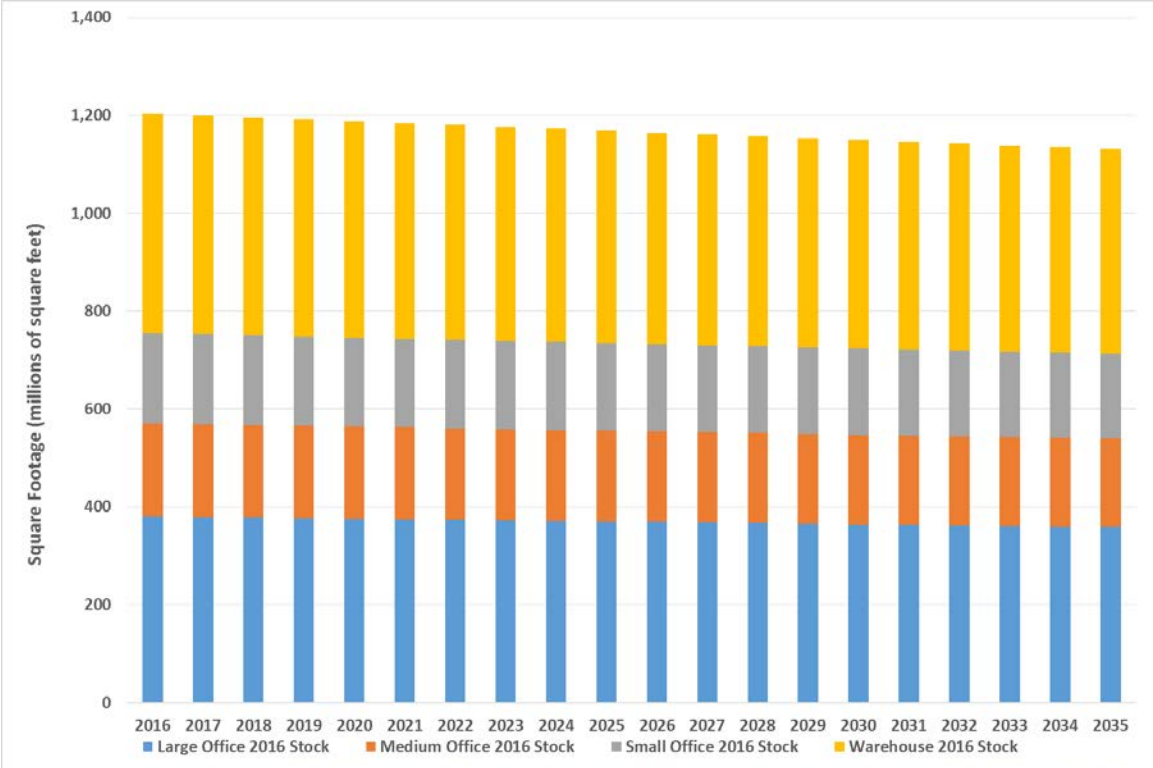


Figure 6. Existing Building Forecast – Total Regional Stock



4.2. Applicable Fixture Stock

4.2.1. Retrofit and Major Renovation

To estimate the total number of applicable fixtures on which LLLC systems can be installed, researchers drew from the 2014 market baseline report prepared by Navigant Consulting. The report, which provides a breakdown of fixture density by office size, and a separate estimate of fixture density for warehouses, contains the best data available for estimating building stock in the region.

The team reviewed interview data collected in 2016 to identify the types of fixture where LLLC systems could be installed. This list of applicable fixtures includes:

- Strip Lighting (Bare and Lensed)
- Pendent Mounts
- Surface Mounts
- Recessed Lighting

By combining this information with the fixture densities from the 2014 market baseline report, the team determined fixture densities by building type that include only fixtures where LLLCs could be installed.

In its 2014 report, Navigant used information from the preliminary CBSA dataset and linked it to the building stock assessments that were available in 2013. Because more recent building stock data is now available through NWPCC's final 7th Power Plan, the Research Into Action team updated the number of installed applicable fixtures in 2016. This update resulted in a significant increase in the number of installed applicable fixtures over the previous potential estimate, as shown in Table 12 below.

Table 12. Installed Fixture Base for 2013 & 2016, by Building Type

Building Type	2013 Installed Applicable Fixture Base*	2016 Installed Applicable Fixture Base**	% Increase from 2013-2016
Large Office	2,153,433	3,268,759	52%
Medium Office	970,210	1,640,337	69%
Small Office	1,138,414	1,583,186	39%
Warehouse	1,426,561	1,839,663	29%

Source: 2014 Navigant LLLC Market Baseline Report, Table 4-1.;
Source: Final 2014 CBSA dataset

The 2014 CBSA dataset also provided updated fixture density weightings based on the final sample. When the Research Into Action team applied the updated weightings to the applicable fixtures, the team computed 2016 fixture densities that are generally much higher than those computed in 2013. Table 13 shows the 2013 and 2016 applicable fixture densities and the percent change from using the complete CBSA sample.

Table 13. Applicable Fixture Density for 2013 & 2016, by Building Type

Building Type	2013 Applicable Fixture Density (per sq. ft.)*	2016 Applicable Fixture Density (per sq. ft.)**	% Increase from 2013-2016
Large Office	0.0086	0.0169	97%
Medium Office	0.0086	0.0181	110%
Small Office	0.0086	0.0272	216%
Warehouse	0.0041	0.0039	-5%

Source: 2014 Navigant LLLC Market Baseline Report, Table 4-1.;
Source: Final 2014 CBSA dataset

The increase in existing building stock – and thus the increase in the number of applicable fixtures and fixture densities – is due solely to the use of the different building stock assessments available during the two different study periods.[8]

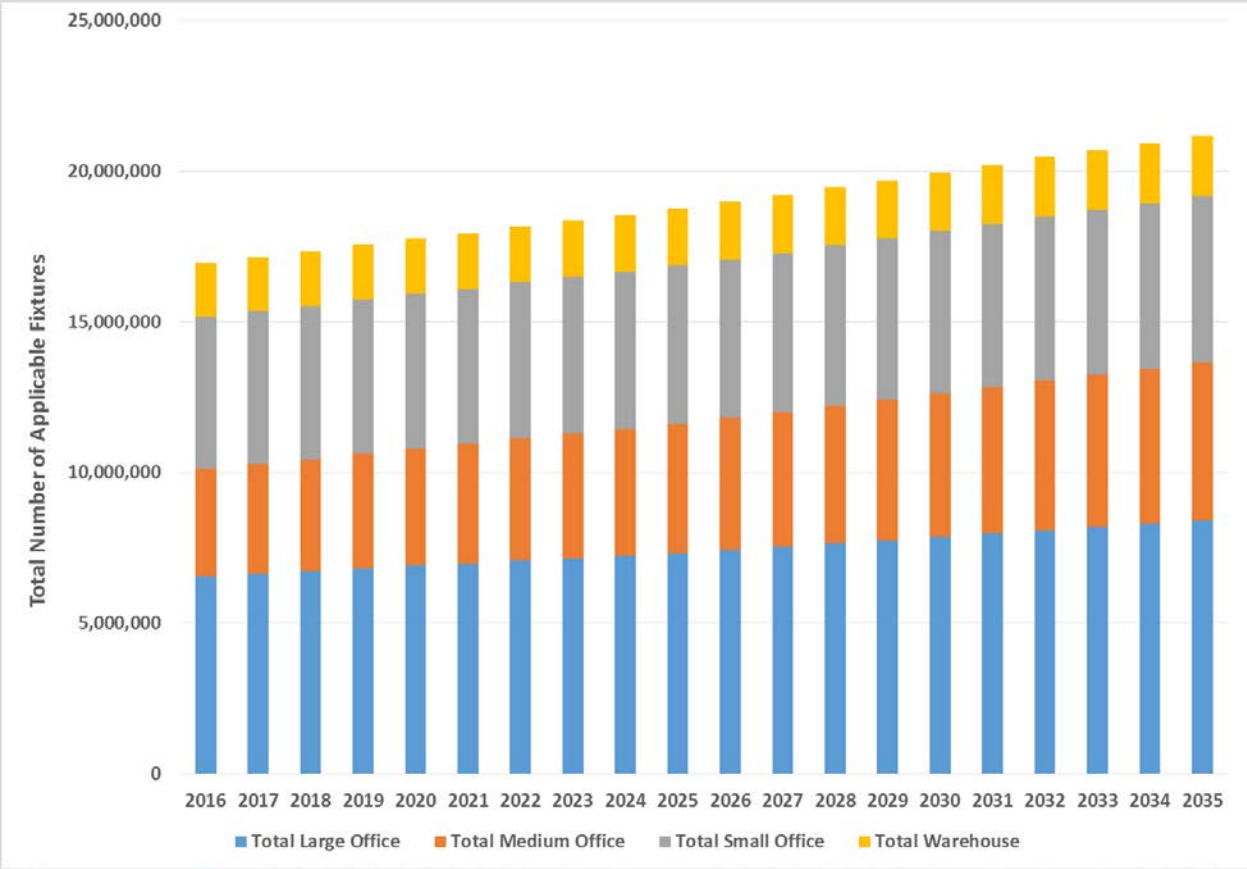
4.2.2. New Construction

To quantify the number of applicable fixtures in new construction projects, the team used the NWPCC new construction forecast estimates and the applicable fixture density from the updated 2014 CBSA dataset. The team assumed that the fixture density in new construction would resemble the fixture density in the existing stock of offices and warehouses because typical space layout and building functions have remained relatively constant. Although our subsequent comparison of the pre-2004 and 2004-2013 buildings did reveal several differences in fixture densities by vintage, the sample sizes of individual subsectors were too small to reliably separate the data by vintage, and we therefore applied a single fixture density across all vintages.

After applying these factors across all project types (new construction, major renovation, and retrofit), the team developed forecasts of the number of applicable fixtures by state, building type, and project type for the years 2016 through 2035. Figure 7 shows the cumulative regional number of fixtures where LLLC installations will be applicable for 2016 to 2035 across all project types.

[8] Navigant noted in their 2014 MRE that only 50% of the CBSA building stock data was available at that time. The large increase in fixture density is due to the incompleteness of the 2013 data set.

Figure 7. Number of Applicable Fixtures – Total Regional Stock Across All Markets



The steady rise in the forecasted number of applicable fixtures is due the fact that the square footage of newly constructed buildings is expected to far outpace the square footage of existing buildings that are demolished over the next 20 years.

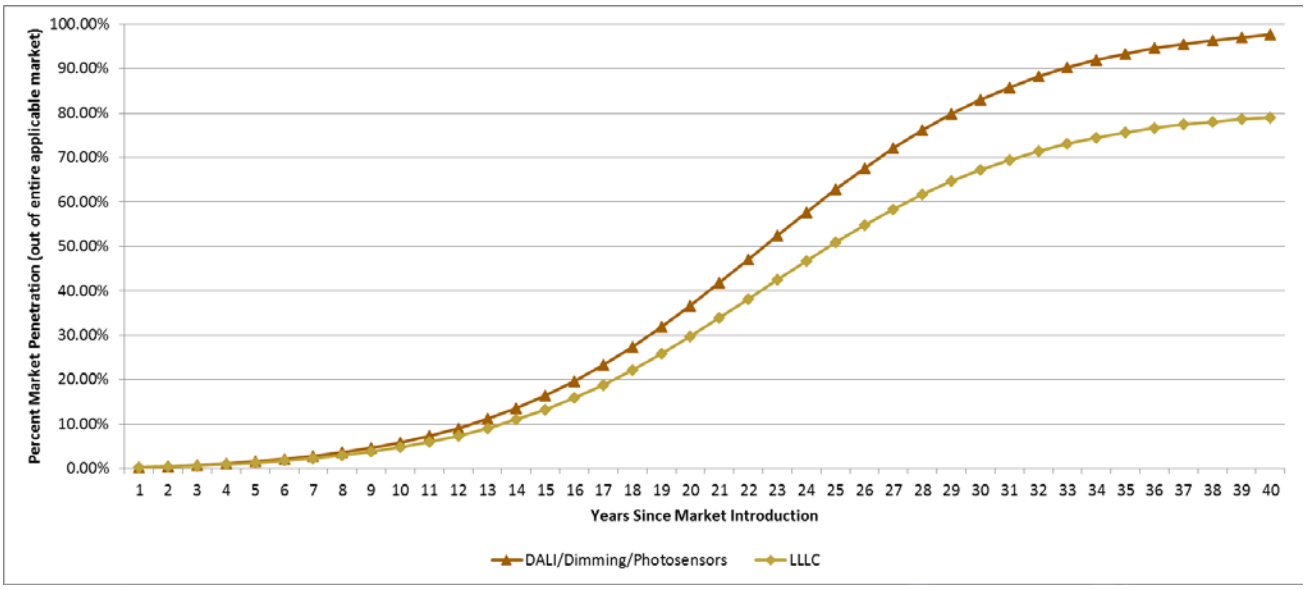
4.3. Installed Base of LLLC Fixtures

The LLLC baseline is defined by the number (or percentage) of LLLC system installations that occurred absent any program intervention. Since LLLC products have been installed in warehouses since 2012 without any program intervention, these installations are included in the baseline. In offices, in contrast, NEEA was instrumental in bringing the first LLLC products into the northwest market. Due to NEEA's early influence in the office market, the baseline period for LLLC systems in offices should show very few installed LLLC systems. Findings from the Research Into Action team's 2016 market actor interviews corroborated this assumption: several manufacturers reported that their LLLC systems are beginning to make up a larger portion of overall sales compared to only a year ago, but that that these sales are still an extremely small portion of overall lighting sales.

The team estimated the percent of LLLC systems already in the market from the Bass diffusion curves developed for the 2014 Navigant LLLC market baseline report. However, the Research Into Action team opted not to use the Bass diffusion curves directly from the 2014 market baseline report: these had been developed by combining the sales curves of several established lighting controls technologies, including the DALI lighting system with photocell and occupancy sensors, networked IT controls, and standalone occupancy sensors. The Research Into Action team, in consultation with NEEA, recognized that the characteristics of LLLC systems are very different from those of networked IT controls or of standalone occupancy sensors, and thus LLLC adoptions are unlikely not follow the adoption patterns of these technologies. Working with NEEA, the team concluded that only the DALI lighting system with photocells and occupancy sensors has characteristics sufficiently similar to those of LLLC systems. The team therefore developed a new adoption curve for LLLCs that is based on the sales curve for the DALI lighting system.

While the DALI lighting system's adoption curve shows the total market penetration only for applicable fixtures, the adoption curve does not account for additional adoption limitations, such as locations where it would be difficult to make a convincing business case for installing an advanced lighting control system. Based on discussions with NEEA, the team adjusted the DALI diffusion curve further to take these likely installation limitations into account. Using data from the final 2014 CBSA dataset, we excluded applicable fixtures in private offices under 300 sq. ft., where NEEA believes LLLCs are unlikely to be installed in the near term. This analysis resulted in a 19% decrease in available applicable fixtures in the near term and we applied this adjustment to the diffusion curve to forecast the market penetration of LLLC systems over time. The adjusted curve, along with the unadjusted DALI diffusion curve used in the 2014 market baseline report for comparison, is shown in Figure 8. LLLC Bass Diffusion Curve Based on DALI Lighting Systems Figure 8.

Figure 8. LLLC Bass Diffusion Curve Based on DALI Lighting Systems with Adjustments



The team also developed new baseline LLLC saturation rates for offices and warehouses based on conversations with NEEA regarding the dates when LLLC systems were introduced in different locations in the Northwest. The "introduction year" defines how far along the market saturation curve LLLC systems are for each building type-state combination.

For offices, although NEEA was instrumental in introducing LLLC systems to office spaces in the Oregon and Washington,[9] manufacturers still do not consider LLLC sales to offices to be a significant portion of their overall sales. The team, in consultation with NEEA, therefore set the year of introduction for LLLC systems in offices to 2013 in Oregon and Washington.

Northwest warehouses, on the other hand, were installing LLLC systems before NEEA began its LLLC warehouse research. Notably, the applicability and benefits of LLLC systems in warehouses were spotlighted in a PG&E case study in 2012. The team, again in consultation with NEEA, therefore established 2012 as the introduction year for LLLCs in warehouses in Oregon and Washington.

The team was not able to obtain state-level sales data through existing secondary sources, nor to obtain quantitative data through the 2016 market actor interviews. As a result, the team applied sales data trends across each state according to a qualitative analysis of manufacturer responses. The team determined through the manufacturer interviews that most LLLC installations occur in regions with stricter codes, utility rebate programs, and where the majority of industries are located. Within the Northwest, most manufacturers identified Portland and Seattle as the most likely locations for major renovation and new construction installations. Additionally, since Idaho has a stricter building code than Montana, LLLC sales are likely to be greater in Idaho than in Montana.

Taking these influence factors from the market actor interviews into account, the team estimated that adoption in Idaho and Montana would likely lag behind adoption in Oregon and Washington by three years, as building codes in Idaho and Montana are generally three years behind those in Oregon and Washington. While LLLC system adoption in Idaho and Montana is expected to follow the same diffusion curve as adoption in Oregon and Washington, the lag in Idaho and Montana will result in fewer installations in these states in the next five years. Table 14 shows the years in which LLLC systems were introduced into offices and warehouses in the four Northwest states based on this analysis.

Table 14. LLLC Year of Introduction

Building Location	Offices	Warehouses
Oregon/Washington	2013	2012
Idaho/Montana	2016	2015

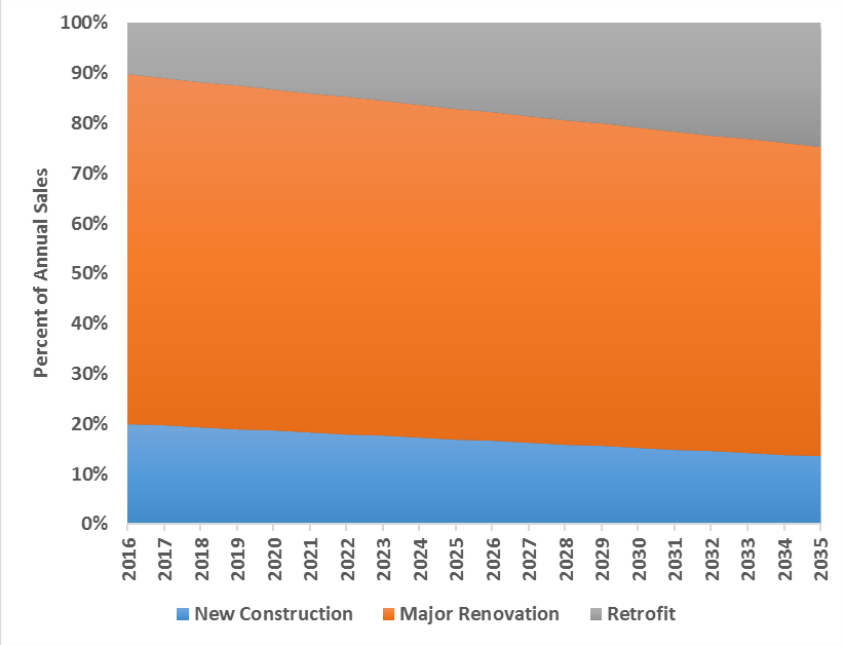
[9] Specifically, NEEA introduced the first LLLC product into the Northwest office market through its Enlighted pilot in 2012 in Seattle, WA, Kent, WA, and Portland, OR.

4.4. Adoption Rates by Project Type

To account for different adoption rates by project type, the team assumed that the installed breakout of LLLC systems by state was analogous to sales by state. The 2014 Navigant market baseline report showed that the majority of LLLC sales were expected to occur in major renovations. New construction was expected to account for the next highest share of LLLC sales, and retrofits were expected to account for the smallest share.[10] The 2016 manufacturer and distributor interviews corroborated these findings: market actors reported that the majority of LLLC installations to date have been renovation and new construction projects, but retrofits are gradually beginning to make up a larger share of the market.

Using annual sales projection data by project type (that is, sales projections for retrofit, major renovation, and new construction), the team forecasted the breakdown of total LLLC installations by project type through 2035. As depicted in Figure 9, LLLC sales to the retrofit market are expected to become a larger portion of total LLLC sales over time (as retrofit technology matures), while LLLC sales to the new construction and major renovation markets are expected to become smaller portions of the total LLLC market over time.[11]

Figure 9. Percent of Overall LLLC Annual Sales by Project Type: 2016 to 2035



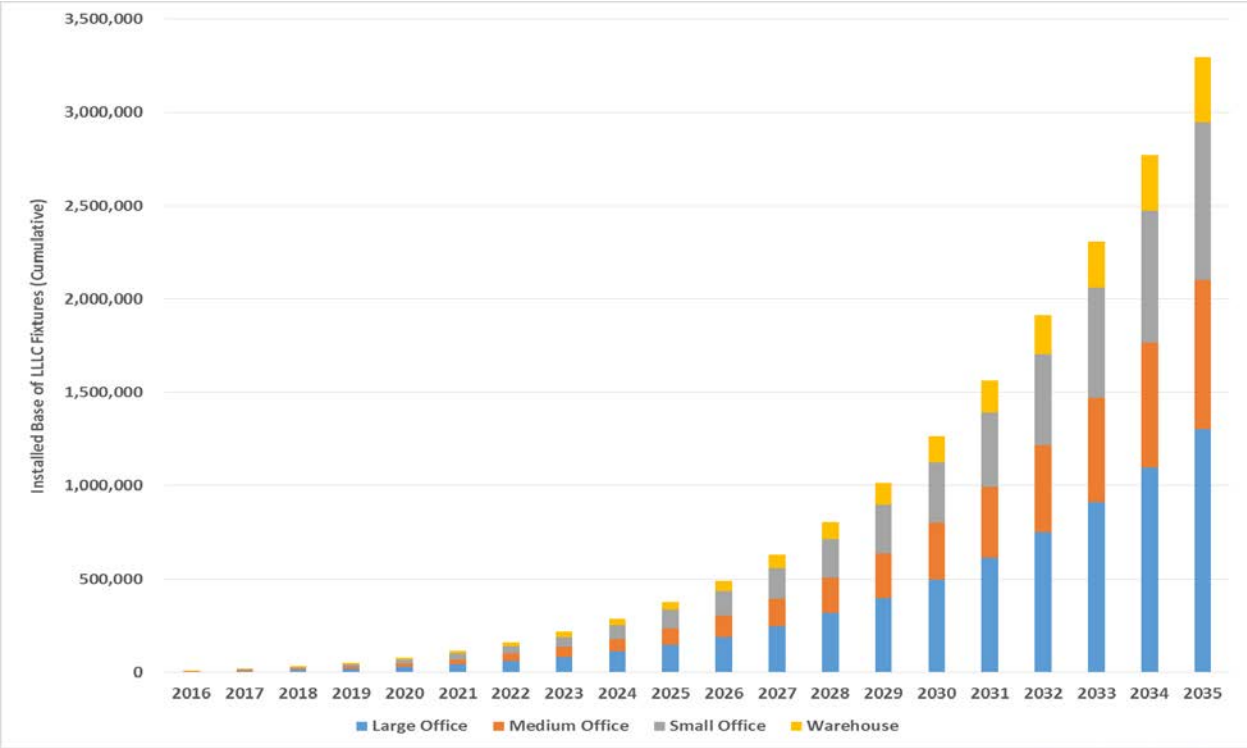
[10] See Figure 4-1 and Table 4-4 in the 2014 market baseline report by Navigant Consulting.

[11] Though Figure 9 appears to show a decrease in sales over time, one needs to bear in mind that the denominator in each year is that year's total forecasted LLLC sales. This figure, therefore, illustrates how each year's total forecasted LLLC sales are expected to be distributed across retrofit, major renovation, and new construction projects.

The team used the LLLC introduction dates in conjunction with the Bass diffusion curve in Figure 8, the introduction date in Table 14, and the sales forecast in Figure 9 to determine the total expected saturation of LLLC systems over time.

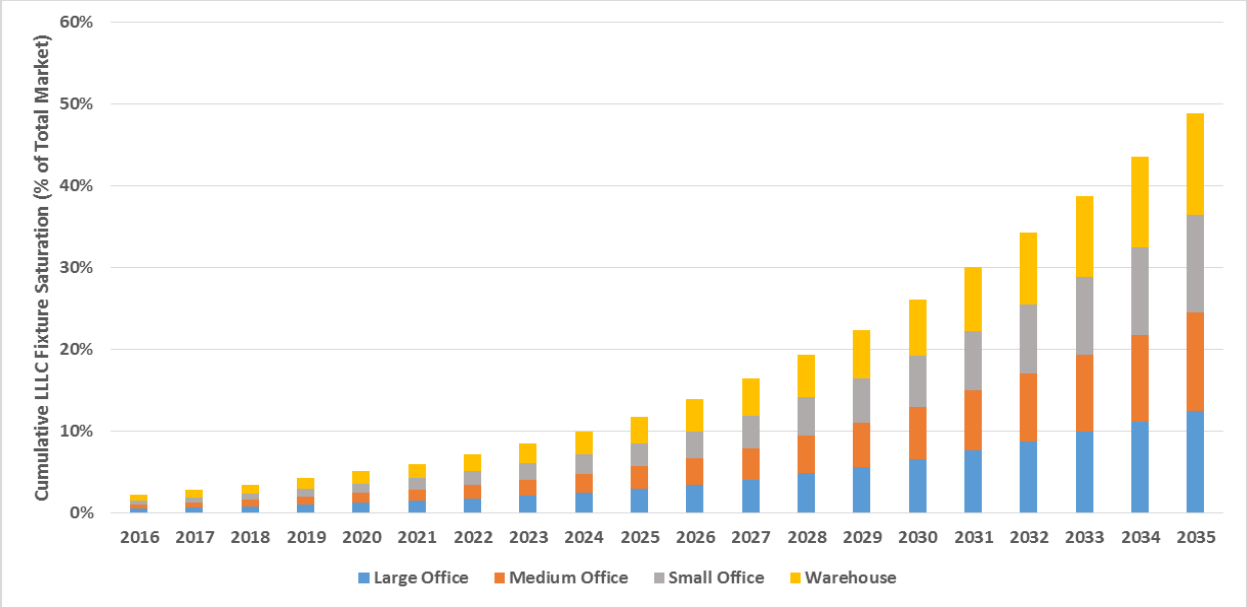
The analysis yielded a baseline fixture installation base of 0.5% for offices and 0.8% for warehouses in 2016, with an increase over time that follows the adjusted bass diffusion curve shown in Figure 8 above. Figure 10 below shows the forecasted total regional stock of baseline LLLC systems for 2016 through 2035. The figure depicts a steady increase in saturation over time as LLLC systems continue to gain popularity and first costs decrease.

Figure 10. LLLC Baseline Fixture Saturation – Total Regional Stock by Building Type



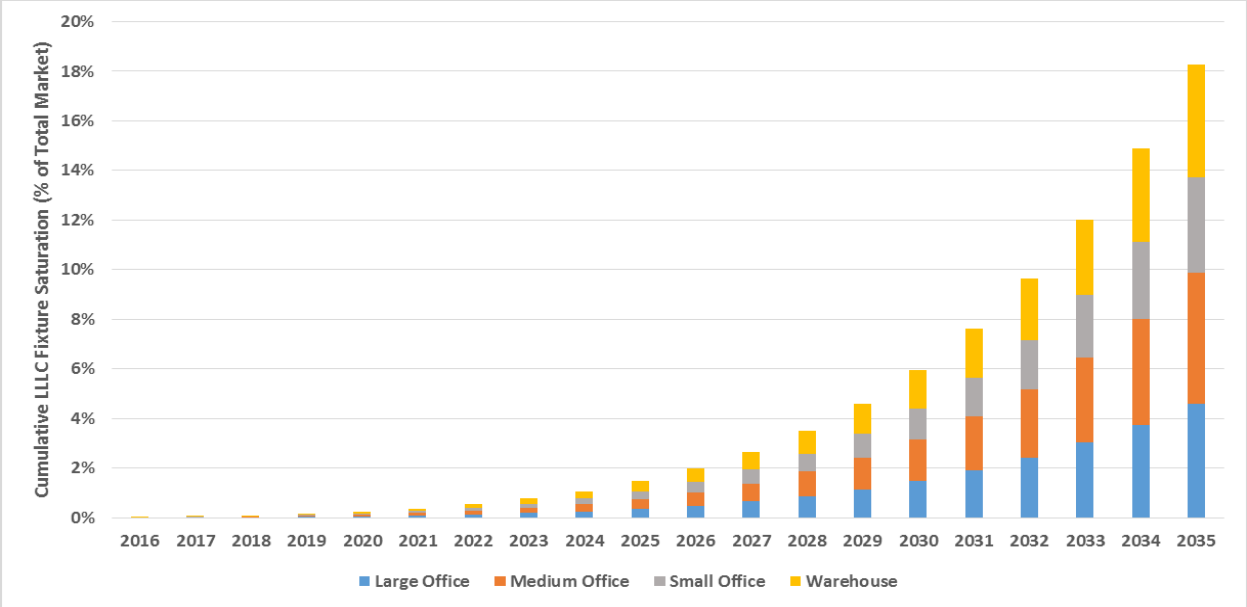
In terms of total market share, Figure 11 shows the cumulative number of LLLC systems forecasted to make up an increasing percentage of the regional fixture stock in the new construction and major renovation markets over time as technology matures and first cost is reduced.

Figure 11. LLLC Fixture Saturation – Percent of Total New Construction and Major Renovation Regional Stock



Similarly, the large existing stock of fixtures presents a substantial opportunity for LLLC system installations, albeit on a smaller scale in terms of the percentage of total fixtures where LLLCs are applicable. Figure 12 shows the estimated saturation of LLLC systems in retrofit projects as a percent of the total retrofit market. These computations support the market actor interview findings that the majority of installations are first occurring in new construction markets since first cost presents a barrier to installation in retrofit projects.

Figure 12. LLLC Fixture Saturation – Percent of Total Retrofit Regional Stock

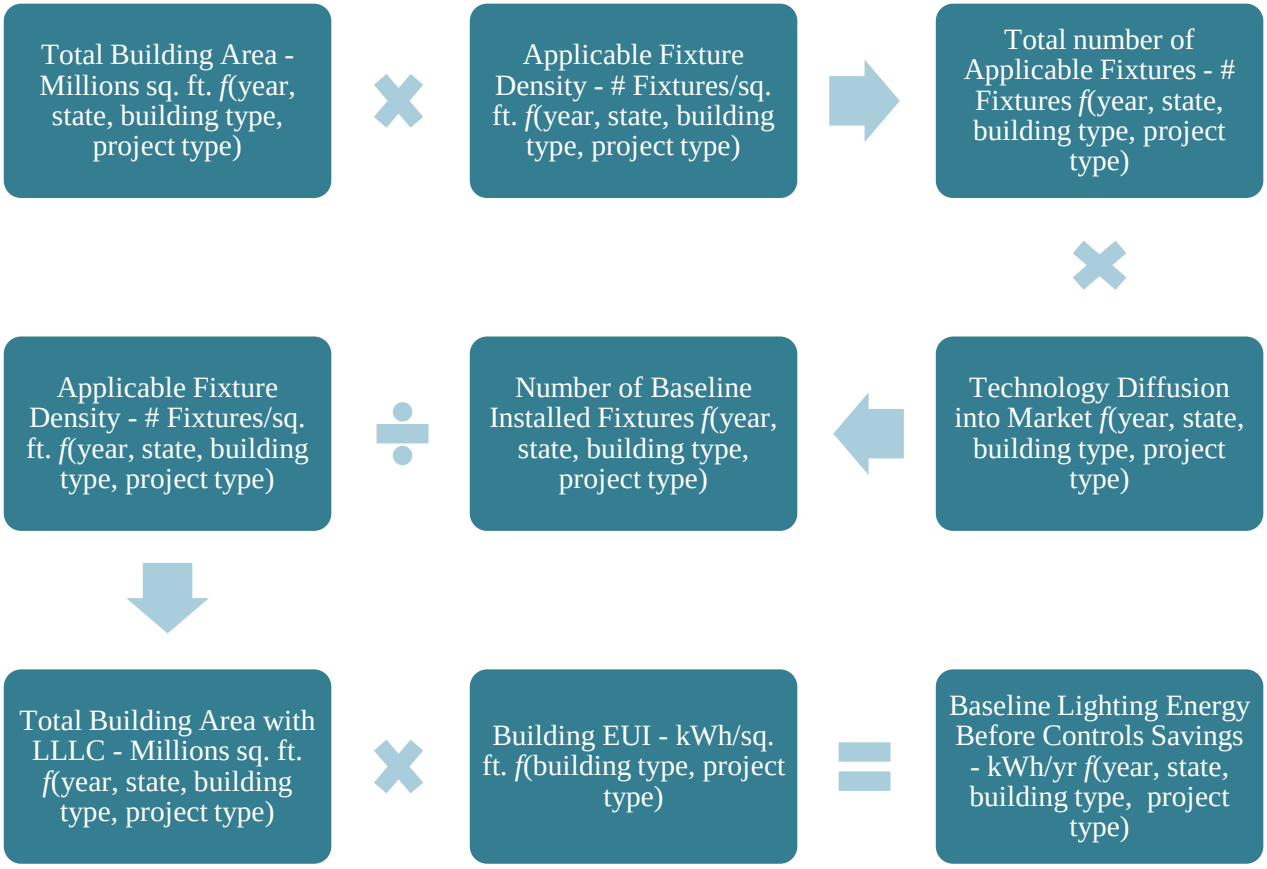


4.5. Baseline Energy Consumption

To estimate LLLC energy savings, we drew on the 2014 CBSA data, state energy codes, and the NWPCC lighting controls energy savings analysis used in the 7th Power Plan. The NWPCC analysis defines energy savings for LLLCs over uncontrolled- or traditionally-controlled baselines, depending on the space.

To determine applicability of spaces for LLLC systems, the team found the space use breakout typical of each building type from 2014 CBSA data. We then referred to the relevant energy codes from each state to restrict the baseline control requirements and thereby define the savings potential for each space. Figure 13, below, demonstrates the step-by-step process used to obtain LLLC system savings after calculating the total building area with installed LLLC systems.

Figure 13. Baseline Estimation Process



To convert the saturation of fixtures into anticipated energy savings, the team required a baseline LPD. This LPD level changes based on whether the LLLC system is installed in an existing building, or a new building adhering to a state specific energy code.

The team used data from the NWPCC 7th Power Plan supply curves that detail baseline Energy Use Intensity (EUI) levels and annual hours of operation for offices and warehouses for all three project types. We used the NWPCC's EUI estimate for existing buildings, and relied upon the average hours of operation and state code LPD requirements to arrive at an EUI for new construction and major renovations. These baseline EUI's and annual hours of operation are shown in Table 15 for each building type across each state in the region.

Table 15. Baseline Energy Use Intensity (EUI) for Existing and New Construction, by Building Type

Building Type	State	Annual Hours of Operation	EUI - Existing [Retro] (kWh/sq. ft.)	EUI - New and MR (kWh/sq. ft.)
Large Office	OR	3300	3.19	3.00
Medium Office	OR	2800	2.70	2.55
Small Office	OR	2600	2.52	2.37
Warehouse	OR	2700	1.34	1.78
Large Office	WA	3300	3.19	2.97
Medium Office	WA	2800	2.70	2.52
Small Office	WA	2600	2.52	2.34
Warehouse	WA	2700	1.34	1.35
Large Office	ID	3300	3.18	2.97
Medium Office	ID	2800	2.69	2.52
Small Office	ID	2600	2.51	2.34
Warehouse	ID	2700	1.34	1.78
Large Office	MT	3300	3.20	2.97
Medium Office	MT	2800	2.69	2.52
Small Office	MT	2600	2.52	2.34
Warehouse	MT	2700	1.34	1.78

Source: NWPCC 7th Power Plan supply curve for interior lighting

The team used the NWPCC's estimates of savings per control type beyond those required by code to arrive at the total savings percentages for offices and warehouse spaces. For both high-bay and troffer fixtures, we applied a 10% energy savings reduction to reflect the presence of controls beyond those required by code. We applied the 10% savings directly to the estimated total lighting energy consumption for each building type, in each state, to estimate LLLC system savings.

We used a 15-year measure life for a LLLC systems to estimate cumulative savings over time. While we anticipate that LPD levels will continually drop over the course of the 15 years, we are uncertain whether future LLLC successor(s) will also save 10% beyond the then-current market baseline. Therefore, the team erred on the conservative side and did not count any savings from replacement LLLC systems that are installed after the initial 15-year-old LLLC systems are retired.

To determine the total baseline lighting energy use in buildings the team used the baseline EUI's from each state (from Table 15 above) in conjunction with the applicable LLLC fixture density (from Table 13 above) and the total building stock square footage. Once we established this baseline lighting energy use, we applied the 10% energy reduction that LLLC systems would have beyond each individual state's energy code LPD levels (or in case of retrofits, the existing building stock LPD) to arrive at cumulative energy savings. Figure 14 below shows the annual LLLC energy savings for each building type for each year of the 20-year forecast period. Figure 15 shows the total cumulative energy savings by building type over the 20-year period, taking into account that LLLC savings are only counted for 15 years beyond their installation date.

Figure 14. LLLC Annual Lighting Energy Savings

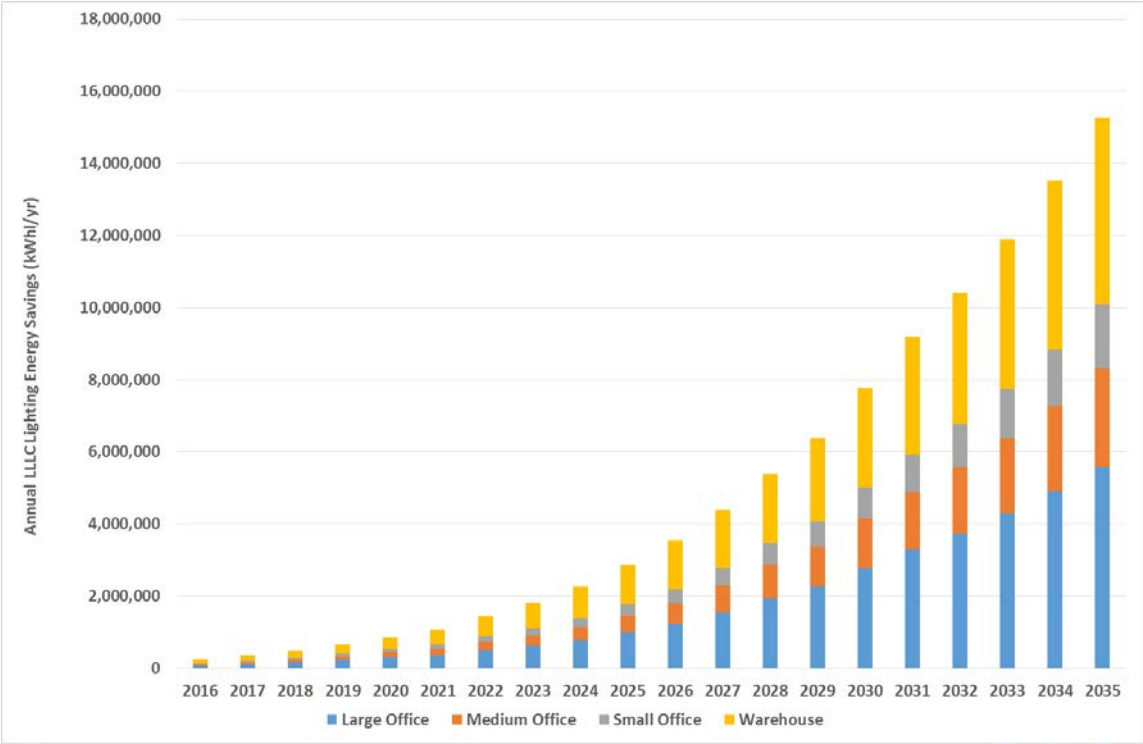
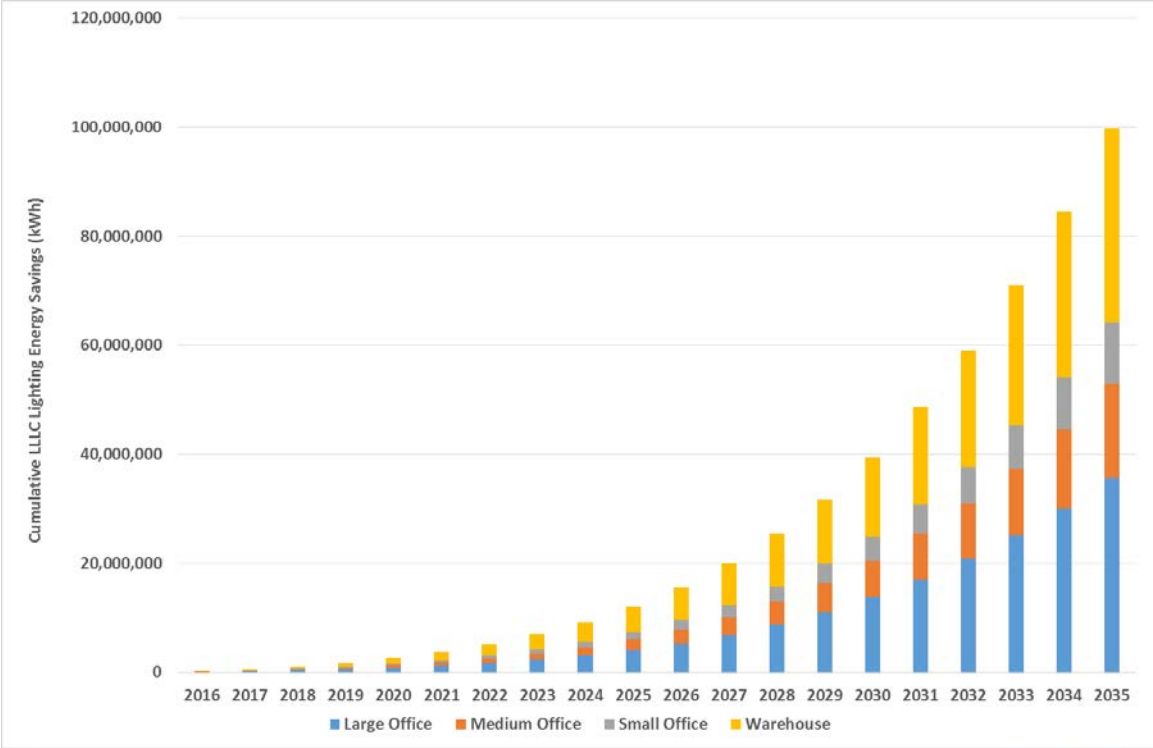


Figure 15. LLLC Cumulative Lighting Energy Savings



5. Key Findings and Recommendations

5.1. Market Characterization

The Research Into Action team's LLLC market characterization resulted in the key findings and recommendations presented below.

Key Finding #1: The shortage of experienced installers poses a barrier to LLLC adoption in the Northwest. Many of these installers over-bid jobs involving LLLCs to compensate for installation processes that they are uncertain of. In fact, manufacturers, distributors, and regional experts all stated that addressing this barrier should take precedence over addressing first cost and market fragmentation barriers. The market actors thought that training the market of lighting installation contractors is critical to increasing the adoption of LLLC systems in the Northwest.

> **Recommendation: Include LLLC systems in NXT Level training.** Although the promise of LLLC systems is that they become easier to install over time compared with traditional lighting controls, NEEA should include topics covering LLLC systems in the NXT Level training curriculum to ensure system acceptability and persistence. NEEA should also explore conducting pre-bid training with distributors and local trade associations that interact directly with lighting installers. Both training types will benefit the market by helping to ensure that LLLC systems are installed correctly and that end-users are satisfied with the product. In addition, once installers become more familiar with LLLC technology, they are less likely to overstate the cost of LLLC installation, thereby rendering LLLC systems more cost-competitive with traditional lighting controls.

Key Finding #2: Manufacturers agree with NEEA that energy codes present an opportunity to promote the adoption of LLLCs in the market. As NEEA pursues code-related work, energy codes that include exceptions for using advanced networked lighting controls or include requirements that those controls may satisfy (such as demand response enablement) represent the greatest opportunity.

> **Recommendation: Continue promoting advanced lighting controls in commercial energy codes.** NEEA should continue to push for the inclusion of advanced lighting controls in regional commercial energy codes through its Commercial Code Enhancement (CCE) initiative. Since many manufacturers integrate energy reporting capabilities within the LLLC system, the organization should also develop case studies and conduct pilot demonstrations that focus on the energy- and capacity-saving features of LLLC systems to make the case for including these technologies in energy codes.

Key Finding #3: Although the LLLC initiative did not initially target lighting designers, regional lighting experts and distributors report that designers play an important role in LLLC system adoption in the new construction and major renovation markets. Regional experts and distributors have both observed that designers are increasingly knowledgeable about advanced lighting controls and often promote these systems during the specification and bidding phases of construction.

> **Recommendation: Engage with lighting designers.** NEEA should interview a sample of lighting designers to identify: the channels through which they currently receive LLLC system information; the training opportunities they are aware of and participate in; the techniques they use to prevent LLLC systems from being taken out of designs; and the barriers they perceive limiting wider LLLC adoption. NEEA should also consider attending and making presentations at local lighting designer trade organization meetings (e.g., American Institute for Architecture (AIA) meetings) to share LLLC information with designers and to further increase designers' awareness.

Key Finding #4: All of the market actors who contributed to this research observed that LLLC systems are most commonly provided via traditional lighting and lighting controls delivery channels. The bulk of LLLC sales—made to all but the largest customers—go through the traditional pathway of manufacturer→ distributor→ lighting installer. Almost all manufacturers reported selling LLLC systems directly to their largest customers.

> **Recommendation: Rely on existing market contacts and leverage points.** Since LLLCs typically reach end-use customers through traditional lighting distribution channels, NEEA should leverage its other initiatives' efforts that target these same distribution channels to influence the supply chain of LLLCs. Similar techniques aimed at increasing distribution of Reduced Wattage lighting or high performance T8's at in the same market channel may also be applied to LLLCs.

Key Finding #5: Several manufacturers said they were skeptical that "lighting as a service"—which has not yet caught on in the marketplace—will ever replace or compete with traditional market channels. However, several manufacturers and regional experts perceive "energy management as a service" as a potential supply chain disruptor.

> **Recommendation: Consider further research to explore the potential for "lighting as a service."** Although key market actors do not currently view "lighting as a service" as a potential market disruptor, the concept has the potential to fundamentally alter traditional LLLC delivery channels for several reasons. For example, because lighting fixtures are ubiquitous in commercial buildings, increased adoption of LLLC systems with reporting capabilities would allow unparalleled access to information about utilization and conditions (such as temperature, or comfort) of each space. This information could seamlessly integrate with other IT-based building energy management solutions to deliver "energy management as a service" more cost-effectively. NEEA should therefore consider further research on how lighting may fit into the broader "energy management as a service" category and explore the potential for increased use of "lighting as a service."

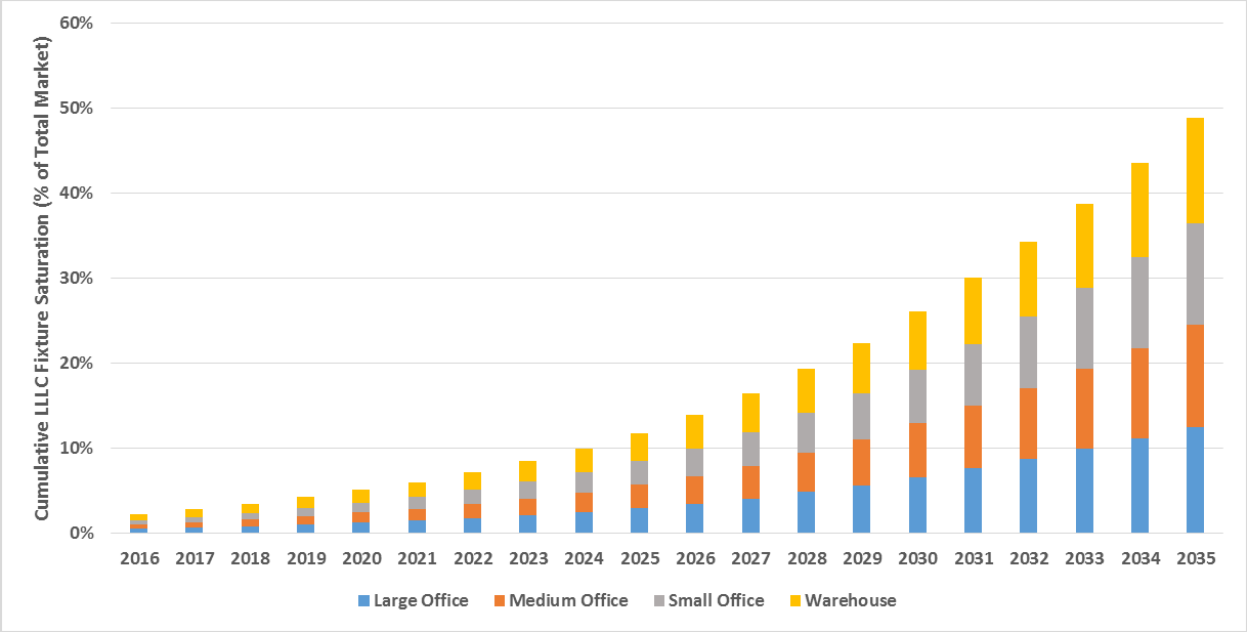
Key Finding #6: Examination of thousands of recent U.S. patents identified powered low-voltage grid systems as the most likely technology with potential to disrupt and/or enhance the market adoption of LLLC systems. This technology offers benefits similar to those of LLLCs: reduced wiring costs, space re-configurability, and potential integration with other whole building systems.

> **Recommendation: Conduct research on powered low-voltage grid system benefits and market awareness.** NEEA should investigate the cost, contractor and end-user awareness, end user benefits, and market uptake of powered low-voltage grid systems to determine if such systems are likely to complement and/or compete with LLLC systems in the new construction and major renovation markets in the near future.

5.2. Baseline and LLLC Adoption Forecast

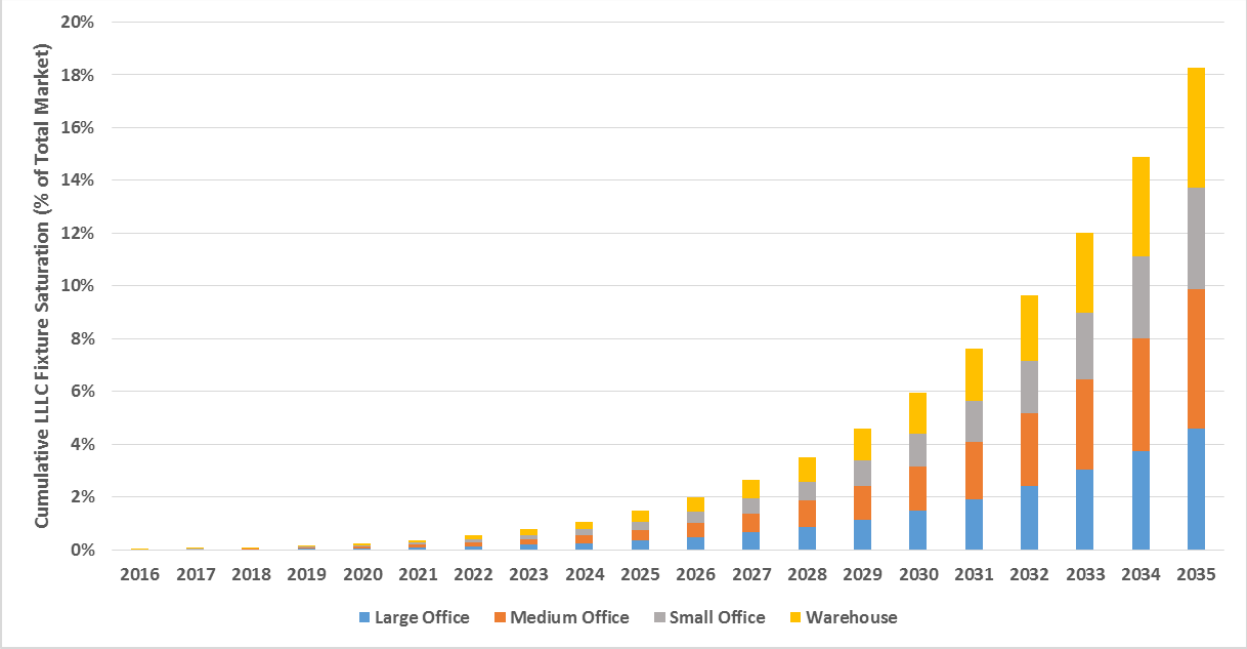
The baseline analysis found the 2016 saturation of LLLC systems is 0.5% for offices (large, medium, and small) and 0.8% for warehouses. The 20-year forecast, spanning the years 2016 to 2035, shows a steady increase in LLLC saturation in new construction and major renovations over time, as LLLC systems become increasingly popular and their first costs decrease. Figure 16 depicts the forecast of LLLC saturation in the new construction and major renovation markets.

Figure 16. LLLC Fixture Saturation – Percent of Total New Construction and Major Renovation Regional Stock



The extensive stock of fixtures in existing buildings presents a substantial opportunity for LLLC retrofit installations. Figure 17 shows the forecasted saturation of LLLC systems in retrofits as a percent of the total retrofit market. This percentages is smaller than the percent in the new construction/major renovation market since LLLCs are not compatible with all lighting retrofits.

Figure 17. LLLC Fixture Saturation – Percent of Total Retrofit Regional Stock



Appendix A. Market Actor Interview Guides

A.1. Staff Interview Guide

A.1.1. Introduction

Thanks for taking the time to talk with me today. We will be talking about the design and vision for Luminaire Level Lighting Control (LLLC), the initiative's target market, opportunities and barriers for LLLC as well as LLLC manufacturers.

A.1.2. Initiative Design and Status

I'd like to start by asking some general questions about LLLC, including questions about its current status, supporting documentation, and structure.

Q1. First, what is your role in Northwest Energy Efficiency Alliance's (NEEA's) LLLC initiative?

Q2. What initiative materials are available for LLLC? We note there is a logic model for LLLC Tier 1. It looks like this logic model was updated yesterday (Sept. 28), but we are unable to access it—can you please share the logic model and the associated new "assumptions" document with the Research Into Action team? Are there logic models for LLLC Tiers 2, 3, and 4? Savings goals?

Q3. Let's talk more specifically about LLLC's structure. Can you please provide additional context on how the LLLC tiers were established?

Probes:

What lead you to the tier demarcations?

Are the tier demarcations primarily based on conversations with LLLC manufacturers about their existing and anticipated product lines, or were they established for other reasons?

Q4. The LLLC product definition requires occupancy sensing control as part of Tier 1. Are there additional requirements on whether the occupancy sensing device operates in an occupancy or vacancy mode?

A.1.3. LLLC Vision

Now I'd like to ask about NEEA's 20-year vision for LLLC.

Q5. The LLLC PowerPoint presentation on NEEAnet entitled *Connected Lighting – The New Frontier: Luminaire Level Lighting Controls* shows the 20 year vision for LLLC being "The vast majority of commercial and industrial luminaires and other electrical devices are autonomous and communicating, using sensors and controls to deliver energy efficiency and non-energy benefits." [*If needed: "This is a document that Romana prepared; Research Into Action received it from Rita.*"] What is the current status of the initiative (i.e., where is it in its lifecycle)?

Probes:

The outcome for the first activity (LLLC Spec Development with Partner Alignment) shows the outputs as "Tier 1 Spec" and "memorandum of understanding (MOU) with Northeast Energy Efficiency Partnerships (NEEP)-DesignLights Consortium (DLC)." Has the Tier 1 spec been finalized? Is the MOU in place?

Where on the Tier 1 logic model do you expect to be in 3, 5, and 10 years?

Have you set any dates for key milestones? Some examples might target dates for getting specific tiers of LLLCs into utility incentive programs in the Pacific Northwest (PNW) or into energy codes.

A.1.4. Target Market

Let's talk now about LLLC's target market.

Q6. From reviewing the *2014 LLLC: Market Baseline Report*, my understanding is that the LLLC initiative primarily targets linear fluorescent fixture replacements in the new construction and major retrofit markets. Can you confirm this is the correct target market for LLLC?

[*If so*] Is the low return on investment (ROI) for controls-only retrofits (called "voluntary retrofits" in the baseline report) the primary reason voluntary retrofits are not targeted by LLLC?

Probes:

As energy codes become more stringent and the first cost of LLLC declines, do you envision LLLC becoming more viable in projects retrofitting only the lighting controls (i.e., voluntary retrofits)?

Do you envision voluntary retrofits being important in achieving LLLC's 20-year vision?

A.1.5. Opportunities and Barriers

I'd like to switch gears now and talk about the opportunities and barriers for LLLC.

Q7. What do you think are the key opportunities for LLLC? What are the key barriers?

Let's talk about some additional LLLC opportunities and barriers that were covered in the *Connected Lighting* PowerPoint presentation. (*Ask Q8 through Q13 for items not covered in Q7; probe for details about additional barriers not mentioned below*).

Q8. The presentation lists "first costs" as a top barrier for LLLC. Tier 1 of LLLC addresses the first cost barrier by influencing manufacturers to embed controls into fixtures at the time of production. Are you aware of other product features or production strategies that may be incorporated into LLLC in order to reduce first cost but were not highlighted in the product or tier definitions?

Q9. The presentation lists "Solid State Lighting (SSL) Trends" as a top opportunity for LLLC. How do you envision the increase in SSL adoption will impact the LLLC market?

Probes:

Are most LLLC products compatible with both linear fluorescent and SSL fixtures, or do LLLC manufacturers typically have separate LLLC products for linear fluorescent and SSL fixtures?

Are there additional LLLC features, such as color shifting, that you anticipate being integrated into LLLC products in order to take full advantage of future SSL products? Please list other features you anticipate being integrated into LLLC.

Q10. The presentation lists "energy code progress" as a top opportunity for LLLC. Have you had conversations with code officials/developers about including LLLC into future energy codes or reach codes?

Probes:

Which organizations have you had conversation with and what were the results of those conversations? Do you have any documentation (e.g., emails, memos) you are able to share with us about your conversations related to integrating LLLC into codes?

What is the current status of addressing LLLC through codes in the various geographies of the PNW? (Please specify for Oregon, Washington, Idaho, Montana, and Seattle). How does this compare to LLLC requirements in California's energy code?

Q11. What is your understanding of the current market adoption of LLLC in the various geographies in NEEA's territory? (Please specify for Oregon, Washington including Seattle, Idaho, Montana, as well as by LLLC tier). How does market adoption vary by geography? How does market adoption vary by LLLC tier, and does tier-specific

adoption vary by geography? How does this compare to LLLCs' market adoption in California?

Q12. Going back again to the *Connected Lighting* PowerPoint presentation, "value proposition" is listed as a top barrier for LLLC. Can you please provide more detail on this barrier?

Probes:

What is your perspective of the importance of non-energy benefits and the success of LLLC?

Q13. The presentation lists "fragmented market" as a top barrier for LLLC. Can you clarify what is meant by "fragmented market?"

Probes:

Does this barrier relate to LLLC manufacturers selling directly to owners and not going through the typical distributor channels? Our understanding is that LLLC manufacturers have been working directly with large customers e.g., major Silicon Valley tech companies to "showcase" their products and technology.

How, if at all, does distribution in the Pacific NW differ from distribution in California?

Do you think the fragmented market is likely to be scalable? Do you see the fragmentation of the market changing? How and how soon? What needs to happen to make the market less fragmented, bring in more market actors, and enable LLLC distribution to be more scalable?

Given the technological and distribution chain differences between LLLC and "standard" lighting, what would be the most effective way to expand the distribution chain to include additional market actors (e.g., lighting designers, installers)?

Q14. A common trend in lighting design for high performance office spaces is to minimize ambient light levels and increase task lighting. What is your vision for LLLC systems in these types of spaces?

Probes:

How do you envision NEEA making LLLC more effective in these low lighting power density (LPD) designs?

Do you envision LLLC having a justifiable ROI in office spaces with LPDs significantly below current code allowances?

A.1.6. Manufacturers

Finally, I'd like to talk about manufacturers of LLLCs.

Q15. LLLCs seem to generally be manufactured by relatively small and new companies. Are you seeing the major incumbent lighting players (General Electric [GE], Sylvania, Phillips) develop LLLCs?

Probes:

Are the major incumbents developing LLLC products across the LLLC tiers or are they tending towards the less ambitious LLLC products (Tier 1)?

Are smaller and newer LLLC manufacturers tending towards developing expensive and ambitious LLLC products (Tiers 2 +) or are they also making more affordable LLLC products (Tier 1)?

Q16. Can you provide insights on the major incumbent manufacturers' (GE, Sylvania, Philips) intentions to develop LLLCs or partner with smaller and newer LLLC manufactures to provide an integrated LLLC luminaire solution?

Q17. As part of the Market Research and Evaluation (MRE), we will be interviewing up to ten LLLC manufacturers, five regional lighting experts, and ten distributors. Do you have any specific questions you would like us to ask any/all of these groups during our interviews to help with your design and implementation of the LLLC initiative?

Probe:

We have compiled a list of LLLC manufacturer contacts. Would you be willing to review this list and recommend contacts to add or delete?

Q18. Is there anything else you think I need to know about the initiative or its vision that we have not discussed?

Those are all of my questions today. If we need to follow-up on anything, would it be OK to contact you directly?

Thanks again for your time.

A.2. Manufacturers Interview Guide

A.2.1. Introduction

Thanks for taking the time to talk with us today. We'd like to start by discussing [MANUFACTURER]'s product line-up of Advanced Lighting Controls. While we are interested in all controls you manufacture, including add-on options, we are primarily interested in controls that are embedded within light fixtures during the manufacturing process and that allow localized control and networking between fixtures (or a group of fixtures). We will refer to these systems as Luminaire Level Lighting Controls (or LLLC) throughout our discussion.

As background information, Energy 350 is conducting a market assessment for the NEEA to help NEEA better understand the current generation of LLLC systems available in the market, how these are expected to evolve over time, and what some of the drivers and barriers are to LLLC systems. This information will assist NEEA in its efforts to enable faster market adoption of LLLC systems.

Before we proceed, please know that your responses will be confidential to the extent permitted by law, and any analyses will not identify individuals, product names, or firms.

A.2.2. Background Knowledge and Firm Characteristics

To start, we would like to get a sense of your firm's scale and the types of lighting projects you engage in, so our first several questions are about your business practices and firm characteristics.

Q1. What is approximate size of your firm in terms of:

1. Number of employees
2. Age of firm (i.e. years in business)

Q2. We understand that your firm produces the following products: [FILL IN WITH SPECIFIC MANUFACTURER INFORMATION PRIOR TO INTERVIEW]

1. LLLC products _____
2. Lighting controls _____
3. Lighting technologies _____
4. Have we missed any products that you manufacturer? If so, what? _____
5. Has your firm partnered with a fixture manufacturer to embed or add-on LLLC controls into the fixture, or does your firm intend on doing so? [*Record fixture partner, if applicable. Specify whether controls are embedded or added-on.*]

Q3. What is your role in projects that include LLLCs? Specifically:

1. Do you ever work directly with customers on lighting projects? [If yes, move to 2]
2. What would be the total number and size of projects completed annually?

3. What is the % or # that involve LLLC systems?
4. What % of these projects (based on $) are new construction? What % are major renovations? What % are retrofits? [*PROBE: Do you scope projects, interact with decision makers, specify equipment, or perform commissioning? Do you have a partnership with other market actors such as distributors or contractors?*]
5. [*If using outside contractors to do commissioning:*] What specific skill sets do you require of LLLC commissioning staff?

Q4. Can you explain how your distribution channels work for LLLC products? That is, what steps would an end user undertake to get an LLLC system installed? [*PROBE: How are most LLLC installations initiated? Have you marketed your system(s) to lighting designers who then recommend your product for their projects?*]

A.2.3. Market Trends

To get a sense of the LLLC market trends you are witnessing, my next questions ask about the current and future state of the advanced lighting controls market.

Q5. Which building types do you see LLLC systems installed in most often? [*PROBE: If offices are mentioned, ask what size: small (<10,000 sq. ft,), medium (10,000 to <50,000 sq, ft,), large (50,000-100,000 sq, ft,) or very large (>100,000 sq, ft,)*]

1. What factors specific to different building types might affect increased adoption of LLLC systems?

Q6. In 2015 in the PNW, what percent of your overall lighting control sales were LLLC sales? Your best estimate is fine.

1. How has the LLLC percent of overall lighting control sales in the Northwest changed over the past 5 years?
2. Do you expect LLLC sales as a percentage of overall lighting control sales to increase or decrease in the next 5 years? Why or why not?

Q7. Is there a particular state in the Northwest where LLLC systems are more commonly installed? Where? Why do you think this is? [*PROBE: Would you say these buildings are mainly in metropolitan or non-metropolitan areas?*]

1. What factors would cause this to change in the short (0-5 years) term?
2. What factors would cause this to change in the long (5-10 years) term?

Q8. Who is typically involved in the purchasing decisions for lighting systems? [*PROBE: Who is the lead decision maker?*]

1. Is this different for LLLC systems compared to typical lighting fixture and standalone control systems?

Q9. Which trade allies—such as lighting contractors, manufacturer reps, or electricians—do you see currently installing LLLC products?

1. What factors would cause this to change in the short (0-5 years) term?
2. What factors would cause this to change in the long (5-10 years) term?

Q10. What lighting technology (e.g., LEDs, linear fluorescents, TLEDs) do you see LLLCs commonly control?

1. What factors would cause this to change in the short (0-5 yrs.) term?
2. What factors would cause this to change in the long (5-10 yrs.) term?

Q11. What communication protocols—or technology—are you currently using for your LLLC systems?

1. **Is this protocol proprietary?**
2. Are you aware of other manufacturers using similar communication protocols?
3. [*If current protocol is proprietary*] Are open communication standards likely to be adopted by your company? Why or why not?
4. What limitations might prevent your protocols from being widely adopted?
5. Do you believe there are benefits to an open communication standard for LLLC systems? Why or why not? [*PROBE: Why do you believe this is perceived as a benefit to utilities?*]

[*PROBE: Is your firm aware of any open standards communications or coordination efforts among Northwest organizations? If needed, probe for awareness of communication or coordination involving Bonneville Power Administration (BPA), Pacific Northwest National Laboratory (PNNL), DLC, and/or NEEA.*]

A.2.4. Barriers and Drivers

Next we'd like to get your take on the barriers your firm faces to increasing market adoption of LLLC systems.

Q12. NEEA has identified a number of barriers they believe stand in the way of widespread adoption of LLLC products in the PNW market. I am going to read you the list of those barriers. For each of the barriers I mention, please tell me, on a 1-to-5 scale, where 5=very important and 1=not important, how important these barriers are to address to increase widespread LLLC adoption.

Barriers		Using a scale of 1-5 where 5 means "very important" and 1 means "not important how important are NEEA's identified barriers to address?						
		1=Not Important	**2**	**3**	**4**	**5= Very Important**	**98- Don't know**	**99- Refused**
a)	High first costs for LLLC products & installation, making payback untenable							
b)	Limited understanding of the capability, viability, and availability of LLLC products							
c)	Perception of poor product persistence, serviceability, or re-configurability							
d)	Limited trained support network established for installers, building IT & facilities							
e)	LLLC systems appear too complex to be installed and commissioned correctly							
f)	Market fragmentation in terms of networking standards, communication protocols, and what even constitutes an advanced lighting control							
g)	Concerns over LLLC aesthetics, complexity, and possible user impact							
h)	A lack of a clearly defined business value for LLLC products							

[*PROBE for any barriers respondent disagrees with: Why?*]
[*PROBE ALL: Beside the barriers we just discussed, are there any other barriers you see to widespread adoption of LLLC products in the PNW?*]

Q13. Have you previously worked with utility efficiency programs on LLLC system demonstrations or installations?

1. [*IF "YES"*] What specific barriers, if any, did you experience when working with utility efficiency programs?

Q14. What barriers have you experienced when installing LLLC products? [*PROBE: What product awareness and training resource barriers have you experienced, especially if using outside contractors?*]

Q15. What specific user-experience barriers have you observed? [*PROBE: Does this vary for different customer types (e.g., tech company office vs warehouse, or if it applies across the board)? What have been their specific likes/dislikes?*]

Q16. Have you experienced supply chain barriers? If so, what are they?

Now let's switch gears and talk about the benefits of LLLCs.

Q17. What do you say to potential buyers about the LLLC systems to convince them to buy an LLLC system?

1. Are there specific benefits of LLLC products you highlight for office space customers? How about for warehouse customers?
2. Which of these benefits have you found most effective in persuading customers in office spaces to install LLLC products? What has worked best for customers in warehouses?
3. What non-energy benefits (or features) of your product line do you promote the most? [*IF NEEDED: for example, security features, energy use tracking, maintenance alerts.*]

Future of Lighting Controls

Now I'd like to talk with you about where you think advanced lighting controls may be heading in the future.

Q18. How do you see the supply chain for advanced lighting controls working in the future? [*PROBE: Do you see future lighting controls systems as likely to go down the path of "lighting as a service," or do you think they are more likely to remain a "product?" Why or why not?*]

Q19. What have you heard your customers ask for from an advanced lighting control system in the future? [*PROBE: Does this vary by customer type?*]

1. Are your customers asking for specific features that are not currently available but likely to be available in the future? If so, what and when? [*PROBE: Do you envision integration with building control systems and if so, do you foresee more/less IT involvement? Why?*]

Q20. Do you see value in having an entity (such as Illuminating Engineering Society of North America [IESNA]) develop standards to assist with proper lighting <u>design</u> for systems that include LLLCs? Why or why not?

Q21. How much effort should be focused on lighting <u>design</u> training versus <u>post-installation</u> training for proper operation?

Q22. Are you familiar with the DLC's specification for Networked Lighting Control Systems? [*If yes, continue to next questions. If no, explain the spec.*]

The DLC is partnering with NEEA to create a specification aimed at defining networked advanced lighting control systems to support utility programs as well as achieve broad market adoption of products. The specification will help set minimum requirements for networked controls for utility incentive eligibility.

Q23. Are you familiar with NEEA's Tier 1 product definition? [*If yes, continue to sub-questions. If no, explain the Tier 1 product definition.*]

NEEA's Tier 1 product definition relies on the DLC base specification to provide incentives to products that exceed the spec and contain specific feature-sets. The Tier 1 initiative focuses on overcoming the high first cost of LLLCs by encouraging manufacturers to embed controls into fixtures when the fixtures are manufactured. NEEA's thinking is that the economies of scale in manufacturing will reduce costs and simplify LLLC installation and support. Products qualifying for Tier 1 will have to:

- Have embedded lighting control strategies (Occupancy & Ambient Light Detector, including all hardware and software)

- Have autonomous (distributed) processing, and

- Be networkable for simple zoning (i.e. conference rooms, private offices, hallways)

2. Do you have current plans for a product that meets the NEEA Tier 1 definition?
3. Are there any aspects of the Tier 1 definition that will be a challenge for your LLLC product to meet? If so what are they?
4. What are your plans for products that may exceed Tier 1? [*PROBE regarding: timeframe, feature-sets, target markets, etc. Specifically ask about features of a Tier 2 product such as preset reduction of light output (Factory Set High End Trim), local user control of lighting (Personal Task Tuning), self-calibration & energy-use monitoring (Energy Monitoring), & status, settings, run-time metrics (Performance Reporting).*]

Q24. How do you think building energy codes will affect the adoption of LLLC systems? Why do you say this? [*PROBE: Do you foresee differences across the NW States?*]

Q25. How do you think utility efficiency programs will affect the adoption of LLLC systems? Why do you say this?

A.2.5. Other

Q26. Did you attend the DLC meeting in Connecticut in October? [IF SO:] What messages did you take away from the meeting regarding the Commercial Advanced Lighting Controls (CALC) qualified products list (QPL) due out this quarter?

Q27. Are there any factors we did not cover that you think will affect the adoption of LLLC products and systems in the coming years?

Those are all of my questions. Thank you once again for your time.

REFERENCE - NEEA LLLC Tier 1 & 2 definitions

1. Standardization tier focuses on overcoming the high first cost barrier by influencing manufacturers to embed controls into fixtures at the time of production. Economies of scale will reduce costs and simplify installation and support. Performance requirements at this level are:

    S1. Embedded lighting control strategies (Occupancy & Ambient Light Detector, including all hardware and software)
    S2. Autonomous (distributed) processing
    S3. Networkable for simple zoning (i.e. conference rooms, private offices, hallways)

2. Communication tier is focused on expanding energy savings by including factory-set high-end trim and personal tuning strategies as well as micro-zone level reporting capabilities. Performance requirements are:

    S1. Factory Set High End Trim (preset reduction of light output)
    S2. Personal Task Tuning (local user control of lighting)
    S3. Energy Monitoring (self-calibration, energy use)
    S4. Performance Reporting (status, settings, run-time metrics)

A.3. Distributors Interview Guide

A.3.1. Introduction (1 minute)

Thank you for participating in this interview. This interview will help the NEEA better understand the performance of its Reduced Wattage Lamp Replacement Initiative (RWLR), which provides incentives and education to promote the sales of 25W and 28W linear fluorescent lamps. We are interested in better understanding how Reduced Wattage (RW) lamps fit into your product offerings, which customer types most often purchase RW lamps, and why other customer types do not. This information will allow NEEA offer the best possible program.[12] Everything you share is anonymous and will be reported in aggregate.

We also have some questions about training—that is, training on lighting design and specification, installation, and sales—and other questions about advanced lighting controls. Are you the right person to talk to about training?

(**If respondent is not the right person to discuss training**) Who should we contact about lighting training? (**Collect alternative contact name, title, email address, and phone number for Top Tier Trade Ally (TTTA): _____**)

Are you the right person to talk to about advanced lighting controls?

(**If respondent is not the right person to discuss advanced lighting controls**) Does anyone in your organization have experience with advanced lighting controls?

> (**IF YES**) Who should we contact about advanced lighting controls? (**Collect alternative contact name, title, email address, and phone number for LLLC:** _____)

A.3.2. Background (4 minutes)

1. What is your primary customer base (e.g., Installers/contractors? Building owners? Designers? Specifiers? Other? (**Probe:** proportions between contractors, direct to end-users, and national accounts)

2. (IF NON-PART) Do you sell 25W or 28W linear fluorescent lamps? Both?

    a. (IF NO) Why is that? (**Probe:** lack of familiarity, customer interest, concerns with technologies
    b. (IF NO) Have you ever stocked/sold them?

[12] Interviewer will review BPA's distributor database, as well as NEEA's communication logs, prior to each interview.

A.3.3. Customer Awareness and Perception (10-12 minutes)

3. Using a scale of "very aware, somewhat aware, not too aware, or not at all aware" please describe your customers' awareness of RW lamps as a replacement option for 32W T8s?

4. Over the last year, would you say that your customers have become a lot more aware, somewhat more aware, remained the same, become somewhat less aware, become a lot less aware of RW lamps? (If answers are a lot/somewhat more aware or less aware, ASK…)

    a. Why do you think that is?
    b. (ASK ONLY IF ANSWER TO Q4 IS A LOT/SOMEWHAT MORE AWARE) Has the change in awareness led to RW lamps being specified in orders more often, less often, or stayed the same in the last year?
    c. (ASK ONLY IF ANSWER TO Q4 IS A LOT/SOMEWHAT MORE AWARE) Have increased special pricing agreements for RW lamps led to RW lamps being specific in orders more often, less often, or stayed the same in the last year?

5. What do you tell your customers about RW lamps?

6. Are there certain types of customers (contractor or end-users) who tend to buy RW lamps? (IF YES, ASK…)

    a. What kind of customer is that?
    b. Why do you think that is?
    c. Do these customers tend to come from certain parts of the non-residential market such as schools, offices, hospitals, etc.? (**Probe:** which parts? Vary by size?)

7. Are there certain customer types that will not buy RW lamps?

    a. (IF YES) What kind of customer is that?
    b. Why do you think that is?
    c. Do these customers tend to come from certain parts of the non-residential market such as schools, offices, hospitals, etc.? (**Probe:** which parts? Vary by size?)

8. In general, have you noticed an increase, decrease, or the same level of interest in RW lamps in the last year? Why do you think that is?

9. Have you noticed an increase, decrease, or the same level of customer purchases in RW lamps in the last year? Why do you think that is?

10. What percentage of customers who order RW lamps ultimately repeat orders for RWs?

11. Assuming a project or purchase will include linear fluorescent lamps, is there any type of project or application for which you would NOT recommend RW lamps? (IF YES, ASK…)

    a. What are these projects?
    b. Why? (**Probe:** Performance problems in a specific application; would recommend a different technology such as 32W or TLED, etc.)

12. What have your customers told you about their experiences with RW lamps?

    a. Does the feedback differ between contractors versus end-users or national accounts? If so, how?

A.3.4. RWLR Participants Only (12-15 minutes)

13. Have you observed any change in your RW sales since enrolling in RWLR?

    a. (IF NOT) Why not?
    b. (IF YES) What factors do you think drove that increase? (**Probe:** Incentives causing lower prices, distributor's own efforts at promoting RWs, etc.)

14. What else could NEEA do to increase RW lamp sales? (**Probe:** Facilitate further discussion with manufacturers.)

15. As you know, the RWLR initiative allows distributors to deploy the NEEA incentives as it sees fit. How have you deployed the incentives? Have you…

    a. Used it for training?
    b. Lowered the cost of RW lamps?
    c. Supplied a portion of the incentives as bonuses to sales staff?
    d. Other: (Specify): _____

16. Please describe the training you provide to your employees regarding RW lamps. (**Probe:** Who receives the training (probe: counter sales, inside sales, outside sales, branch managers, etc.), benefits/applications of RWs relative to 32W, benefits of RWLR)?

17. Do you utilize any NEEA-provided materials for training?

    a. (IF YES) Which materials? Are there other materials you would find useful?
    b. (IF NO) Why? What other materials do you use instead?

18. Are you currently participating in any other regional midstream programs? (*By midstream we mean programs that pay incentives directly to distributors.*)

    a. (IF YES) Which programs and why?
    b. (IF NO) Have you ever? Why not?

19. How would you compare the merits of the following lighting program models:

    a. Midstream programs that use increasing incentives based on predetermined milestones?
    b. Midstream programs that use per lamp rebates?
    c. An upstream program that works through manufacturers to buy down prices?
    d. A downstream program that works through end-users and contractors and uses per lamp rebates?

20. Are there any ways you recommend changing or restructuring the RW program for greater impact or uptake?

    a. (IF YES) How so?

21. Are there any other energy efficiency products you feel would work well in a similar mid-stream market transformation program model?

    a. (IF YES) Which products and why?

A.3.5. RWLR Non-Participants Only (1-2 minutes)

22. Do you participate in any utility lighting incentive programs?

    a. (IF YES) What other incentive program(s) do you participate in?
    b. Do you have any recommendations or knowledge to share with NEEA based on your experiences with those programs?

A.3.6. Promotion, Stocking, and Pricing (10-12 minutes)

23. When a customer purchases RW lamps from you, who typically most influences the purchase decision? Is it the distributor, the contractor, specifier, or the end-user?

24. Has your stocking of RWs changed over the last few years (or, if participant, since joining the Initiative)?

    a. (IF YES) How has it changed and why?

25. Approximately, what percentage of your customers have maintenance specifications that recommend RW lamps?

    a. If the customer has a maintenance spec that specifies 32W, how could NEEA work to change that specification to a RW option?

26. Regarding ballast failure, what percentage of the time do your customers… [READ OPTIONS]

- o Replace the ballast and maintain the fluorescent system (_____ %)
- o Move towards and integrated fixture (possibly light-emitting diode [LED] _____ %)
- o Perform a group replacement of all ballasts (_____ %)
- o Others (please specify) _____ (_____ %)

27. Assuming equivalent volumes, typically what is the price premium you would pay manufacturers for RW lamps relative to 32W lamps?

Lamp	Price Differential
32W	100%
28W	____%
25W	____%

28. Please explain what factors you consider in setting prices for RW lamps compared to 32W lamps?

    a. [Ask only participating retailers] How have you applied the NEEA incentive to that paradigm?

29. Using a scale of "very sensitive, somewhat sensitive, not too sensitive, or not at all sensitive" please describe how sensitive are customers to the disparity, if any, in pricing between 32W/RW lamps?

30. Have you secured any special pricing agreements (SPAs) with manufacturers for RW T8 lamps?

    a. If not, are you actively pursuing SPAs with manufacturers for RW lamps? Why/why not?
    b. What about with customers? If not, are you actively pursuing SPAs with customers for RW lamps? Why/why not?
    c. Are there any requirements on your end to maintain SPAs with the manufacturer?
    d. Are there any ways you believe NEEA could assist in securing or maintaining SPAs with manufacturers?

31. Holding all other factors equal (customer, order size, time of year, etc.), are sales of RW lamps more profitable or less profitable for you than 32W lamps?

    a. Why is that?
    b. Do you think this will change in the next few years? How would it change?

A.3.7. Market and Sales (10-15 minutes)

32. Please give us your best estimate of the region's total 4-foot T8 annual sales.

33. What is your estimated market share of T8 lamps sales in the Northwest?

34. (IF NON-PART) Approximately, what percent of your current total 4-foot T8 sales would you estimate are RW lamps?

35. Generally, what factors do you believe are most important to driving future RW lamp sales?

36. How do you think upcoming general service fluorescent lamp federal standards will impact RW lamp sales?

37. What do you see as barriers to increased RW lamp adoption in the maintenance market?

    a. **Probe:** Availability, performance, cost, LED penetration, customer perception/awareness

38. Are there any barriers specific to 25W lamps as opposed to 28W lamps?

    b. (IF YES) What are these barriers?

39. Can you talk about the interaction between TLEDs and RW lamps in the maintenance market?

    a. Do certain customer types tend to choose one over the other? Which one? Why?

40. Please estimate to your best ability the percent (out of 100%) of 25W, 28W and 32WT8 lamps going to each sector:

Sector	32W Lamps	28W Lamps	25W Lamps
Commercial	____%	____%	____%
Industrial	____%	____%	____%
Total	100%	100%	100%

41. What are the challenges to selling RW lamps in these three different scenarios?

    a. Spot replacement?
    b. Group replacement?
    c. Renovation projects?

A.3.8. LLLC (15 minutes)

(If respondent stated in introductory section that they are the right person to discuss advanced lighting controls) We are also seeking to understand the use of advanced lighting control technologies, specifically focusing on LLLC. We use LLLC to refer to technology that has sensors embedded directly into each light fixture during the manufacturing process so that localized control over each fixture (or group of fixtures) is possible.

1. Is now a good time to talk with you about LLLCs?

2. (IF NO) Can you please tell me a few days and times over the next two weeks when we can schedule a short follow-up discussion about LLLCs? (**Record at least two days/times for follow-up discussion: _____**)

3. (IF YES) Can you tell us about your experience with LLLC products? Specifically:

   a. What manufacturers of LLLC products do you currently carry?
   b. Are any of these LLLC manufacturers more actively promoting LLLCs than others? If so, which?
   c. What positive experiences can you share with us regarding LLLC products?
   d. What negative experiences can you share with us regarding LLLC products?

4. What training, if any, have the LLLC manufacturers provided to you?

5. What building types or types of businesses have you seen LLLC products installed in?

6. How has your customers' interest of LLLC products changed over the past three years? [*Probe: What types of customers seem to have the greatest interest in LLLC technology?*]

7. Assuming equivalent fixtures, typically what is the price premium you would pay for an LLLC equipped fixture relative to standard separate systems (ex. occupancy sensor & fixture)?

8. How do you see that changing over the next three years?

9. How are you promoting LLLCs?

10. What barriers have you experienced when trying to sell LLLC products?

11. What benefits have you observed regarding LLLC installations? [*Probe: What benefits did customers mention specifically?*]

12. Is there anyone else in any field that we should talk to as part of our research on LLLC systems (architects, lighting designers, etc.)?

A.3.9. TTTA (30 minutes)

(**If respondent stated in introductory section that they are the right person to discuss training**) NEEA is also developing a training program for lighting trade allies to improve the energy savings from the projects they design, sell, and install. Therefore, we would like to get your insights about what training might be most valuable for lighting contractors you work with.

1. Is now a good time to talk with you about training?

2. (IF NO) Can you please tell me a few days and times over the next two weeks when we can schedule a short follow-up discussion about training? (**Record at least two days/ times for follow-up discussion: _____**)

(IF YES) First, I'd like to get a little bit of information about your company and the other companies you work with.

3. How many employees does your company have?

4. Approximately what percentage of your sales are equipment that go into non-residential facilities?

5. What other kinds of companies do you work with to provide lighting design and installation services for clients and in what ways do you work with them?

[*Probe about how they work with, and how much of their work is done with, the following:*]

a. Lighting designers
b. Architects and design engineers
c. Interior designers
d. Energy Service Companies (ESCOs)
e. Lighting installers
f. Electrical contractors
g. Other [specify]

6. How, if at all, does the work you do with these types of companies vary by…

a. The type or size of project
b. The location where the work is being done [*Probe about whether it is done in an urban or rural area*]

7. How do you and other employees of your company stay up-to-date about the latest lighting and lighting control technologies?

[*Probe for sources such as word-of-mouth from colleagues, trade association training seminars, and manufacturer rep presentations*.]

8. How frequently do you and other employees of your company receive this information or attend these sessions?

9. Do these resources provide sufficient support to keep you and other employees of your company up-to-date on lighting and lighting control technologies?

10. [*If not*] What is lacking?

11. How do you and your staff/colleagues stay up-to-date about building and equipment energy codes?

12. Do these resources provide sufficient support to keep you and your staff/colleagues up-to-date on codes?

13. [*If not*] What is lacking?

14. All in all, about how many hours a year, on average, would you say you and other employees of your company spend getting information on lighting, lighting control technologies, and codes through these resources?

15. What lighting certifications, if any, do you and your staff/colleagues currently hold?

16. In what ways, if any, do you pass information about the latest lighting and lighting control technologies on to the lighting design and installation contractors you work with?

17. What contractors, or types of contractor, are you most likely to share that kind of information with, if any? Why?

18. In what ways might it affect your business if the lighting design and installation contractors you work with took advanced training on lighting and lighting controls? [*Probe about how it might affect the following:*]

    a. What they would sell or be willing to sell
    b. The risk of callbacks or dissatisfied customers
    c. Whether or not they were willing to recommend a contractor to a customer

19. I'm going to read each of the following types of service that a lighting contractor might provide. For each one, please tell me whether you think the current overall level of expertise in the market is completely adequate, nearly adequate, or far from adequate. [*Read list of topics*]

    a. Conducting lighting audits of existing buildings
    b. Assessing the technical characteristics of lighting technologies
    c. Selecting the best lighting control product or system for a given application
    d. Setting up and commissioning lighting control systems
    e. Training others how to operate lighting control systems
    f. Knowledge of standards and best practices in lighting design

g. Using photometric software for planning LED luminaire selection and placement
h. Energy code requirements, including when and where they apply
i. Communicating the benefits of retrofit and design options

20. How important do you think it is that lighting contractors have expertise in luminaire-level lighting controls, also known as "smart fixtures" and "illuminated intelligence"? [Probe for reasons why they do or do not think it is important]

21. How likely would you be to encourage the lighting contractors you work with to take advanced lighting training developed by NEEA? Why? What would you do to encourage them?

22. What would prevent lighting distributors, such as yourself, and the lighting contractors that work with them from taking advanced training on lighting and lighting controls?

23. What might encourage them to take such training?

24. What benefits, if any, might you offer to contractors with advanced training on lighting and lighting controls to get them to work with you?

25. Other than by offering a formal training curriculum, how else could NEEA assist you in bringing the lighting design and installation contractors you work with up to speed on the latest lighting and lighting control technologies?

26. Suppose that a good proportion of the top lighting contractors in the region got advanced training like we've been talking about – what affect, if any, would that have on the adoption of more efficient lighting? What would keep building and business owners from adopting the most efficient lighting?

27. Finally, we would like to get a sense of advanced lighting and control technologies are currently sold with and without utility incentives. First, over the past year or so, about what percentage of your sales did advanced lighting and lighting control technologies comprise? [If needed: "By advanced lighting and lighting controls, I mean highly efficient lighting like LEDs, luminaire-level lighting, and advanced lighting controls such as scheduling or networked controls.]

28. When proposing projects customers that included advanced lighting or lighting controls, how often do you discuss whether or not they are planning to apply for utility incentives? [Probe for differences between customers that are end-users and those that are contractors. Try to get %]

29. [*IF DISCUSSES INCENTIVES AT LEAST HALF THE TIME*] For each of the following types of advanced lighting and control technologies, can you give me your best estimate of the percentage of sales that are done with utility incentives? [*IF NEEDED: As opposed to being done <u>without</u> utility incentives.*]

a. LED high bay, screw-in, and exterior

b. All other LED types
c. T5 and Super T8 tubes
d. Occupancy-based, scheduling, and daylighting dimming lighting controls
e. EMS or networked lighting controls
f. Luminaire-level lighting controls

Finally, just a couple of questions about the Northwest Lighting Network (NWLN) website.

30. How many times would you say you have visited the Northwest Lighting Network website in the past six months?

31. [IF VISITED NWLN website] What information were you looking for on the website?

32. [IF VISITED NWLN website] How was your experience using the website? [*Probe about whether they found the information, how difficult it was to navigate, how useful it was*]

Thank you for your time and input – we are always available for any questions or feedback you may have as we continue this research.

A.4. Regional Expert Interview Guide

A.4.1. Introduction

Thanks for taking the time to talk with me today. We will be talking about the current market for advanced lighting controls. Specifically, we are interested in lighting systems that embed controls directly in the fixture during the manufacturing process. We refer to these as Luminaire Level Lighting Controls, or LLLCs.

As background information, Energy 350 is conducting a market assessment for the NEEA to help NEEA better understand the current generation of LLLC systems available in the market, how these are expected to evolve over time, and what some of the drivers and barriers are to LLLC systems. This information will assist NEEA in its efforts to enable faster market adoption of LLLC systems.

Before we proceed, please know that your responses will be confidential to the extent permitted by law, and we will not identify any individuals, product names, or firms in our reporting.

A.4.2. LLLC Market Characterization and Trends

I'd like to start by asking some general questions about LLLC, including questions about your experience with those systems.

Q1. First, what is your professional role with regard to lighting and lighting controls?

Q2. Are you familiar with the Design Lights Consortium spec for Commercial Advanced Lighting Controls (CALC)? [*If yes, continue to sub-question 1. If no, explain the spec. and skip to sub-question 2*]

The DLC is partnering with NEEA to create a specification aimed at defining networked advanced lighting control systems to support the broad adoption of these products in the market. The specification will also help utilities with setting minimum eligibility requirements for networked controls for their incentive offerings.

1. [IF YES] Have you attended DLC stakeholder meetings to talk through the specification for advanced lighting control systems? [IF SO] What was your understanding of the group's conclusions regarding industry agreement on a unified specification?
2. [IF NO] How do you think creating a unified spec to define "advanced lighting control systems" that spell out specific product requirements would impact the lighting industry? Why or why not?
3. Do you think LLLC manufacturers would comply with an advanced lighting control system specification? Why or why not?

Explain NEEA's Tier 1 goal:

NEEA's Tier 1 product definition relies on the DLC base specification to provide incentives to products that exceed the spec and contain specific feature-sets. The Tier 1 initiative focuses on overcoming the high first cost of LLLCs by encouraging manufacturers to embed controls into fixtures when the fixtures are manufactured. NEEA's thinking is that the economies of scale in manufacturing will reduce costs and simplify LLLC installation and support. Products qualifying for Tier 1 will have to:

- Have embedded lighting control strategies (Occupancy & Ambient Light Detector, including all hardware and software)

- Have autonomous (distributed) processing, and

- Be networkable for simple zoning (i.e. conference rooms, private offices, hallways)

Q3. Do you have any insight into how the advanced lighting control distribution channel currently works? That is, what steps does an end user take to get an advanced lighting control system installed? [*PROBE: How are most LLLC installations initiated? Are systems primarily designed, specified, installed, and commissioned by manufacturers or their reps? Who are the most active reps you see in the PNW for advanced lighting controls?*]

Q4. In what types of projects do you see LLLC systems installed most often? [*PROBE: retrofits of several fixtures, new construction projects, major renovations involving many fixture change-outs and space reconfiguration.*]

1. Are there specific applications/scenarios where LLLCs would never make sense to install? Why or why not?

Q5. What lighting technology (e.g., LEDs, linear fluorescents, TLEDs) do you see LLLCs most commonly control?

1. What factors would cause this to change in the short (0-5 years) and long (5-10 years) terms?

Q6. Who is typically involved in purchase decisions for lighting systems? [*PROBE: Who is the lead decision maker?*]

A.4.3. Target Market

Now let's talk about the types of buildings and market sectors that LLLC systems are being targeted at currently.

Q7. Which market(s) (new construction, major renovation, retrofit) do you think should be the initial target for LLLC systems in the PNW? Why or why not?

PROBES IF THEY DO NOT MENTION RETROFIT MARKET:

As energy codes become more stringent and the first cost of LLLC declines, do you envision LLLC becoming more viable in projects where only the lighting controls are retrofit (i.e., voluntary retrofits)?

Q8. Are there specific building types you believe would be the best to target with LLLC systems? Why do you say this?

Probes:

Do you perceive adoption and saturation of LLLC products to vary based on building size within these building types?

A.4.4. LLLC Long-Term Vision

Now I'd like to ask about your 20-year vision for LLLC systems.

Q9. How do you see the supply chain for advanced lighting controls evolving over the next 20 years? [*PROBE: Do you see future lighting controls systems as likely to go down the path of "lighting as a service," or do you think they are more likely to remain a "product?" Why or why not?*]

Q10. Are customers asking for specific features that are not currently available but likely to be available in the future? If so, what are these features and when do you think these will be available? [*PROBE: Do you envision integration with building control systems and, if so, do you foresee more/less IT involvement? Why?*]

Q11. Are you aware of any other advanced lighting technologies coming to market in the future that may be an alternate approach to LLLC? [*PROBE: Do you see these as complimentary feature-sets of LLLC systems or a competing technology?*]

Q12. Do you see value in having an entity develop standards to assist with proper lighting design for systems that include LLLCs? [*PROBE: How much effort should be focused on lighting design training versus post-installation training for proper operation? Who do you think that entity should be? (ex. NEEA, DLC, IESNA)*]

A.4.5. Opportunities and Barriers

I'd like to switch gears now and talk about the opportunities and barriers for LLLC.

Q13. How do you think building energy codes in the next 5, 10 and 20 years will affect the adoption of LLLC systems? Why do you say this? [*PROBE: Do you foresee differences across the NW States?*]

Q14. How do you think utility efficiency programs will affect the adoption of LLLC systems over the next 5, 10 and 20 years? Why do you say this?

Q15. Are there other factors or entities that you foresee affecting the adoption of LLLC systems over the next 5, 10 and 20 years?

Q16. NEEA has identified a number of barriers they believe stand in the way of widespread adoption of LLLC products in the PNW market. I am going to read you the list of those barriers. For each of the barriers I mention, please tell me on a 1-to-5 scale, where 5=very important and 1=not important, how important these barriers are to address to increase widespread LLLC adoption.

Barriers		Using a scale of 1-5 where 1 means "not important" and 5 means "very important," how important are NEEA's identified barriers to address?						
		1=Not Important	**2**	**3**	**4**	**5=Very Important**	**98-Don't know**	**99-Refused**
a)	High first costs for LLLC products & installation, making payback untenable							
b)	Limited understanding of the capability, viability, and availability of LLLC products							
c)	Perception of poor product persistence, serviceability, or re-configurability							
d)	Limited trained support network established for installers, building IT & facilities							
e)	LLLC systems appear too complex to be installed and commissioned correctly							
f)	Market fragmentation in terms of networking standards, communication protocols, and what constitutes an advanced lighting control							
g)	Concerns over LLLC aesthetics, complexity, and how the controls may affect end users							
h)	A lack of a clearly defined value to the end-user for LLLC products							

[*PROBE for any barriers respondent disagrees with: Why?*]
[*PROBE ALL: Beside the barriers we just discussed, are there any other barriers you see to widespread adoption of LLLC products in the PNW?*]

Q17. How do you envision the increase in Solid State Lighting (SSL) adoption will impact the LLLC market?

Probes:

Have you found that most LLLC are products compatible with both linear fluorescent and SSL fixtures, or do LLLC manufacturers typically have separate LLLC products for linear fluorescent and SSL fixtures?

Are there additional LLLC features, such as color shifting, that you anticipate being integrated into LLLC products in order to take full advantage of future SSL products? Please list other features you anticipate being integrated into LLLC.

Q18. "Energy code progress" is seen as a top opportunity for LLLC systems. Have you had any indication from code officials/developers about the inclusion of LLLCs into future energy codes or reach codes?

Probes:

What is the current status of addressing LLLC through codes in the various geographies of the PNW? Please specify for Oregon, Washington, Idaho, Montana, and Seattle. Are you aware of how this compares to LLLC requirements in California's energy code?

Q19. What is your understanding of the current market adoption of LLLCs in the various geographies in NEEA's territory?

1. How does market adoption vary by geography? Please specify for Oregon, Washington including Seattle, Idaho, Montana.

Q20. What is your perspective on the importance of non-energy features, such as color shifting or asset tracking, to the success of LLLC systems?

1. What do you think are the most influential non-energy features for LLLCs?
2. Are there additional non-energy features you think will be important to increase adoption of LLLCs in 5, 10, and 20 years? If so, what are they?

A.4.6. Other

Q21. Are there any factors we did not cover that you think will affect the adoption of LLLC products and systems in the coming years?

Q22. As part of this research, we will be interviewing other regional lighting experts, LLLC manufacturers, and lighting distributors. Are there any questions you would it would be beneficial for us to ask any/all of these groups to help with our understanding of the LLLC market?

Those are all of my questions today. Thanks again for your time.

Appendix B. Final Design Lights Consortium (DLC) Advanced Lighting Controls Specification

DESIGNLIGHTS CONSORTIUM

Networked Lighting Control Systems Specification

Version 1.01
Issued April 21, 2016
Revised May 6, 2016

Schedule of Revisions

Revision Number	Date	Description
1.0	April 21, 2016	• Initial Specification Published
1.01	May 7, 2016	• Clarified that the specification is for Interior Control Systems. Systems designed and marketed exclusively for exterior applications are not eligible to be qualified.

This document defines requirements to be met or reported for lighting control systems listed on the DesignLights Consortium™ (DLC) Networked Lighting Controls Qualified Products List (QPL).

Scope of Specification

This is a specification for Interior Networked Lighting Control systems. Such systems are defined for the purposes of this specification as the combination of sensors, network interfaces, and controllers that effect lighting changes to interior luminaires, but does not include the luminaires themselves. Any luminaire specific control requirements are addressed separately by the DLC's Solid-State Lighting specification and Qualified Products List.

"Required" vs. "Reported" Capabilities

The specification is built upon "required" and "reported" system capabilities.

"Required" Capabilities: Shall be present in all systems to be listed on the QPL. Systems that do not have these capabilities are not eligible to be listed. A successful application will provide information on the presence of these capabilities and characteristics. Key information provided by the manufacturer will be published on the QPL.

"Reported" Capabilities: DLC will report on the presence or absence of, type, and/or characteristics of each reported capability for qualified systems. While systems are not required to include these capabilities, a successful application will provide information on the presence or absence of these capabilities and characteristics. Key information provided by the manufacturer will be published on the QPL.

Additional Requirements

Warranty – DLC requires a minimum 5 year warranty for all components of the system addressed by the specification.

Commercial Availability and Verification – All systems must be fully commercially available, able to be purchased, with complete, final documentation and literature readily available on the manufacturer's website before they can be listed. DLC requires that a qualified system has been installed and operated successfully in at least one actual field installation. DLC will verify this through a case study and/or a customer reference. See the Application Form for more information.

System Overview Presentation - As part of the Application Review Process, the DLC requires a system overview to be presented via webinar or in-person to the DLC. See the Application Form for more information.

All Specification documents including the Application Form, Instructions, and supporting documentation can be found on the DLC website at http://www.designlights.org/content/CALC/SpecificationAndQPL

Table 1 provides a Summary of "Required" and "Reported" System Capabilities.

Table 1

'Required' System Capabilities	'Reported' System Capabilities
• *Networking of Luminaires and Devices*	• *Type of User Interface*
• *Occupancy Sensing*	• *Luminaire-Level Control (non-integrated)*
• *Daylight Harvesting*	• *Luminaire Level Control (integrated)*
• *High End Trim*	• *Localized Processing / Distributed Intelligence*
• *Zoning*	• *Scheduling*
• *Luminaire and Device Addressability*	• *Personal Control*
• *Continuous Dimming*	• *Load Shedding (DR)*
	• *Plug Load Control*
	• *BMS/EMS/HVAC Integration*
	• *Energy Monitoring*
	• *Device Monitoring / Remote Diagnostics*
	• *Operational and Standby-Power*

Table 2 provides the detailed definition for each Required Capability. Please note that the Application Form specifies in more detail what information the DLC requires from manufacturers for each capability and what information will be published on the QPL.

Table 2: Required System Capabilities

Row	Capability	Definition
1	Networking of Luminaires and Devices	The capability of individual luminaires and control devices to exchange digital data with other luminaires and control devices on the system. This capability is required at the room or space level, but not at the whole building level or beyond (e.g. non-lighting systems, or the internet).
2	Occupancy Sensing	The capability to affect the operation of lighting or other equipment based upon detecting the presence or absence of people in a space
3	Daylight Harvesting	The capability to automatically affect the operation of lighting or other equipment based on the amount of daylight and/or ambient light that is present in a space.
4	High-End Trim (aka Task-Tuning)	The capability to set the maximum light output of an individual or group of luminaires at the time of installation or commissioning. High-End Trim must be field reconfigurable.
5	Zoning	The capability to group luminaires and form unique lighting control zones for a control strategy. Zoning is required for Occupancy Sensing, High-End Trim, and Daylight Harvesting control strategies except for systems that feature Luminaire Level Control (LLC) capabilities as defined in this specification under "Reported Capabilities", in which case zoning is only required for Occupancy Sensing and High-End Trim control strategies.
6	Luminaire and Device Addressability	The ability to uniquely identify and/or address each individual luminaire, sensor, controller, and user interface device in the lighting system, allowing for configuration and re-configuration of devices and control zones independent of electrical circuiting. Please note that while DLC requires systems to have this addressability capability, systems that also offer traditional electrically circuited control zones as an option (e.g. zones defined by 0-10V wiring) will not be disqualified.
7	Continuous Dimming	The capability of a control system to provide control with sufficient resolution (100+ steps) to support light level changes perceived as smooth (as opposed to step dimming with a few discrete light levels).

Table 3 provides the detailed definition for each Reported Capability. Please note that the Application Form specifies in more detail what information the DLC requires from manufacturers for each capability and what information will be published on the QPL.

Table 3: Reported System Capabilities

Row	Capability	Definition
8	Type of User Interface	The type of interface used by the control system for reading and adjusting control system settings during system start-up, commissioning, and/or ongoing operation.
9	Luminaire Level Control (LLC, non-integrated)	The capability to have an occupancy sensor, ambient light sensor and luminaire controller installed for each luminaire.
10	Integrated Luminaire Level Control (LLC, integrated)	The capability to have an occupancy sensor and ambient light sensor installed for each luminaire, and directly integrated or embedded into the luminaire form factor during the luminaire manufacturing process.
11	Localized Processing / Distributed Intelligence	The capability of sensors and luminaires to execute pre-programmed energy saving strategies in the absence of (resulting from either a loss of network connection or failure) a gateway or central processor.
12	Scheduling	The ability to affect the operation of lighting and/or other equipment based on time of day or astronomical event.
13	Personal Control	The capability for individual users to adjust the illuminated environment to their personal preferences within a space.
14	Load Shedding (Demand Response)	The ability to reduce the energy consumption of a lighting system, in a pre-defined way, on a temporary basis, in response to a demand response signal. The method by which the system implements this capability must be clearly described in the application.
15	Plug Load Control	The ability to control the power delivered to receptacles through scheduling or occupancy sensing. The method by which the system implements this capability must be clearly described in the application.
16	Other Building Systems Integration (e.g. BMS,EMS,HVAC, Lighting)	The ability to exchange data with other building systems such as Building or Energy Management Systems (BMS/EMS), Heating Ventilation and Air Conditioning (HVAC) Systems, or other Lighting systems. The method by which the system implements this capability must be clearly described in the application.
17	Energy Monitoring	The ability of a system, luminaire, or device to report its own energy consumption, or the energy consumption of any controlled device via direct measurement or other methodology. The method by which the system implements this capability must be clearly described. The accuracy or reported data must be specified, and the method by which accuracy is determined must be clearly described in the application.
18	Device Monitoring / Remote Diagnostics	The ability to monitor, diagnose, and report operational performance including system and/or component failures.
19	Operational and Standby Power Consumption	The power use of control system devices, in both active and standby modes, if available. DLC will collect this information but will not report it on the QPL.

Appendix C. Interim Market Characterization Memo

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Memorandum

To: Rita Siong, Project Manager, NEEA

From: Nicholas O'Neil, Paul Schwarz, and Ellen Rubinstein

Date: May 13, 2016

Re: LLLC Preliminary Market Characterization

Market actor interviews were the primary data source for the Luminaire Level Lighting Control (LLLC) market characterization. We present the market actor interview objectives and describe the sample in the following section. The remainder of this memo presents the LLLC market characterization findings.

Throughout this memorandum, we use the term "LLLC system" to refer to the lighting sensors that are embedded in luminaires combined with the networking infrastructure that enables these sensors and luminaires to work together.

Market Actor Interviews

From January 19, 2015 through March 14, 2016, staff from Research Into Action, Inc., and Energy 350 ("the team") interviewed individuals with in-depth knowledge about LLLCs from four distinct groups of market actors: manufacturers, distributors, regional lighting experts, and building owners. The team conducted the market actor interviews to:

- Understand the availability of LLLC products in the market and the current sales volume of LLLCs
- Determine whether the currently installed base of LLLC products varies by geography and/or by building type
- Gain an understanding of who installs LLLC products
- Determine if LLLC systems follow traditional lighting supply chain delivery channels

- Define market actors' target market for LLLC products in the near-term, including LLLC's current market penetration and near-term growth
  - Determine the barriers, drivers, and non-energy benefits (NEBs) market actors associate with the installation and adoption of LLLC systems, and determine if Northwest Energy Efficiency Alliance's (NEEA's) LLLC initiative appropriately addresses these barrier, drivers, and benefits
- Determine whether manufacturers are in agreement over the DesignLights Consortium (DLC) specification approach
- Identify whether LLLCs fit in with regional open-communication standards strategies

Table 16 shows targeted sample sizes and the final number of individuals we interviewed in each category:

Table 16. Market Actor Interview Sample

Market Actor	Target Sample	Achieved Sample	Notes
Manufacturers	10	10	Interviews covered large manufacturers as well as smaller, controls-only manufacturers
Distributors	10	9	Due to other regional efforts involving lighting distributors, the team was asked to cease interviewing distributors to avoid interview fatigue.
Regional Experts	3-5	6	Interviewed more than the original target sample, as NEEA required more information from regional experts than the team was able to obtain from the original sample
Building Owners	0*	4	Building owners are a difficult group of market actors to reach. The LLLC respondents were interviewed as part of RWLR's ongoing market assessment.

* Although interviews with building owners were not part of the initial LLLC evaluation scope, interviews conducted through the Reduced Wattage Lamp Replacement (RWLR) evaluation captured information pertinent to LLLCs.

The team developed the manufacturer sample from two data sources: the list of manufacturers with relevant prior Design Lights Consortium (DLC) meeting involvement who also had a history of involvement in utility efficiency programs, and LLLC contacts that NEEA provided. Regional experts were picked by the team based on prior contacts provided by NEEA as well as knowledge of their involvement with lighting controls initiatives. The RWLR team picked the sample of distributors and building owners based on discussion with NEEA program managers on sample frame and availability of interviewees.

The team asked each respondent about the topics and issues pertinent to their position and experience regarding the marketing, sale, or installation of LLLC systems. As a result, not all interviews covered all topics.

Summary of Key Findings

The team discovered several notable findings from the market actor interviews. We have provided key findings at the end of each section below, and a summary of key findings from the market actor interviews is provided in **Table 17** for reference.

Table 17. Summary of Key Findings

#	FINDING
1	All major manufacturers plan to meet the finalized DLC specification for advanced lighting controls by the end of 2016.
2	Eight of ten LLLC manufacturers currently offer solutions that work with fluorescent luminaires. These solutions, however, are not installed at the time of manufacture and are likely to be phased out over the next five years as LED costs continue to decline.
3	Though LLLC systems are currently a small percentage of overall lighting sales (for all but two of the manufacturers we interviewed), their share of overall lighting shares is expected to grow over the next five years as manufacturers produce more solutions to fit varying customer needs and as LLLC prices continue to decline.
4	In retrofit applications, most LLLC manufacturers use manufacturer reps and regional distributors to sell products to end users. In the new construction and major renovation markets, lighting designers play a key role in LLLC sales.
5	Market actors agreed with NEEA that offices and warehouses show the greatest potential for LLLC installations. Market actors also suggested educational facilities, and exterior lighting in all building types, as markets with a good deal of LLLC potential.
6	Most LLLC systems are now installed using licensed electricians; these are the same market actors who typically install traditional standalone lighting controls.
7	Although manufacturers have different approaches to training and commissioning, all agree that increased training will help drive adoption of LLLC systems.
8	LLLC manufacturers generally target the subset of end users within one or more building types whose specific lighting needs match the features and capabilities of the LLLC system.
9	Manufacturers agree that a lack of training on the installation and commissioning of LLLC systems is a critical barrier to adoption; it is more important than NEEA's initial barriers of reducing first cost and addressing market fragmentation.
10	According to manufacturers and distributors, code can be an important driver of LLLC system adoption, especially when code requires features such as demand response that LLLC systems can easily accommodate.
11	NEBs are important to the promotion of LLLC systems, though they are rarely monetized and included in financial calculations. Once performance metering is regularly included with most LLLC systems, the reduction in program evaluation costs will likely become an important NEB to utilities.

Product Availability, Lamp Compatibility, and Sales

The team drew on the manufacturer and distributor interviews, as well as on a review of manufacturers' websites, to gauge the availability of LLLC products in the market, their compatibility with light-emitting diode (LED) and fluorescent lamps, and their current sales volumes.

Product Availability

Reviewing manufacturer's websites, the team affirmed that all of the manufacturers in the sample offer a product line considered to be an advanced lighting control system with embedded sensors that are capable of networked communication. We learned from the interviews, however, that only seven of the ten manufacturers have products available that completely meet DLC's current advanced lighting controls specification.[13] The other three manufacturers offer LLLC products that do not meet the DLC specification for 2-way communication and high-end trim, and one of these manufacturers also did not meet software based reconfigurable zoning. However, these three manufacturers anticipated offering products that meet the DLC specification by the third quarter of 2016.

Table 18 lists the current DLC specification's requirements and the numbers of manufacturers able to meet those requirements at the time of the interviews.

Table 18. Manufacturers Offering Products in Compliance with Current DLC Requirements (n=10)

DLC Required Capability	Meet	Do Not Meet
Networking of Luminaires & Devices	7	3
Occupancy Setting	10	0
High-End Trim (aka Task Tuning)	7	3
Software Reconfigurable Zoning	9	1
Continuous Dimming	10	0

Regional distributors provided information only for the products they represent. None of the nine distributor respondents mentioned supply chain issues as a barrier to adoption. Six of the nine distributor respondents carry products from more than one LLLC manufacturer.

Six of the nine distributors also reported that manufacturers have been heavily promoting their LLLC products recently, though the method of promotion varies by market sector. Two of the six distributors explained that several of the manufacturers they represent market directly to specifying engineers working on new construction projects. Distributors also noted that some manufacturers commonly rely on regional tours to conduct product demonstrations of retrofit applications for building owners and distributors.

LED and Fluorescent Luminaire Compatibility with LLLC Systems

All of the manufacturer respondents offer LED luminaires that are embedded with LLLC sensors at the time of manufacture. Manufacturers' production of these systems is driven by their

[13] The DesignLights Consortium is in the process of creating a specification and qualified products list on advanced lighting controls. Draft 2 was released January 6, 2016, located here: *https://www.designlights.org/resources/file/DLC_NetworkCtlSpec_Draft2*.

popularity with distributors and contactors: distributors and contractors value the systems' continuous dimming capabilities and the fact that they simultaneously use less energy than traditional fluorescent luminaires with comparable light output.

Eight of the ten manufacturers also offer fluorescent luminaires that can be LLLC enabled, though none of these manufacturers embed sensors within their fluorescent luminaires at the time of manufacture. Instead, the luminaires must be retrofitted in the field to install LLLC sensors that work with fluorescents lamps. A drawback to this retrofit-kit approach was highlighted by two distributors who stated that it resulted in added project costs and, in most cases, longer product lead times for the add-on sensors. Furthermore, the current DLC specification states that eligible luminaires must include continuous dimming functionality which is not a feature inherent to most fluorescent luminaires; enabling continuous dimming sometimes requires the use of two ballasts, which also increases the cost of LLLC-capable fluorescent luminaires.

The eight manufacturers who currently offer fluorescent luminaire products with add-on sensors commented that they are likely to be phased out over the next five years as the penetration of LEDs increases in the market and the cost of LEDs becomes comparable to, or less than, the cost of fluorescents.

Current LLLC Sales

Two of the ten manufacturers reported that 100% of their sales are LLLC systems, though both are newer, smaller companies whose brands are almost exclusively focused on wireless lighting control. Another three manufacturers did not have viable LLLC products at the time of the interviews and were therefore unable to comment.

The other five manufacturer respondents were unable or unwilling to estimate their sales of LLLC systems as a percentage of their total lighting sales. These respondents were wary that the percentages they would provide could be linked to their overall sales values which are proprietary. Several manufacturers also explained that LLLC sales are difficult to estimate because LLLC systems are packaged in many different ways: while some may be standalone products others are add-ons to flagship product lines. Further, respondents said that because LLLC systems are sometimes used in just a few locations on larger projects, they were not able to easily separate LLLC system costs from overall project costs during the course of the interview. While unable to give a precise number, four manufacturers stated that sales of LLLC systems were a very small percentage of their overall sales.

The five manufacturers with LLLC sales less than 100% of total sales all expected their product line-ups to expand in the coming months to suit varying customer needs and their sales of LLLC systems as a percentage of their overall sales to rise as well. One claimed its LLLC sales were growing to 30% of its total sales if they counted luminaries that shipped with sensors already installed, regardless of whether the luminaires were used in a networked LLLC system or not.

The team asked manufacturers whether their LLLC sales differed by geography, both by region of the country and by urban versus rural locations. Three of the ten manufacturers reported that, within the northwest, greater numbers of their LLLC products have been installed in Oregon and Washington than in Idaho and Montana. Four manufacturers said the majority of their LLLC

installations sites are in California, and attributed this to California's recent code changes favoring LLLC systems in new construction and major renovation projects. All four of these manufacturers added that their LLLC sales are greater on the east coast and California where the incentives for lighting controls are richer than they are in the Pacific Northwest.

Manufacturers provided less information about differences in sales between urban and rural areas: seven of the ten manufacturers said they did not have sufficient sales data to comment on differences between urban and rural areas. While two manufacturers reported greater LLLC sales in metropolitan areas than in rural areas, these two manufacturers focus primarily on office retrofit spaces which are concentrated in more urban areas. Another manufacturer that specializes in lighting for warehouse and manufacturing facilities observed that their LLLC installations vary geographically based on where these building types are located, rather than on whether customer sites are in urban or rural areas.

Distributors, while not directly asked about sales of LLLC products, commented that the uptake of LLLC systems is likely to increase over the next five years due to the increasing ease of installation, user friendliness of the product, and availability of utility incentives for controls.

Finding #1: All major manufacturers plan to meet the finalized DLC specification for advanced lighting controls by the end of 2016.

Finding #2: Eight of ten LLLC manufacturers currently offer solutions that work with fluorescent luminaires. These solutions, however, are not installed at the time of manufacture and are likely to be phased out over the next five years as LED costs continue to decline.

Finding #3: Though LLLC systems are currently a small percentage of overall lighting sales (for all but two of the manufacturers we interviewed), their share of overall lighting sales is expected to grow over the next five years as manufacturers produce more solutions to fit varying customer needs and as LLLC prices continue to decline.

Supply Chain Delivery Channels

The LLLC retrofit supply chain is evolving much more quickly than anticipated. When NEEA discussed supply chain evolution with LLLC manufacturers just one year ago, they reported that, due to the complexity of LLLC systems at the time, manufacturers commonly owned and managed the entire LLLC supply chain from system production to salespeople and installers.

The details of LLLC system supply chains, however, varied by manufacturer size. The largest manufacturers sold LLLC products through manufacturer representative-distributor-contractor channels typical of the lighting retrofit market. Most small controls manufacturers, on the other hand, commonly partnered with larger, established luminaire manufacturers and automation companies: through these arrangements, the smaller companies had their controls installed into the larger companies' luminaires. From these conversations, NEEA assessed it would be several

years before LLLC systems from all but the largest manufacturers were sold through traditional distribution channels.

The interviews we conducted as part of this market research—just one year after NEEA's earlier discussions—suggest that the LLLC retrofit supply chain has changed a great deal over a relatively short time. Nine of ten manufacturers we interviewed reported that the bulk of their LLLC systems now find their way to end users through traditional market channels. They generally rely on manufacturer representatives working with local contacts or electrical distribution firms, where the local contacts/distributors have sales forces dedicated to selling the manufacturers' products to end users. While this supply chain channel is a primary source of sales, the nine manufacturers also reported that they still sell LLLC systems directly to large account end users (e.g., Fortune 500 companies), and many of these manufacturers offer these customers tailored full-service solutions. The one manufacturer that does not follow this pattern offers end users a turnkey solution only, or sells their products through Energy Service Companies (ESCOs).

Both manufacturers and distributors reported that in the new construction and major renovation markets, lighting designers act as LLLC product specifiers (as they would for traditional standalone lighting controls), while manufacturer representatives and distributors act as sales agents by promoting the products they understand to be most appropriate for the project. One distributor elaborated on these market actors' roles in new construction and major renovation projects. He explained that his organization commonly finds multiple sensor options specified at the outset of a project so that the project likely qualifies for rebates. Additionally, no value engineering of the lighting and controls system can take place without the lighting designer being involved. This finding suggests that **lighting designers play a large role in specifying LLLC systems as well as in preventing LLLC systems from being cut from the design during the construction phase.**

Finding #4: In retrofit applications, most LLLC manufacturers use manufacturer reps and regional distributors to sell products to end users. In the new construction and major renovation markets, lighting designers play a key role in LLLC sales.

Installations by Building Type

When asked about the types of buildings where LLLC systems have gained the most traction and offer the greatest potential, the market actors named commercial offices most often. **Table 19** shows all of the building types where manufacturers, distributors and regional experts think LLLC hold the greatest potential.

Table 19. Building Types where LLLCs Have the Greatest Potential

Building Type	Manufacturers (N=10)	Distributors (N=9)	Regional Experts (N=6)	Manufacturers NC/MR: Retrofit*
Commercial Offices	8	5	3	6:2
Warehouse/Distribution	3	4	4	1:2
Education	5	1	1	3:2
Industrial/Manufacturing	2	2	3	1:1
Retail	2	2		1:1
Hospitals/Healthcare	3	1		1:2
Parking Lots/Garages	1		1	0:1
Cold Storage	1		1	0:1
Stadiums	1			0:1
Convention Centers	1			1:0
Government/Municipal	1			1:0

* NC/MR means new construction or major renovation.

Of the eight manufacturers who see substantial potential for LLLCs in offices, six expounded by saying there is more potential for LLLC installations in the new construction/major renovation market than in the office retrofit market; the other two thought the retrofit market holds greater LLLC potential.

Manufacturers offered differing views about the size of offices where the greatest LLLC potential lies: one specifically stated there is greater potential in large offices, while another thought there is great potential in offices more generally, regardless of size. Nonetheless, all of the manufacturers mentioned that because larger installations produce better returns on investment (ROI), LLLC systems are less likely to be "engineered out" during a large project's construction phase—that is, they are more likely to actually get installed in larger spaces. Manufacturers also explained that systems using wireless communication are good candidates for major renovations because their installation:

- Does not require moving power systems, so eliminates the need for new wiring
- Does not require work above the ceiling grid, and therefore keeps asbestos and other unknown substances in the ceiling contained
- Enables simple one-for-one change-outs, rather than requiring lighting layout changes, and still maintain acceptable light levels

Regional experts also noted that LLLC systems have great potential when retrofitted into warehouses and industrial facilities. The low occupancy rates and high-wattage luminaires in these types of facilities result in high ROIs for LLLCs, making LLLC an attractive option.

Several manufacturers, too, saw good potential for LLLCs in warehouses and industrial facilities. They explained that warehouses are often interested in installing LLLC systems to eliminate the need for control wiring routing over long spans through high-bays. The manufacturers elaborated that LLLC systems coupled with LEDs yields the additional benefit of reducing bulb replacement maintenance, a significant value proposition to facilities with high-bay spaces.

Five manufacturers also opined that education facilities offer good potential for LLLCs. Because these facilities have predictable run hours, they are a natural fit for the expanded feature sets of LLLC systems (for example, color tuning can be focused to keep students awake after lunch and to quiet them down after recess) and manufacturers recommended they be considered as a target for the LLLC initiative.

Manufacturers said they have seen more LLLC systems in the new construction market for several building types (namely offices, education facilities, convention centers, and government facilities) as designers become increasingly comfortable with wireless technology. In fact, they noted that designers often act as specifiers for these products. Similar to the major renovation market, manufacturers reported that large cost savings can be realized for the majority of luminaires in the new construction market by installing LLLCs and thereby eliminating the need for installers to pull large amounts of electrical wire.[14]

Both manufacturers and regional experts stated that the **exterior lighting** market holds great potential for LLLCs. Four out of ten manufacturers expressed concern that by focusing the LLLC initiative on offices and warehouses, NEEA may be overlooking the large potential for LLLCs in exterior lighting present in many other building types. Manufacturers and regional experts observed that exterior lighting makes up a large share of the existing lighting market and that LLLC system designs, coupled with their lower lifecycle costs (in comparison to traditional standalone controls), enable them to be cost-effectively retrofitted into exterior spaces. Furthermore, one regional expert explained that while exterior lighting control has historically been either absent from code or simple to comply with using rudimentary controls, recent code updates are requiring more advanced controls with lower power allowances. LLLC systems, coupled with low wattage LEDs, appear to have the capability to cost-effectively meet these more stringent exterior lighting control requirements.

Finding #5: Market actors agreed with NEEA that offices and warehouses show the greatest potential for LLLC installations. Market actors also suggested educational facilities, and exterior lighting in all building types, as markets with a good deal of LLLC potential.

[14] Electrical codes in the Northwest still require a wire to run from a manual wall switch to the primary lighting luminaire in a space, therefore not all wiring costs can be eliminated.

LLLC Target Market Characteristics

The team gleaned information about the LLLC target market through our discussions with market actors about:

- Key commercial lighting decision makers
- The installer base for commercial lighting
- The installation and commissioning of LLLC systems
- The communication protocols currently employed by LLLC systems and the rationale for their selection
- The types of lighting systems on which LLLC systems are currently and projected to be installed

We present our findings on each of these topics, in turn, below.

Key Decision Makers

Though five of the six the manufacturers who were able to answer questions about LLLC decision makers said that facility managers contribute to those decisions, they gave varying answers about the other market actors who are involved and the reasons for those actors' involvement. Only one manufacturer reported that LLLC decisions makers are largely the same as the decision makers involved with standalone lighting controls, namely facility managers or owners/property managers. **Table 20** shows the responses from all six manufacturers.

Table 20. Key Decision Makers Involved with Lighting and Controls System Selection (n=6)

MANUFACTURER	MANUFACTURER FOCUS	DECISION MAKER	REASON WHY INVOLVED
C	NC & Retrofit Warehouse & Office	Facility Manager	LLLC systems are more expensive than standard controls and many people use them. Also, facility managers are able to compare energy use across multiple facilities and make decisions.
D	Retrofit Warehouse	Facility Manager and Operations department	These actors have a strong interest in facility operational information for their line of business (e.g., utilization of process machinery or product layout).
G	NC Office & Education	General Contractor & Design Team	In new construction, the project "driver" is the key LLLC decision maker, except where the building owner opts to involve himself/herself. In the retrofit market, building owners are more typically engaged.

Manufacturer	Manufacturer Focus	Decision Maker	Reason why Involved
H	Retrofit Office & Retail	All (Facility Manager, Property Manager, Owner, Architect, Designer, Engineer)	None given.
J	Retrofit Office	Facility Manager, General Contractor, Owner	Same decision makers as traditional standalone controls.
K	Retrofit Office, Education, Healthcare	Facility Manager, Property Manager	Whichever market actor has a vested interest in the health of the building.

Responding to a similar line of questioning, one distributor commented that **the Northwest is generally a designer/specifier market—as opposed to a general contractor market**— so designers/specifiers naturally play key roles in making decisions about energy-efficient lighting options. Four manufacturers and two distributors independently supported this claim, stating that they have witnessed lighting designers play a critical role in LLLC system installations.

With such a small sample, the team cannot confidently conclude that the key decision makers who opt for LLLC systems are different from those who opt for traditional standalone controls. Nonetheless, because the market actors listed in NEEA's logic model closely match those the LLLC manufacturers identified as key decision makers, the team believes that NEEA is pursuing an appropriate set of market actors through the LLLC initiative.

Installer Base, Training, and Commissioning

Similar to the findings regarding the supply chain delivery channels, nine of the ten manufacturers said traditional lighting market actors, primarily licensed electricians, generally install their LLLC products. The remaining manufacturer offers a turnkey solution and therefore rarely relies on traditional lighting installers.

Although most manufacturers reported that the contractors who install their LLLC systems are the same people who install standalone lighting controls, the manufacturers' commissioning and training requirements vary substantially from one another. Eight of the ten manufacturers typically use their own trained staff or manufacturer's representatives to commission LLLCs, though four of the eight also permit third-parties to commission their systems. Of the four who permit third-party commissioners, only two provide training for third-party commissioning staff and end users:

- One requires third-party staff to attend a two-day training course that includes a pre-qualification quiz and mockup jobsite walk
- The other only requires third-party staff to be manufacturer certified and trained on their LLLC system

The remaining two manufacturers of that group do not currently open their training to third-party commissioning staff. Both manufacturers, however, believe that training is a key to successful adoption of their product and plan to be involved with the DLC's open training program in the future.

Several manufacturers who do not use third-parties to commission their products explained they do not need to do so because the **ease of commissioning is a key feature** of their LLLC systems. These manufacturers intentionally designed their LLLCs products to be easier to install and use than traditional lighting controls. Three of the ten manufacturers stated that commissioning was a minor endeavor involving only 15-20 minutes of setup once installed, or that the product comes pre-commissioned and requires almost no intervention on the part of the installer or end user once connected. The manufacturers who focused on the ease of commissioning stated that they generally offer training only when installers or end users specifically request it after an installation is complete.

Table 21 shows the varying commissioning and training services offered by the ten manufacturers we interviewed.

Table 21. Manufacturers' LLLC Commissioning and Training Offerings (n=10)

Manufacturer	Self-Perform / Field Rep Commissioning	Use 3rd Party Commissioning	Minimal Commissioning Required	Offers Training
A	X	X		X
B			X	X
C	X	X		X
D	X			X
E	X			
F	X	X		
G	X			X
H	X		X	
J			X	
K	X	X		

Distributors and regional experts also thought that user-friendly products that are simple to commission are more likely to be adopted in the future. Distributors, manufacturers, and regional experts all view **training of the installer base as a critical component to widespread market acceptance and adoption of LLLCs**.

Target Market and Value Proposition

The team asked manufacturers about the types of customers they are pursuing and how they persuade key decision makers to install LLLC systems in lieu of traditional standalone controls. We found that while many manufacturers have systems that could compete with one another,

almost all of the manufacturers **target specific niche markets** and therefore generally do not compete for the same end users.

For example, although eight of the ten manufacturers target commercial offices, each of the manufacturers we spoke with targets a different set of commercial office end users, each with its own specific needs. One manufacturer primarily focuses on offices looking for a simple, pre-packaged solution that requires little commissioning, comes programmed with typical set-points for dimming based on previous installation feedback, and allows for very limited user control. This manufacturer's system is competitively priced with standard controls packages. The system is intended for use in open office areas where clients prefer systems with limited individual control so as to minimize disruptions in the shared space.

In contrast, another manufacturer that also targets commercial offices sells a higher-end product focused not only on improvements to a space's lighting and energy savings, but also on providing a great deal of user control and on integrating lighting with other building systems. The manufacturer explained that its target market includes end users interested in data acquisition who think about business intelligence and view lighting as one possible solution. The end users in this manufacturers' target market, therefore, are unlikely to be interested in the same line-up of LLLC systems as the end users in the previous manufacturers' target market who seek relatively simple LLLC solutions.

Similarly, the manufacturers that target warehouse spaces offer LLLC systems designed for specific types of end users. One such manufacturer promotes its product to customers by explaining that the warehouse's relatively high hours of use and low occupancy rates, coupled with the LLLC product's reduced maintenance costs, renders the LLLC system very cost-effective. In addition, the manufacturer describes its value proposition to prospective customers by explaining that its product offers not only overall light reduction and energy savings, but also a wealth of information about safety and productivity that customers can use to benefit their businesses. This manufacturer has found a niche customer base that values the increased business intelligence its product provides, enabling its customers to remain competitive in their specific lines of business.

Conversely, two other manufacturers that sell LLLC systems for warehouses offer pre-packaged solutions similar to the open-office solution described above. One of these two manufacturers additionally offer a more holistic system that compares energy use and business intelligence across a portfolio of facilities. Since these products address customers with specific needs, the target markets for these manufacturers are quite different from the markets targeted by manufacturers whose products focus primarily on lighting energy savings.

Our findings also suggest that several manufacturers are targeting their products to end users whose information needs match the LLLC system's data acquisition and reporting capabilities, more so than to end users seeking a particular type of control system.

Finding #6: Most LLLC systems are now installed using licensed electricians; these are the same market actors who typically install traditional standalone lighting controls.

Finding #7: Although manufacturers have different approaches to training and commissioning, all agree that increased training will help drive adoption of LLLC systems.

Finding #8: LLLC manufacturers generally target the subset of end users within one or more building types whose specific lighting needs match the features and capabilities of the LLLC system.

Adoption Barriers and Drivers—Including Non-Energy Benefits

The team gleaned insight into the barriers and drivers currently influencing adoption of LLLC systems through our interviews with manufacturers, distributors, and regional experts. We segmented our interview questions into three different barrier sets: Adoption, Installation, and Utility Engagement. The interviewees also provided insight into the NEBs most valued by end users, as well as the NEBs promoted during the sale of LLLC systems.

Adoption Barriers

The team used the barriers identified in NEEA's original LLLC logic model as a starting point to our discussions about market barriers and market drivers.[15] We asked manufacturers to rate, on a scale of 1 to 5 (with 1 being "not important" and 5 being "very important"), the importance they placed on addressing each barrier. The results are shown in **Table 22**. Note that the table reports the mode of each response, rather than the average, to clearly illustrate the importance the majority of (the small sample of) respondents placed on each barrier.

Table 22. Barriers Manufacturers Perceive to LLLC Adoption (n=9)

NEEA Identified Barrier	Mode
Limited understanding of the capability, viability, and availability of LLLC products	5.0
LLLC systems appear too complex to be installed and commissioned correctly	5.0
Limited trained support network established for installers, building IT, & facilities	5.0
A lack of a clearly defined business value for LLLC products	5.0
High first costs for LLLC products & installation, making payback untenable	3.0
Perception of poor product persistence, serviceability, or re-configurability	1.0
Market fragmentation in terms of networking standards, communication protocols, and what even constitutes an advanced lighting control	1.0
Concerns over LLLC aesthetics, complexity, and possible user impact	1.0

[15] At the time of this writing NEEA was in the process of revising the logic model to focus on key barriers to adoption.

While all of the manufacturers agreed that NEEA addressed important barriers to LLLC adoption, they remarked that several of the barriers identified as critical in the original LLLC logic model were not as important as others. As an example, all but one manufacturer noted that the fragmented market, identified as a critical barrier in NEEA's logic model, was not influential to the future adoption of LLLC systems.[16]

The fact that eight of the ten manufacturers operate with proprietary communication protocols and do not perceive open-source communication systems as a significant benefit to the end user may support this perspective. Furthermore, when regional experts were also asked about the importance of addressing the fragmented market, none mentioned the lack of an open-source communication protocol as a significant barrier. Instead, both manufacturers and regional experts stated that open-source end-to-end communication (that is, between the lighting system and the building management system) was more important than open-source point-to-point communication between luminaires.

Manufacturers stated their preference for a proprietary communication was because they typically "own the system" once it is installed, and would not be able to guarantee that an ecosystem of third-party sensors and luminaires would interact correctly with their system if it were developed as open-source. They added that commissioning also becomes more complex once a variety of third-party sensors are used, even if the protocol is open-source.

Many manufacturers also explained that current open-source standards do not have sufficient bandwidth to take advantage of all of the features offered with their LLLC systems, and that removing those features to comply with open-communication standards would remove the competitive edge of LLLCs over traditional controls. While two of the eight manufacturers said they might move to a non-proprietary communication protocol if standards advanced to accommodate their systems requirements, many were wary of open-source communication security issues. Only one manufacturer currently offers a system that uses open-source communications and noted that the primary benefits are price and customization for the end user.

Installation Barriers

A different set of barriers we asked interviewees to address were installation barriers, such as the difficulties of LLLC systems to be specified, installed, and set up correctly. Eight manufacturers stated that there is inadequate training on system installation and that this lack of training is a key barrier to adoption. One manufacturer added that **the evolution of these systems over the next five to ten years will require advanced installer and end user training to ensure LLLCs are properly integrated into other building systems**. Only the two manufacturers who focus on ease of commissioning and perform their own system commissioning did not view inadequate training as a barrier.

While six out of ten manufacturers mentioned first cost as a barrier, they did not think it as important as other barriers. Both regional experts and manufacturers stated that the first cost of

[16] As of this writing, NEEA has an updated logic model that does not include the fragmented market as a barrier.

LLLC systems was declining, and the payback was already in a financially viable range for many end users.

However, several manufacturers commented that installers commonly overestimate the costs of LLLC systems in their bids, explaining that the over-stated bids are due to installers' lack of familiarity with LLLC products and their wariness about the amount of time required to correctly commission the systems. With the increased labor costs for installation and commissioning, end users often conclude that the LLLC system paybacks are not financially viable. Distributors and manufacturers stated that this significantly limits the adoption of LLLCs since **many LLLC systems get value-engineered out of the design.**[17] Both manufacturers and distributors therefore perceive installers as key market actors in furthering the adoption of LLLC systems, especially as LLLC feature-sets continue to expand.

Efficiency Program Barriers

Our third barrier to address dealt with utility efficiency programs and barriers that exist for manufacturers trying to incorporate their system into utility incentive programs. Three manufacturers see the Northwest utilities' current LED incentives as one of the greatest barriers to LLLC adoption. Because the region's LED incentives are so robust, the manufacturers thought that the value proposition for adding an LLLC system gets marginalized and it becomes much easier to value-engineer LLLCs out of a lighting upgrade if costs and timeline are a concern for the end user. Three regional experts and four manufacturers agreed that, due to the long life of LEDs, once an LED system gets installed it becomes a missed opportunity for installing controls.

However, one regional expert and one manufacturer did not share this view. The expert opined that manufacturing a device that lasts for 20 or more years is not sustainable from a business perspective unless the manufacturer shifts to a different model or owns an extremely large share of the overall market. Along similar lines, one manufacturer said that due to their customers' changing demand their company is transforming from a lighting-only company into an information services company.

As noted above, the barriers listed in Table 22 are based on the original LLLC logic model. The revised logic model (currently a work-in-progress) includes barriers focused on increasing awareness, lowering first costs, and reducing the complexity of LLLC systems, and closely aligns with the team's findings.

Adoption Drivers

Six of nine manufacturers stated that energy savings were the primary driver for end users choosing LLLC systems. When coupled with utility rebates, they find that the large energy savings that result from low-cost sensor integration—offering daylight harvesting, occupancy control, and dimming—render LLLCs an attractive option to end users.

[17] Value-engineering is the process of removing design elements deemed "non-essential" by the contractor, design team, and/or owner in an effort to save on construction or operating costs.

One manufacturer, however, noted that dollar value of energy savings is typically small relative to an end user's rent, and smaller still relative to the end user's wages. This manufacturer felt that **to provide value to the end user, LLLC systems need to do much more than save energy**: they need to tie lighting controls to the people in the space and provide information on how that space is used.

Another manufacturer opined that the lighting market is primarily driven by cost and a manufacturer's ability to offer different solutions to meet each end user's needs. Since low-end, commodity luminaires still comprise the bulk of sales, this respondent thought that integrating inexpensive, efficient lighting with controls meets end users' desires for low-cost tailored solutions, and is therefore key to increasing LLLC adoption.

For commercial office spaces specifically, all ten manufacturers included code requirements as an important driver to adoption. They cited the example of California, where a recent change in the state's Title 24 code requires automated demand response capabilities for lighting in new construction and major renovations. Four of the ten manufacturers noted that California's code changes have led to a large increase in LLLC adoption in that state. Furthermore, they reported that Title 24 requires a third-party agent to commission the building's systems (in order for the building to receive a certificate of occupancy). This requirement has led to the development of LLLC systems that can be easily commissioned because manufacturers want to ensure the commissioning process is not the cause for a delay in a building's occupancy.

On the other hand, one manufacturer commented that energy codes can be a double-edged sword: while more controls may be installed as a result of the code, if the code is not enforced, installers and end users will seek—and find—loopholes. Two manufacturers noted that building codes for the retrofit market can also be barriers—rather than drivers—to LLLC adoption. They described recent experiences in California where building owners who may have considered installing lighting controls opted instead to forego the retrofits altogether, fearing that the upgrade might require them to pull a permit which would increase the expense and duration of the retrofit.

Non-Energy Benefits

NEEA staff and industry regional experts have long recognized that the NEBs of LLLC systems are likely to play an increasingly large role in LLLC adoption over time. As described in previous sections, NEBs can be more important to LLLCs' acceptance within some target markets than are the energy reduction benefits.

The team asked manufacturers, distributors, and regional experts, which NEBs they promote most often and which NEBs are most frequently requested by end users. Most manufacturers promoted and heard request for a variety of NEBs, and all were in agreement that the importance of NEBs is highly dependent on each customer's specific needs. **Table 23** shows the NEBs mentioned by all sets of three market actors.

Table 23. Non-Energy Benefits of LLLCs

NON-ENERGY BENEFIT	INDUSTRY
Gunshot detection to dispatch emergency response	Municipal
Room occupancy tracking	Hospital
Ad targeting using Bluetooth sensing	Retail
Color temperature adjustment to stimulate activity	Office, Education
Space re-configurability without re-wiring	Office
Asset tracking with Radio Frequency Identification (RFID) tag integration	Hospital
Comfort level from dimming instead of on/off	Office
Space planning based on daily activity	Warehouse
Security and communication between teachers during crisis	School

None of the manufactures offered methodologies for quantifying the value of these NEBs for use in utility efficiency program financial calculations. While they do promote the NEBs of their systems and describe how they help meet their customers' needs, the manufacturers explained that aside from quantifying reductions in maintenance for longer lasting equipment, they do not include NEBs in payback calculations or incentive applications.

Several regional experts noted that one of the largest NEBs they see contributing to the future adoption of LLLCs will benefit utility efficiency programs rather than end users: once onboard energy performance metering becomes commonplace for LLLC systems, utility programs will be able to rely on the information from these systems in lieu of costly site evaluations and project verification. One expert also noted that the creation of an industry performance metering protocol will provide defensibility to utility programs, reduce the economic burden of performing evaluations, and increase trust among regulators.

Finding #9: Manufacturers agree that a lack of training on the installation and commissioning of LLLC systems is a critical barrier to adoption; it is more important than NEEA's initial barriers of reducing first cost and addressing market fragmentation.

Finding #10: According to manufacturers and distributors, code can be an important driver of LLLC system adoption, especially when code requires features such as demand response that LLLC systems can easily accommodate.

Finding #11: NEBs are important to the promotion of LLLC systems, though they are rarely monetized and included in financial calculations. Once performance metering is regularly included with most LLLC systems, the reduction in program evaluation costs will likely become an important NEB to utilities.

Appendix D. Interim Baseline and LLLC Adoption Forecast Memo

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Memorandum

To: Rita Siong, Project Manager, NEEA

From: Nicholas O'Neil, Energy 350, Paul Schwarz & Ellen Rubinstein, Research Into Action

Date: June 16, 2016 (Revised July 19, 2016)

Re: LLLC Market Baseline and 20-year Forecast

Alongside market actor interview findings conducted in 2016, the Northwest Power and Conservation Council (NWPCC) interior lighting and lighting controls supply curve data and the 2014 LLLC Market Baseline report prepared by Navigant Consulting (NEEA Report #E14-301) were the primary sources we used to establish the LLLC market baseline and 20 year forecasts.

We developed baseline and forecasts for the four northwest states in three market sectors: retrofit, major renovation, and new construction. Within these three sectors, two building types were targeted for baseline and forecast estimation: commercial offices and warehouses.

We describe the information utilized from each source in the following sections along with the market baseline and forecast findings.

Existing Building Stock Area and Forecasts

We utilized the 2014 Commercial Building Stock Assessment survey (CBSA) data to develop the baseline and forecast of office and warehouse area (millions of sq. ft.) within the new construction, major renovation, and retrofit market sectors. We began with this building stock forecast, which is broken down by state (OR, WA, ID and MT) and building type (Large Office – above 50,000 sq. ft. Medium Office – between 5,000 sq. ft., and 50,000 sq. ft., Small Office – below 5,000 sq. ft. and Warehouse) and spans from 2016 until 2035.

Building stock assessment data from CBSA was collated by the NWPCC for use in the 7th Power Plan and was not modified as part of our analysis. In this way, the total stock of buildings projected over the next 20 years for possible LLLC system installations is in alignment with NWPCC building stock forecasts. Figures 1 and 2 below show the forecast of regional building stock for large office, medium office, small office, and warehouse in millions of square feet for new buildings and existing buildings, respectively. These figures illustrate fluctuations in new

commercial floor space over time due to the Council's employment projections, as well as to forecasted changes in the stock of building types that are not represented in these graphics but that affect office and warehouse stocks. For example, warehouse new construction is affected by retail changes due to the increased amount of e-commerce requiring warehousing. For existing buildings, the figures show a steady demolition of buildings over time that are replaced by new construction.

Figure 24. New Construction Forecast – Total Regional Stock

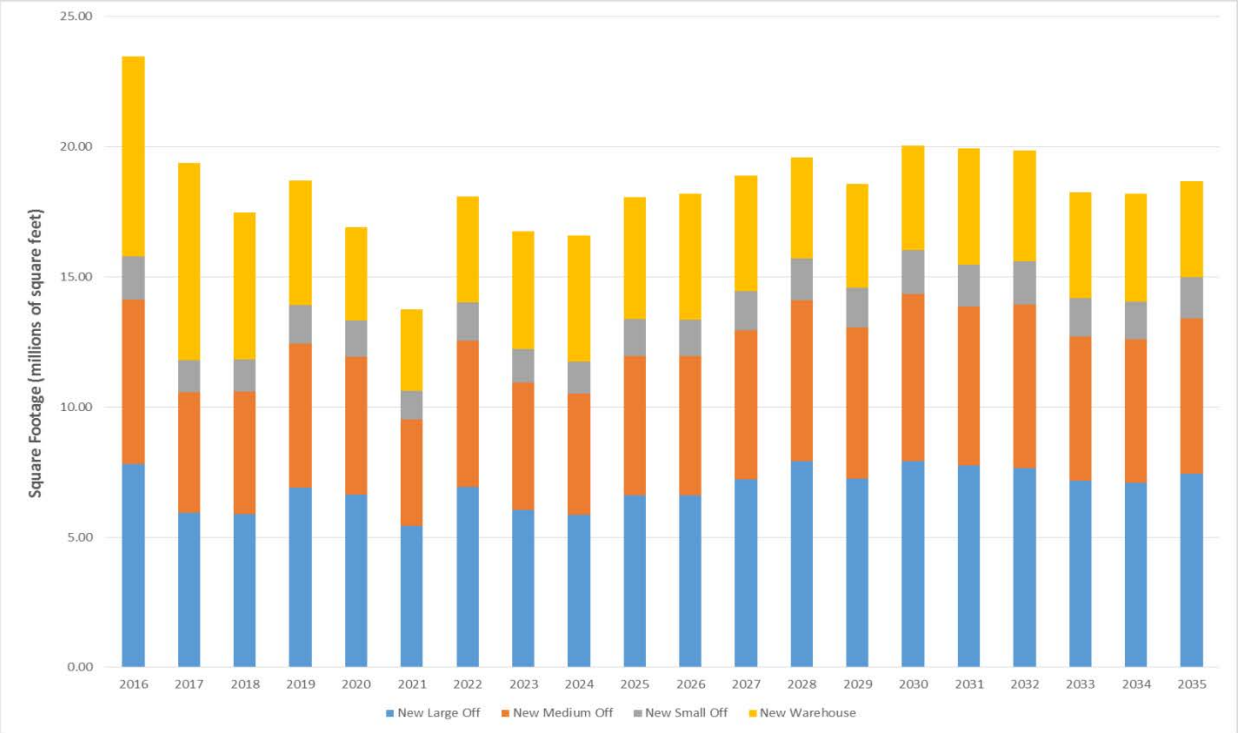
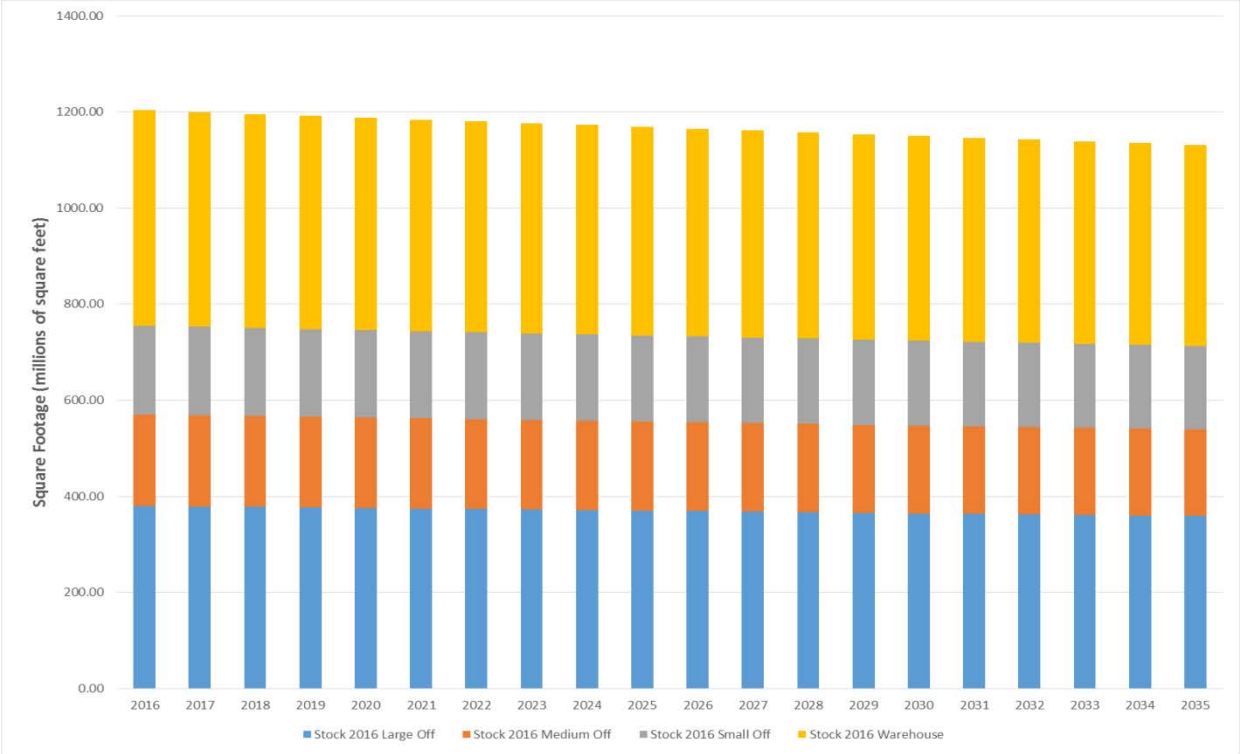


Figure 2. Existing Building Forecast – Total Regional Stock



Applicable Fixture Stock

Retrofit and Major Renovation

Our estimation of the total number of applicable fixtures on which LLLC systems can be installed, required knowledge of the fixture density within each building type. To estimate this density, we drew on the 2014 market baseline report by Navigant Consulting, which provided a breakdown of fixture density based on the square footage for offices and warehouses and represents the best available data for estimating building stock in the region.

Secondly, we reviewed interview data collected in the 2016 market research in conjunction with the 2014 market baseline report to identify the fixture density data pertinent to only those fixtures where LLLC systems could be installed. This list of applicable fixtures includes:

- Strip Lighting (Bare and Lensed)
- Pendent Mounts
- Surface Mounts
- Recessed Lighting

The information in the Navigant report was originally sourced from the preliminary CBSA dataset and linked to building stock assessments that were available in 2013. With the completed building stock now available as part of NWPCC's 7th power plan, we updated the number of installed applicable fixtures in 2016, which added a significant increase to the previous estimate of potential, as shown in Table 1 below.

Table 3. Fixture Density and Installed Fixture Base for 2013 & 2016 by Building Type

Building Type	Applicable Fixture Density (per sq. ft.)	2013 Installed Applicable Fixture Base	2016 Installed Applicable Fixture Base	% Increase from 2013-2016
Large Office	0.0086	2,153,433	3,268,759	52%
Medium Office	0.0086	970,210	1,640,337	69%
Small Office	0.0086	1,138,414	1,583,186	39%
Warehouse	0.0041	1,426,561	1,839,663	29%

Source: 2014 Navigant LLLC Market Baseline, Table 4-1

The increase in existing building stock, and thus the increase in the number of applicable fixtures, is due solely to the use of different building stock assessments available during the two different study periods.[18]

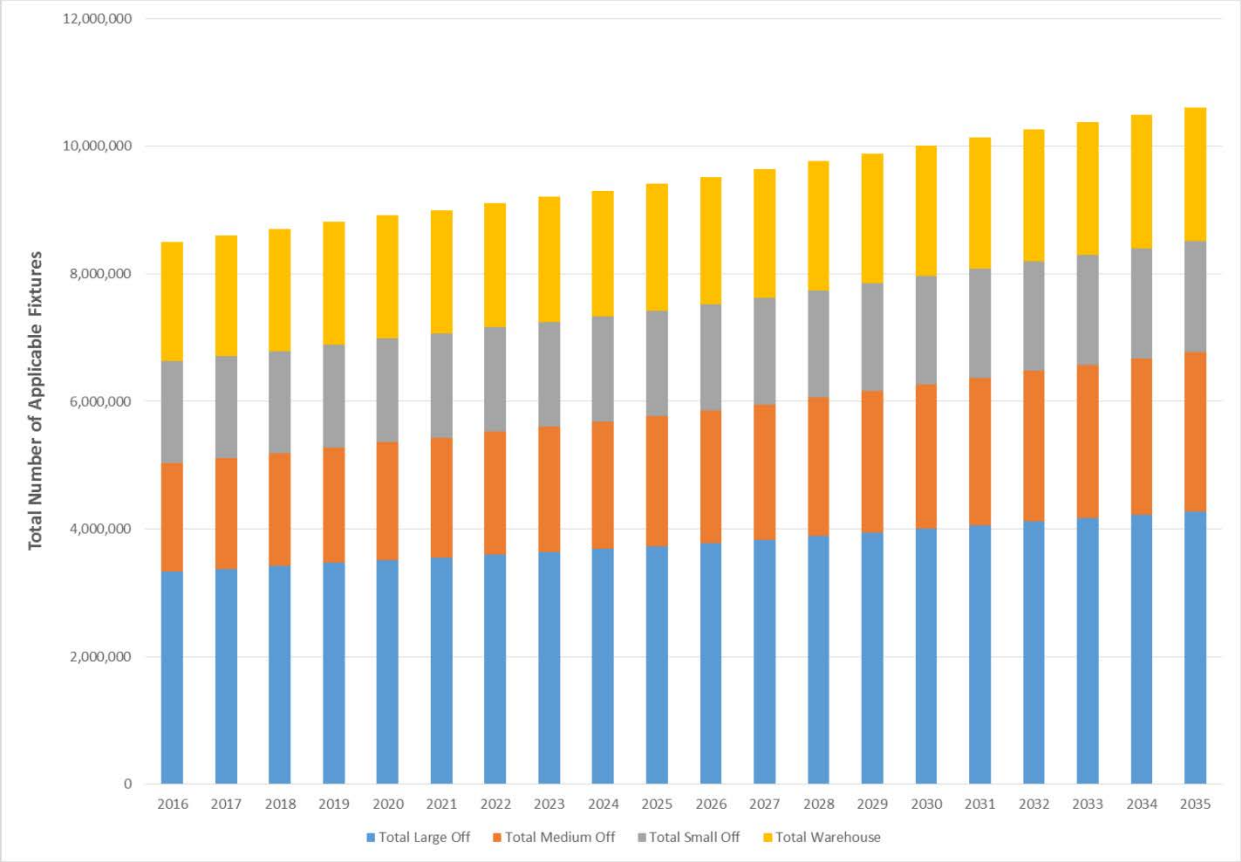
New Construction

To quantify the number of applicable fixtures in the new construction sector, we used the NWPCC new construction forecast estimates and the applicable fixture density from the 2013 CBSA dataset. We assumed that the fixture density in new construction will be similar to the fixture density in the existing stock of offices and warehouses because typical space layout and building functions have remained relatively constant.

After applying these factors across all market sectors, we developed forecasts of the number of applicable fixtures by state, building type, and market sector (retrofit, major renovation, and new construction) from 2016 until 2035. Figure 3 below shows the cumulative regional number of fixtures applicable for LLLC installation from 2016-2035 across all market sectors. We see a steady rise is in the forecasted number of applicable fixture due the fact that new construction buildings are expected to far outpace building demolition rates over the next 20 years.

[18] Navigant noted in their 2014 MRE that only 50% of the CBSA building stock data was available at the time, which is why the increase is so large.

Figure 3. Number of Applicable Fixtures – Total Regional Stock Across All Market Sectors



Installed Base of LLLC Fixtures

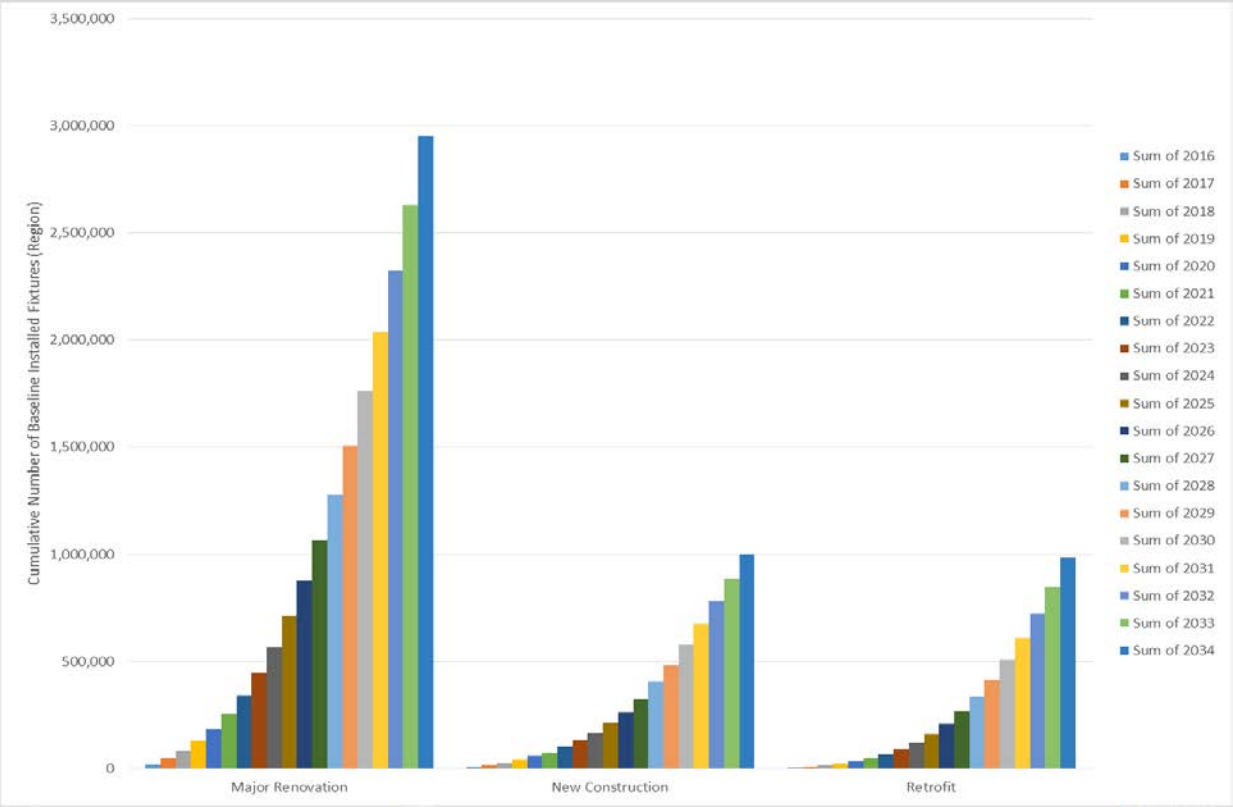
Our estimation takes into account the fact that LLLC products exist in the market already, absent program intervention, and therefore need to be part of the baseline. We confirmed this assumption through the 2016 market actor interviews that substantiated claims that several manufacturers have LLLC systems which are beginning to make up a larger portion of overall sales compared to only a year ago.

We estimated the percent of LLLC systems already in the market by relying on the Bass diffusion curves developed for the 2014 Navigant LLLC market research report. The LLLC saturation rate in 2016 was determined based on the 2013 saturation rate defined by Table 4-3 in the Navigant report coupled with the bass diffusion curve (Figure 3-2) to determine 2016 expected saturation. Our interview findings from the 2016 market actor research did not yield more significant statistics on overall sales of LLLC products, however several major manufacturers did comment that LLLC systems are beginning to make up a larger percentage of overall sales.

Given the short two-year time span between the 2014 Navigant report and the 2016 market actor interviews, we assumed the trend of LLLC systems would increase at a rate similar to rates measured in the recent past. Our analysis yielded a baseline fixture installation base of 6% for

offices and 8% for warehouses in 2016. Figure 4 shows the forecasted total regional stock of baseline LLLC systems from 2016-2035. The figure depicts a steady increase in saturation over time as LLLC systems continue to increase in popularity and as first costs decrease.

Figure 4. LLLC Baseline Fixture Saturation – Total Regional Stock by Market Sector

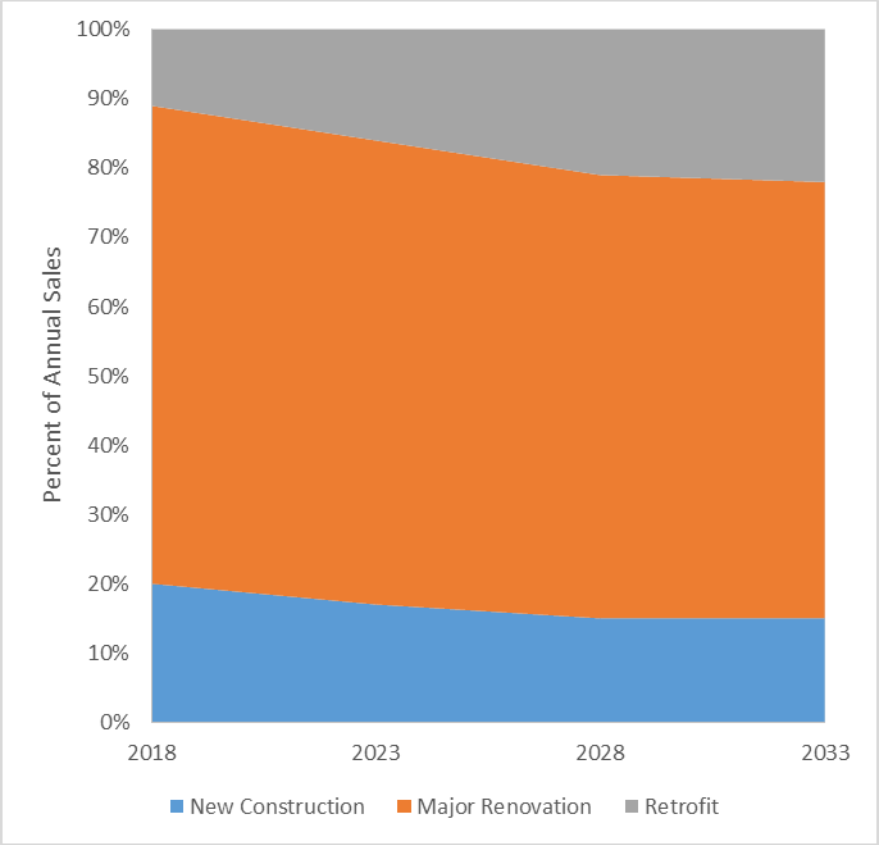


Adoption Rates by Market Sector

To account for different adoption rates by market sector, we assumed the installed breakout of LLLC systems by state is analogous to sales data. Information contained in Figure 4-1 and Table 4-4 of the 2014 Navigant report indicated that the majority of LLLC sales are expected to occur in major renovations. New construction is expected to account for the next highest share of LLLC sales, and retrofits are expected to account for the smallest share.

Our 2016 market actor interviews with manufacturers and distributors corroborated this finding, with major renovation and new construction comprising the larger market share of past LLLC installations, but retrofits beginning to make up a larger share of the market over time. We then used the annual sales projection data by construction type to calculate the percentage of LLLCs added each year that would enter through the retrofit, major renovation, and new construction market sectors. These percentages are shown in Figure 5.

Figure 5. Percent of Annual Sales by Market Sector – 2018 - 2033



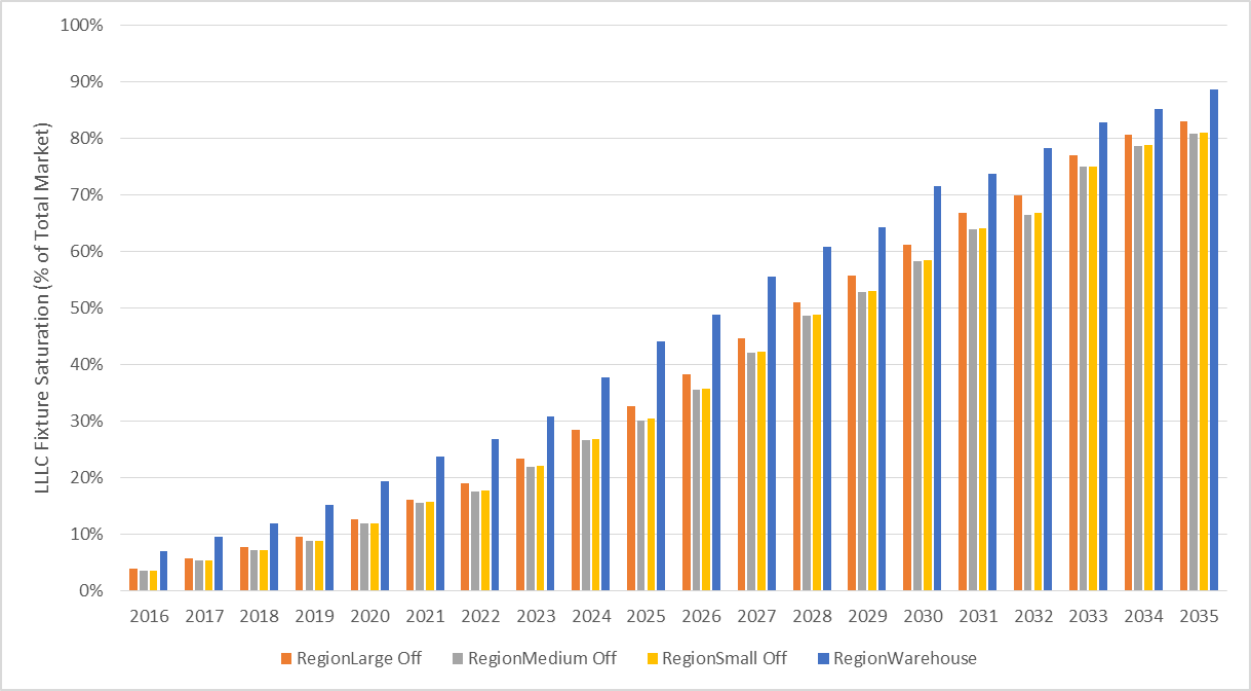
Since state level sales data were not available through existing secondary sources, nor were we able to obtain quantitative data through the 2016 market actor interviews, we applied sales data trends across each state according to a qualitative analysis of manufacturer responses. We determined through these interviews that most LLLC installations occur in regions with stricter codes, utility rebate programs, and where the majority of industries are located. Within the Northwest, most manufacturers pointed to Portland and Seattle for major renovation and new construction installations. Additionally, Idaho has a stricter building code than Montana and therefore would be expected to see a larger percentage of the remaining sales.

Taking these influence factors from the market actor interviews into account, we estimated that adoption in Idaho and Montana would lag behind adoption in Oregon and Washington by five years. While LLLC system adoption in Idaho and Montana is expected to follow the same diffusion curve as adoption in Oregon and Washington, the lag in Idaho and Montana results in fewer installations in these states in the next five years.

Our final step multiplied the regional square footage, applicable fixture densities, and overall sales data together to provide a forecast of total LLLC installations by market sector, building type, and state.

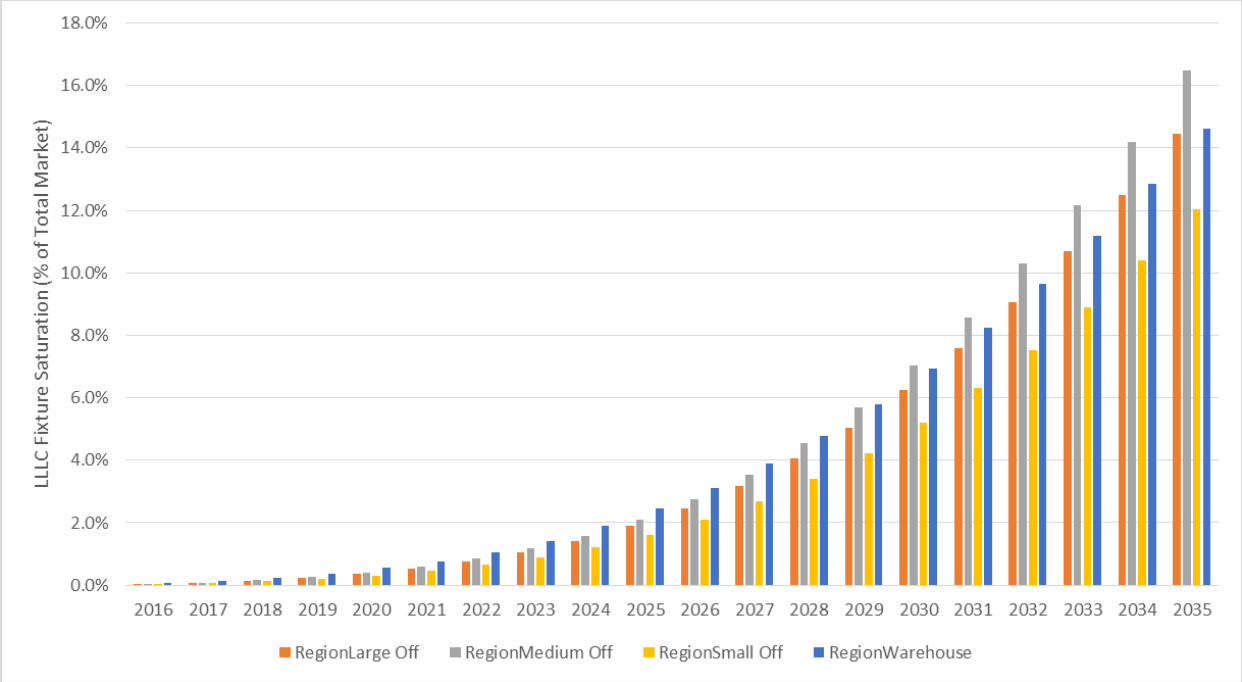
Figure 6 shows that LLLC systems are expected to continue to make-up a larger share, on a percentage basis, of the regional fixture stock in the new construction and major renovation markets over time as technology matures and first cost is reduced.

Figure 6. LLLC Fixture Saturation – % of Total Regional Stock for New Construction and Major Renovation



Similarly, the large existing stock of fixtures presents a substantial opportunity for LLLC system installations, albeit on a smaller scale in terms of percentage of total applicable fixtures. Fixture 7 shows the estimated saturation of LLLC systems in the retrofit sector as a percent of the total retrofit market. These computations support the market actor interview findings that the majority of installations are first occurring in new construction markets as first cost presents a barrier to installation in the retrofit sector.

Figure 7. LLLC Fixture Saturation – % of Total Regional Stock for Retrofit



Baseline Energy Consumption

To convert the saturation of fixtures into anticipated energy savings, a baseline LPD is needed. We utilized data from the NWPCC 7th power plan supply curves that detailed baseline LPD levels for office and warehouse spaces for all three market sectors, as shown in Table 2.

Table 2. Fixture Density and Installed Fixture Base for 2013 & 2016 by Building Type

BUILDING TYPE	EUI EXISTING BUILDINGS (KWH/SQ. FT.)	EUI NEW BUILDINGS/MAJOR RENOVATION (KWH/ SQ. FT.)
Large Office	3.2	2.6
Medium Office	2.7	2.2
Small Office	2.5	2.1
Warehouse	1.3	1.6

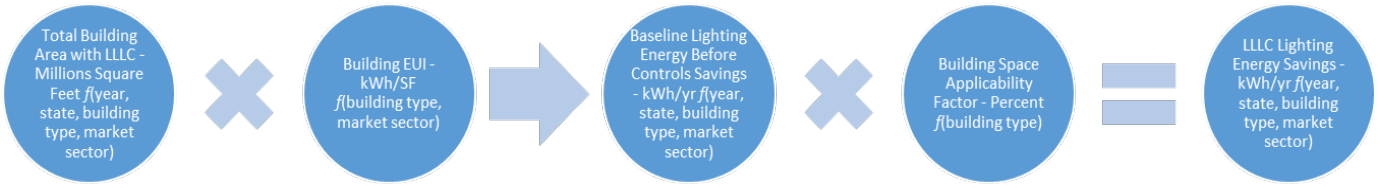
Source: NWPCC 7th Power Plan supply curve for interior lighting

We used the LPD from the Council's supply curves with the applicable LLLC fixture density (Table 1 above) to determine the total applicable building area with LLLCs as a function of state, building type, and market sector from 2016 until 2035.

To define LLLC energy savings, we drew on the 2014 CBSA data, state energy codes, and the NWPCC lighting controls energy savings analysis. The NWPCC analysis defines energy savings

for LLLCs over uncontrolled, and traditionally controlled, baselines depending on the space. To determine applicability of spaces for LLLC systems, we relied on CBSA data to define the space use breakout typical of each building type. Then we pulled in the relevant energy codes from each state to restrict the baseline control requirements in order to define the savings potential for each space. Figure 8 below demonstrates our step-by-step process to obtain LLLC system savings once we calculate the total building area with installed LLLC systems.

Figure 8. Process for Determining LLLC Lighting Energy Savings



Our final step in the analysis was a roll-up of a percent lighting savings for each building type taking into account different state code requirements. After applying these energy savings factors to our forecast, we arrived at a forecast for LLLC energy savings as a function of state, building type, and market sector from 2016 until 2035. Figures 9-11 show this breakout by building type for each market sector.

Figure 9. 2016 - 2034 Cumulative Lighting Energy Savings – New Construction (Region)

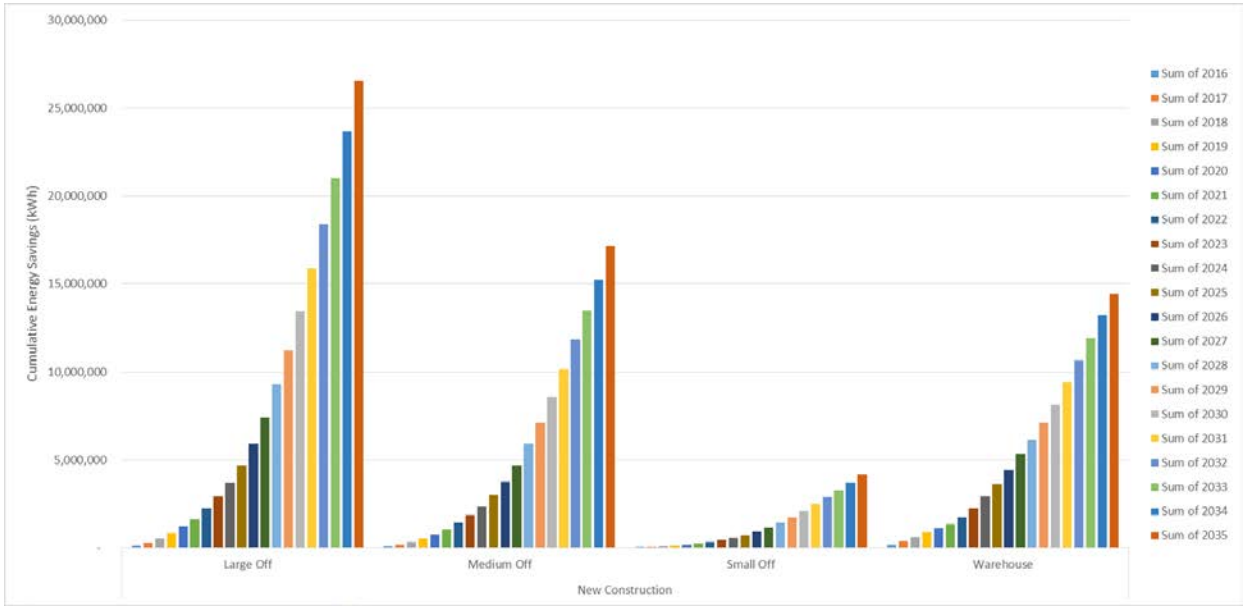


Figure 10. 2016 - 2034 Cumulative Lighting Energy Savings – Major Renovation (Region)

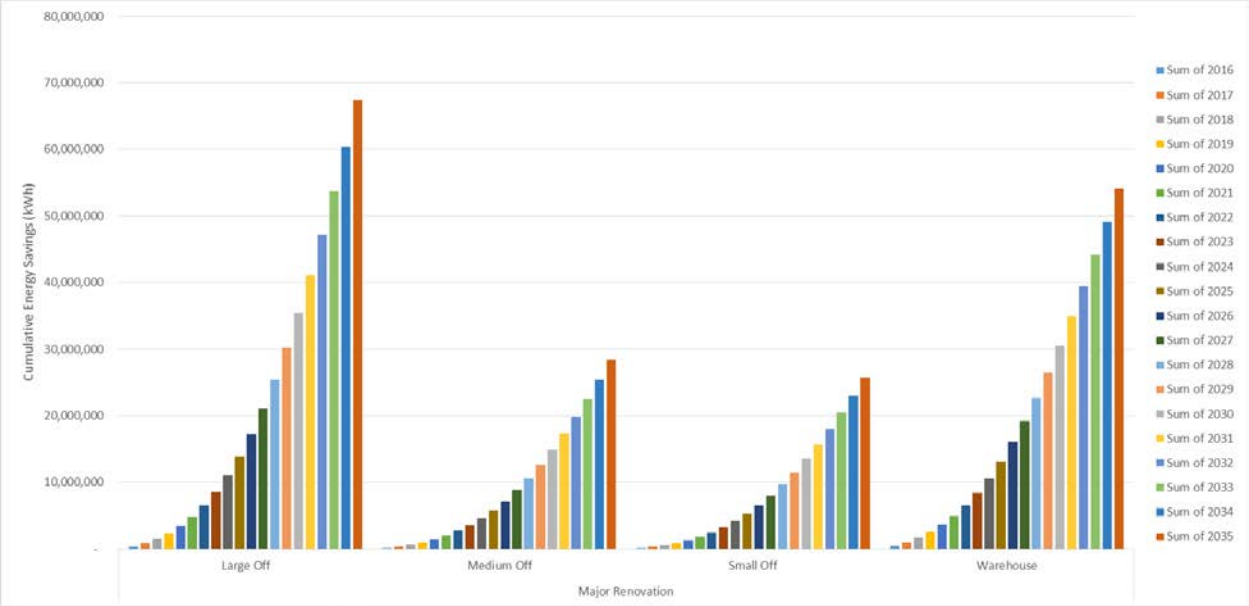
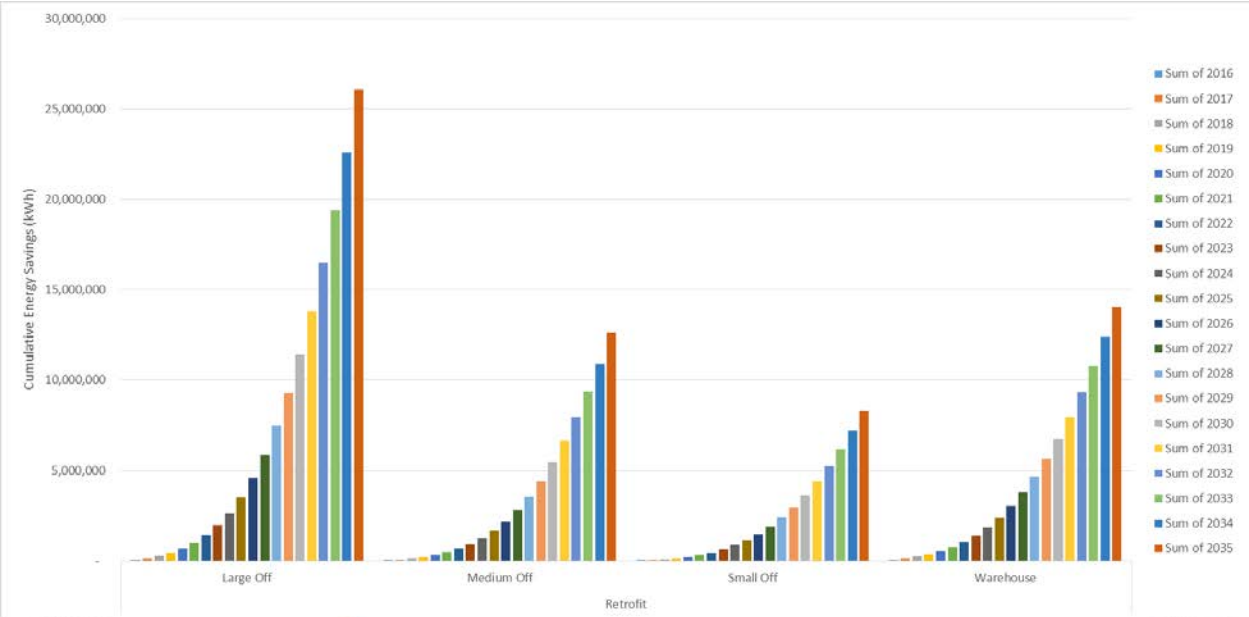


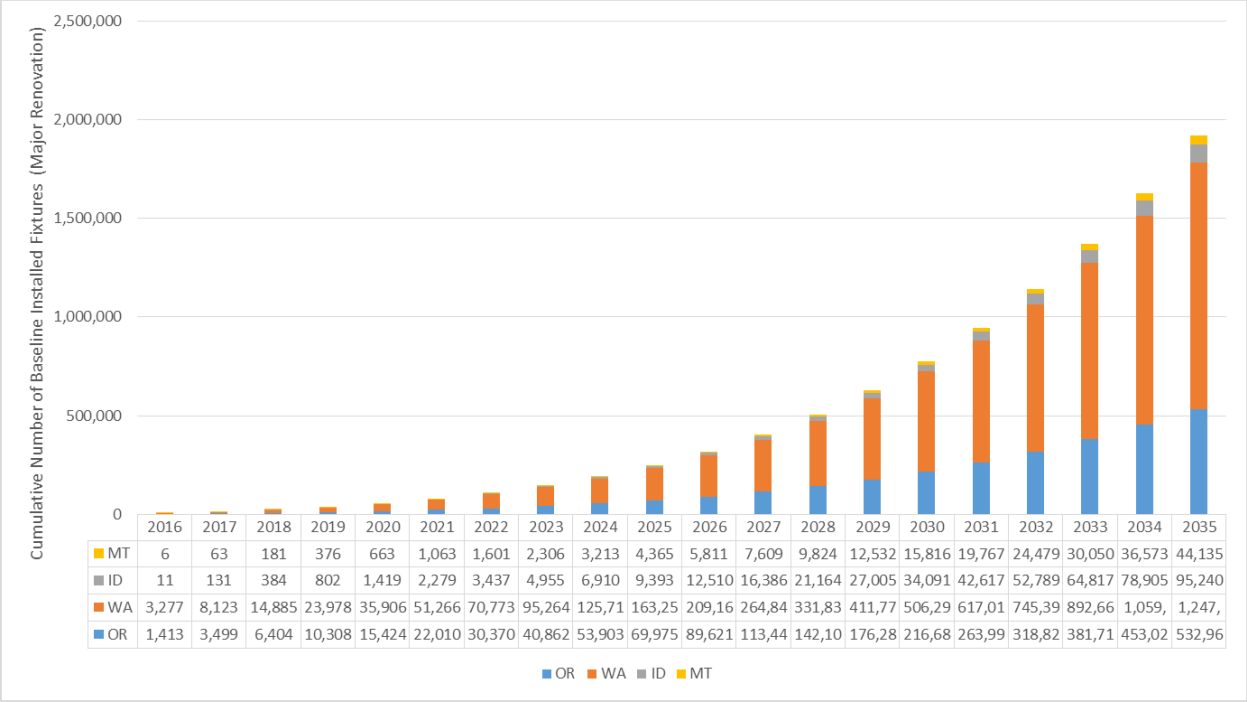
Figure 11. 2016 - 2034 Cumulative Lighting Energy Savings – Retrofit (Region)



Appendix E. Additional Figures

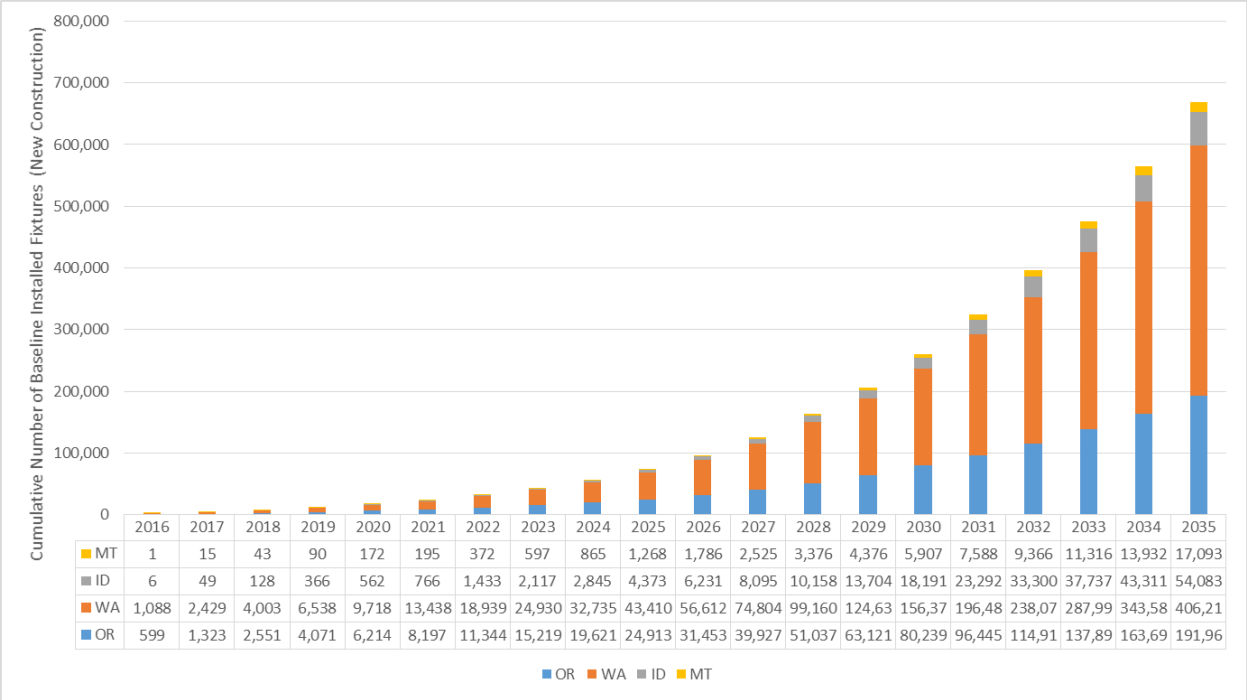
The figures below show estimates and forecasts over the 20-year period at a more granular level of detail than the summary charts contained within the main body of this report.

Figure 18. Installed Base of Fixtures by State – Major Renovation



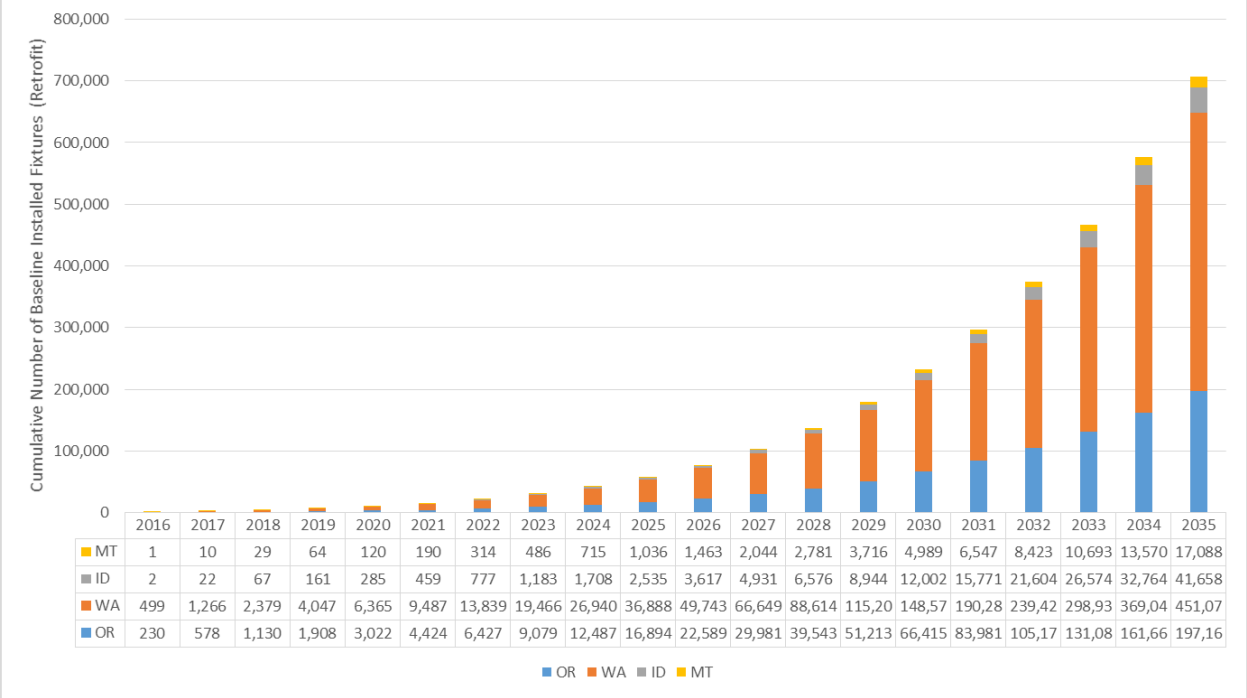
	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
MT	6	63	181	376	663	1,063	1,601	2,306	3,213	4,365	5,811	7,609	9,824	12,532	15,816	19,767	24,479	30,050	36,573	44,135
ID	11	131	384	802	1,419	2,279	3,437	4,955	6,910	9,393	12,510	16,386	21,164	27,005	34,091	42,617	52,789	64,817	78,905	95,240
WA	3,277	8,123	14,885	23,978	35,906	51,266	70,773	95,264	125,71	163,25	209,16	264,84	331,83	411,77	506,29	617,01	745,39	892,66	1,059,	1,247,
OR	1,413	3,499	6,404	10,308	15,424	22,010	30,370	40,862	53,903	69,975	89,621	113,44	142,10	176,28	216,68	263,99	318,82	381,71	453,02	532,96

Figure 19. Installed Base of Fixtures by State – New Construction



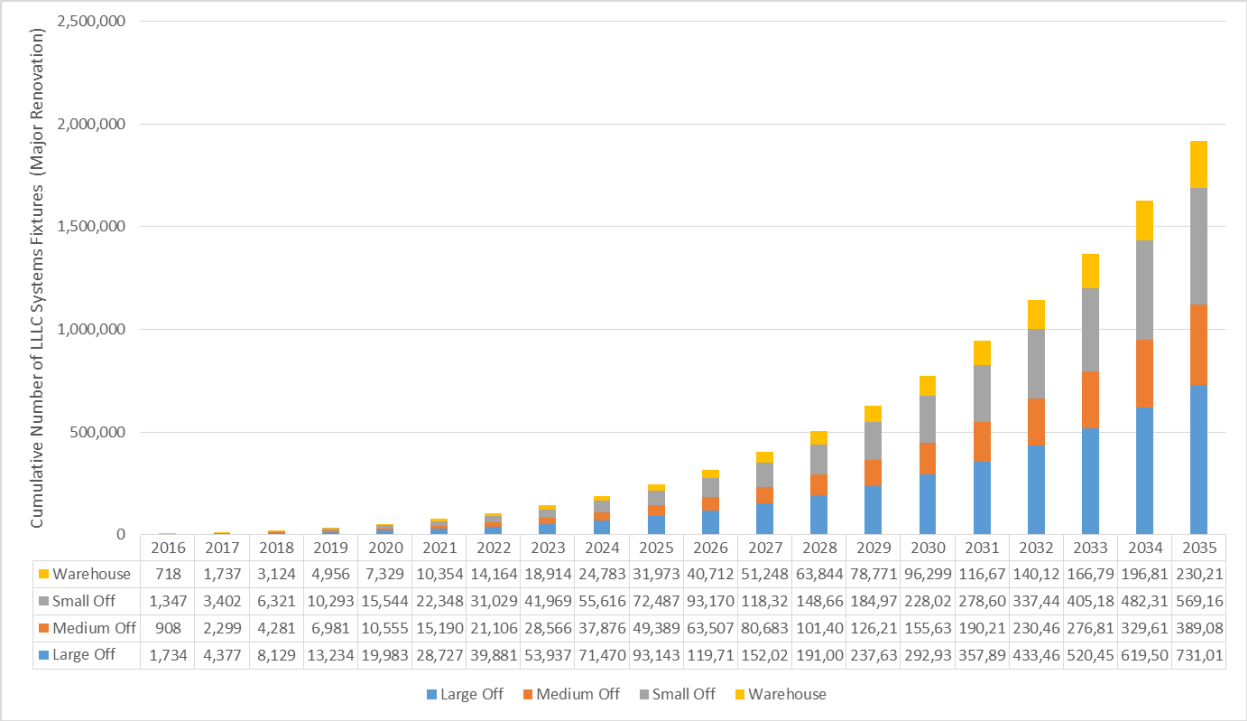
	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
MT	1	15	43	90	172	195	372	597	865	1,268	1,786	2,525	3,376	4,376	5,907	7,588	9,366	11,316	13,932	17,093
ID	6	49	128	366	562	766	1,433	2,117	2,845	4,373	6,231	8,095	10,158	13,704	18,191	23,292	33,300	37,737	43,311	54,083
WA	1,088	2,429	4,003	6,538	9,718	13,438	18,939	24,930	32,735	43,410	56,612	74,804	99,160	124,63	156,37	196,48	238,07	287,99	343,58	406,21
OR	599	1,323	2,551	4,071	6,214	8,197	11,344	15,219	19,621	24,913	31,453	39,927	51,037	63,121	80,239	96,445	114,91	137,89	163,69	191,96

Figure 20. Installed Base of Fixtures by State – Retrofit



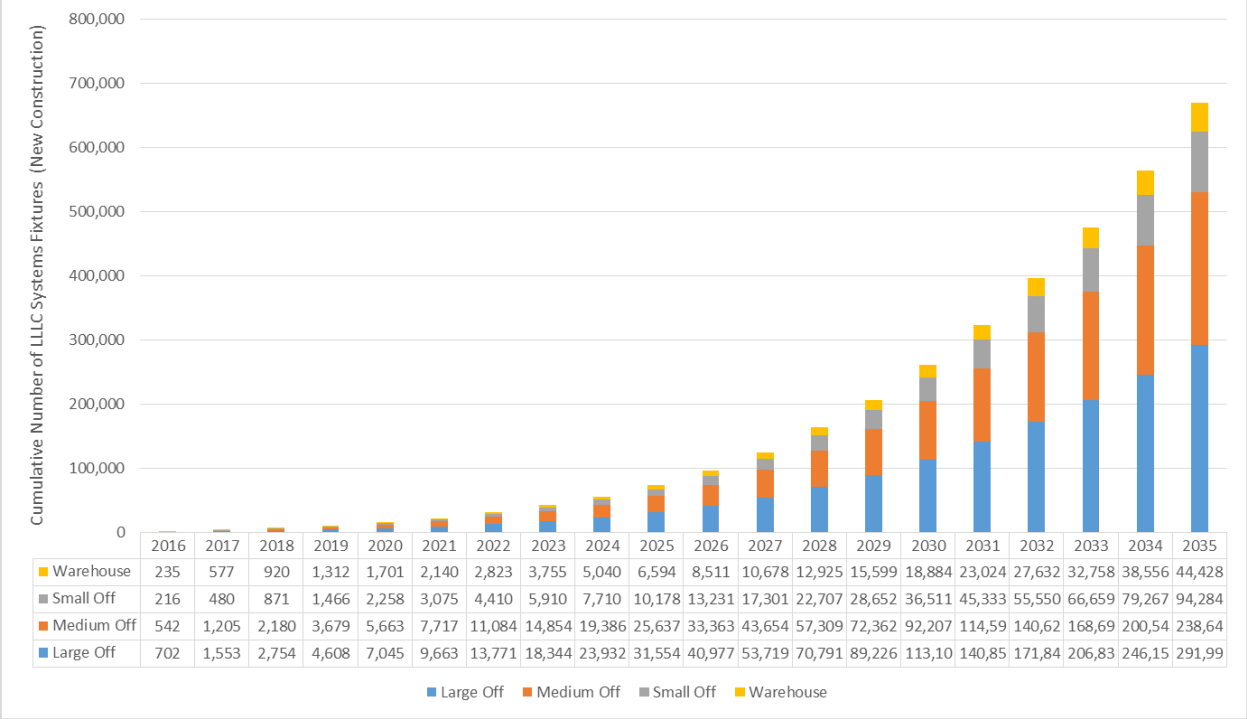
	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
MT	1	10	29	64	120	190	314	486	715	1,036	1,463	2,044	2,781	3,716	4,989	6,547	8,423	10,693	13,570	17,088
ID	2	22	67	161	285	459	777	1,183	1,708	2,535	3,617	4,931	6,576	8,944	12,002	15,771	21,604	26,574	32,764	41,658
WA	499	1,266	2,379	4,047	6,365	9,487	13,839	19,466	26,940	36,888	49,743	66,649	88,614	115,20	148,57	190,28	239,42	298,93	369,04	451,07
OR	230	578	1,130	1,908	3,022	4,424	6,427	9,079	12,487	16,894	22,589	29,981	39,543	51,213	66,415	83,981	105,17	131,08	161,66	197,16

Figure 21. Installed Base of Fixtures for Region – Major Renovation



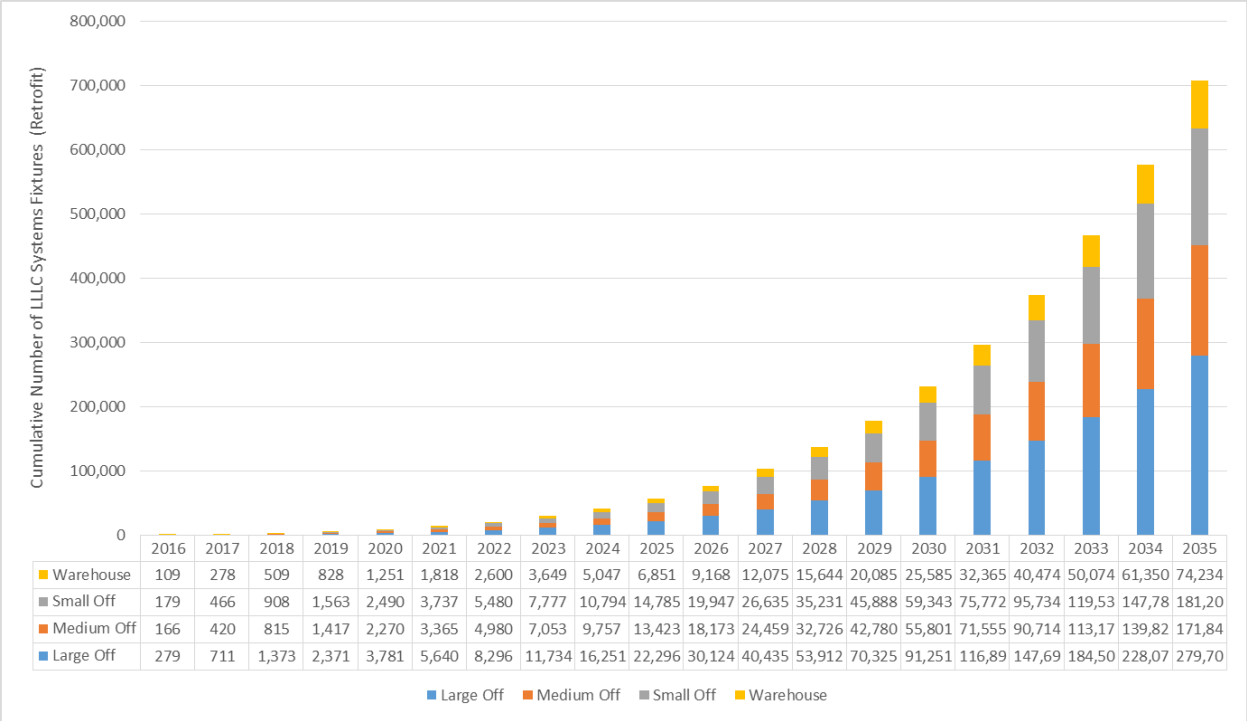
	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Warehouse	718	1,737	3,124	4,956	7,329	10,354	14,164	18,914	24,783	31,973	40,712	51,248	63,844	78,771	96,299	116,67	140,12	166,79	196,81	230,21
Small Off	1,347	3,402	6,321	10,293	15,544	22,348	31,029	41,969	55,616	72,487	93,170	118,32	148,66	184,97	228,02	278,60	337,44	405,18	482,31	569,16
Medium Off	908	2,299	4,281	6,981	10,555	15,190	21,106	28,566	37,876	49,389	63,507	80,683	101,40	126,21	155,63	190,21	230,46	276,81	329,61	389,08
Large Off	1,734	4,377	8,129	13,234	19,983	28,727	39,881	53,937	71,470	93,143	119,71	152,02	191,00	237,63	292,93	357,89	433,46	520,45	619,50	731,01

Figure 22. Installed Base of Fixtures for Region – New Construction



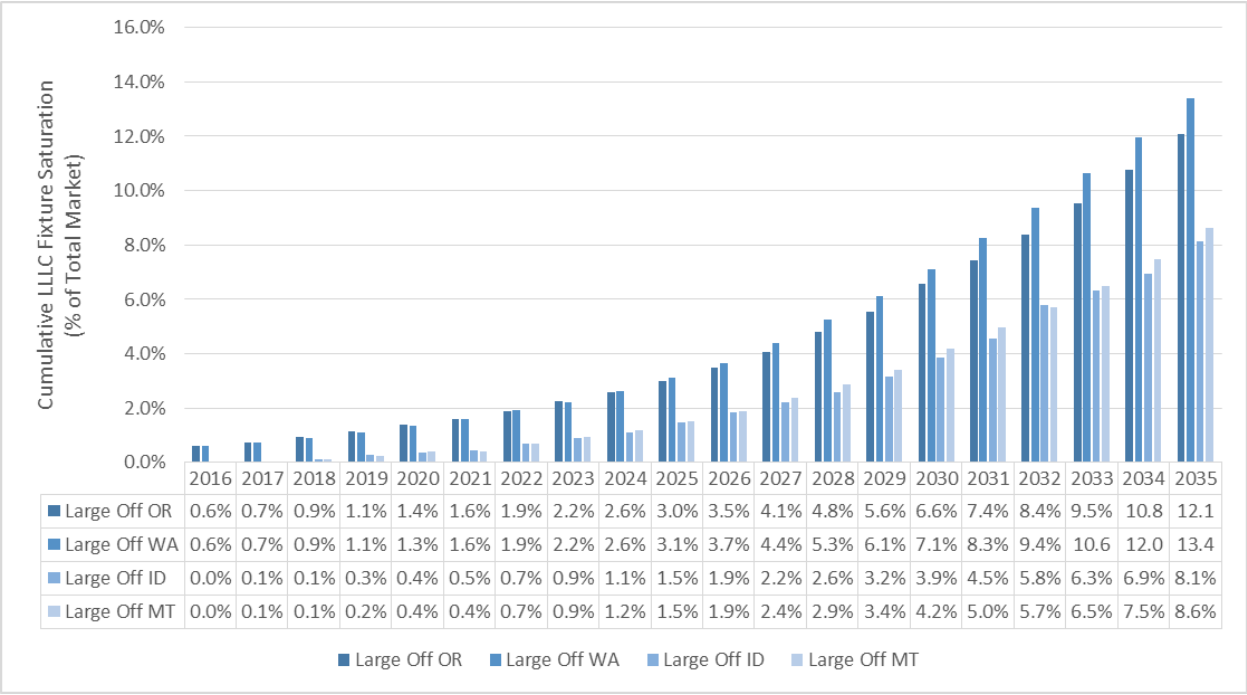
	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Warehouse	235	577	920	1,312	1,701	2,140	2,823	3,755	5,040	6,594	8,511	10,678	12,925	15,599	18,884	23,024	27,632	32,758	38,556	44,428
Small Off	216	480	871	1,466	2,258	3,075	4,410	5,910	7,710	10,178	13,231	17,301	22,707	28,652	36,511	45,333	55,550	66,659	79,267	94,284
Medium Off	542	1,205	2,180	3,679	5,663	7,717	11,084	14,854	19,386	25,637	33,363	43,654	57,309	72,362	92,207	114,59	140,62	168,69	200,54	238,64
Large Off	702	1,553	2,754	4,608	7,045	9,663	13,771	18,344	23,932	31,554	40,977	53,719	70,791	89,226	113,10	140,85	171,84	206,83	246,15	291,99

Figure 23. Installed Base of Fixtures for Region – Retrofit



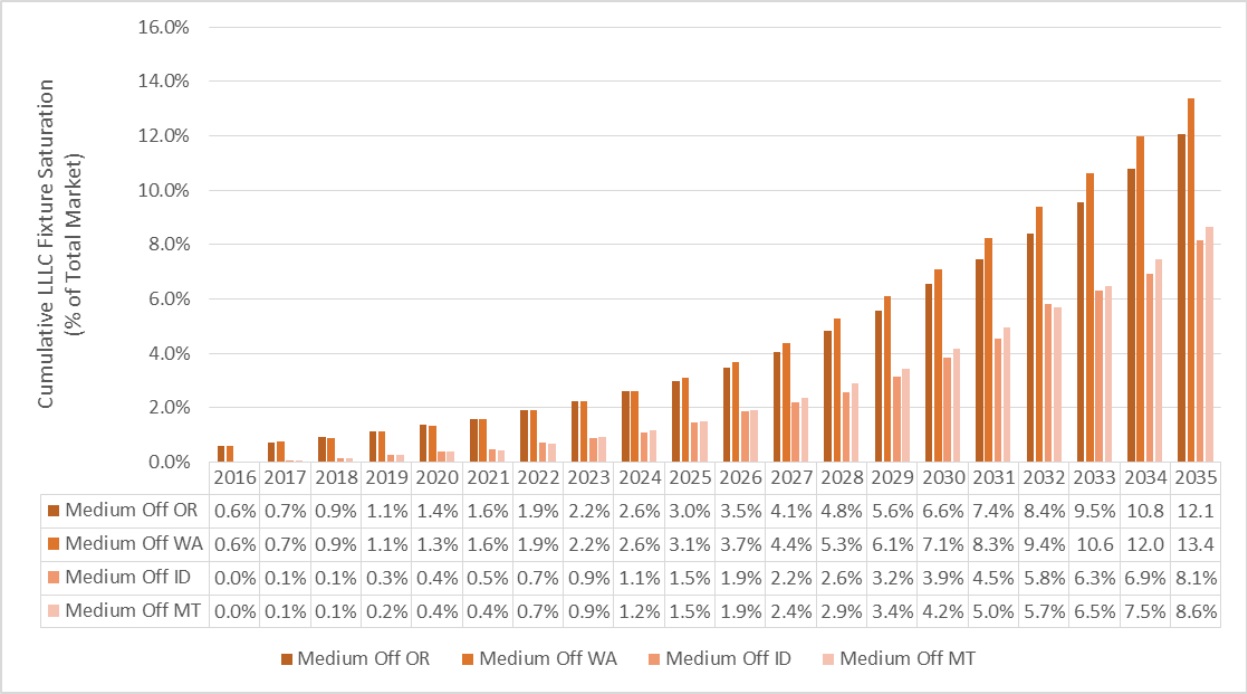
	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Warehouse	109	278	509	828	1,251	1,818	2,600	3,649	5,047	6,851	9,168	12,075	15,644	20,085	25,585	32,365	40,474	50,074	61,350	74,234
Small Off	179	466	908	1,563	2,490	3,737	5,480	7,777	10,794	14,785	19,947	26,635	35,231	45,888	59,343	75,772	95,734	119,53	147,78	181,20
Medium Off	166	420	815	1,417	2,270	3,365	4,980	7,053	9,757	13,423	18,173	24,459	32,726	42,780	55,801	71,555	90,714	113,17	139,82	171,84
Large Off	279	711	1,373	2,371	3,781	5,640	8,296	11,734	16,251	22,296	30,124	40,435	53,912	70,325	91,251	116,89	147,69	184,50	228,07	279,70

Figure 24. Cumulative LLLC Fixtures Saturation by State – Large Office Percent of Total NC/MR Market



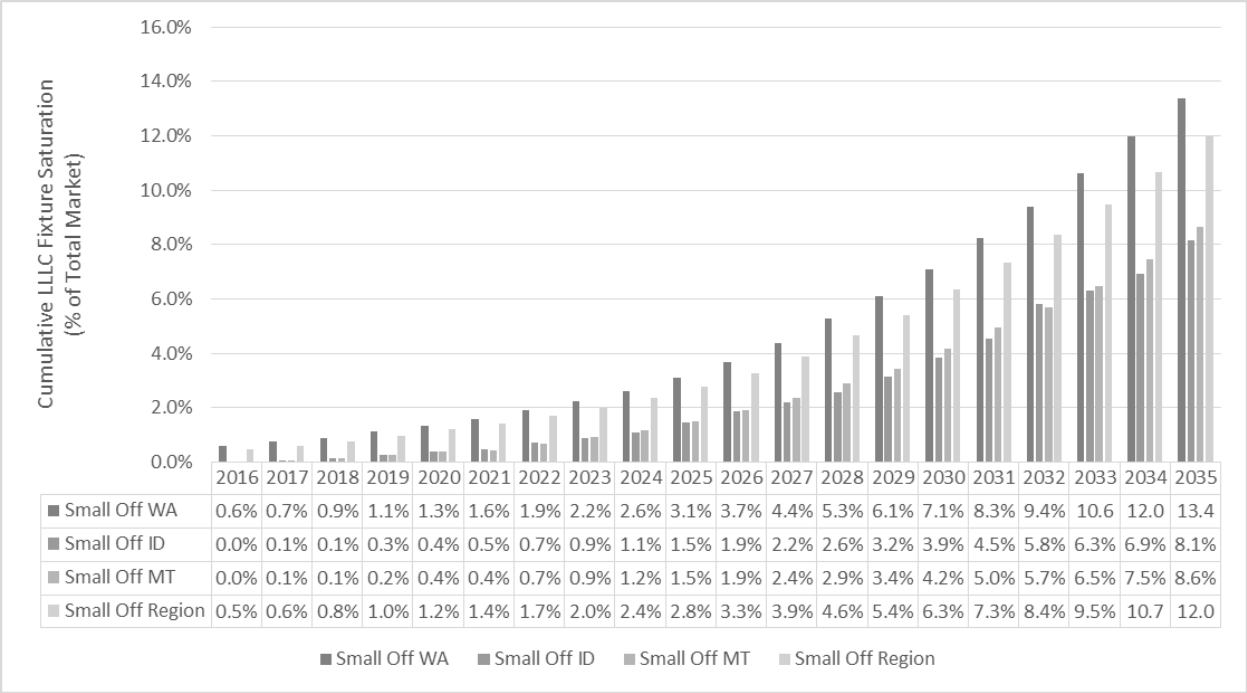
	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Large Off OR	0.6%	0.7%	0.9%	1.1%	1.4%	1.6%	1.9%	2.2%	2.6%	3.0%	3.5%	4.1%	4.8%	5.6%	6.6%	7.4%	8.4%	9.5%	10.8	12.1
Large Off WA	0.6%	0.7%	0.9%	1.1%	1.3%	1.6%	1.9%	2.2%	2.6%	3.1%	3.7%	4.4%	5.3%	6.1%	7.1%	8.3%	9.4%	10.6	12.0	13.4
Large Off ID	0.0%	0.1%	0.1%	0.3%	0.4%	0.5%	0.7%	0.9%	1.1%	1.5%	1.9%	2.2%	2.6%	3.2%	3.9%	4.5%	5.8%	6.3%	6.9%	8.1%
Large Off MT	0.0%	0.1%	0.1%	0.2%	0.4%	0.4%	0.7%	0.9%	1.2%	1.5%	1.9%	2.4%	2.9%	3.4%	4.2%	5.0%	5.7%	6.5%	7.5%	8.6%

Figure 25. Cumulative LLLC Fixtures Saturation by State – Medium Office Percent of Total NC/MR Market



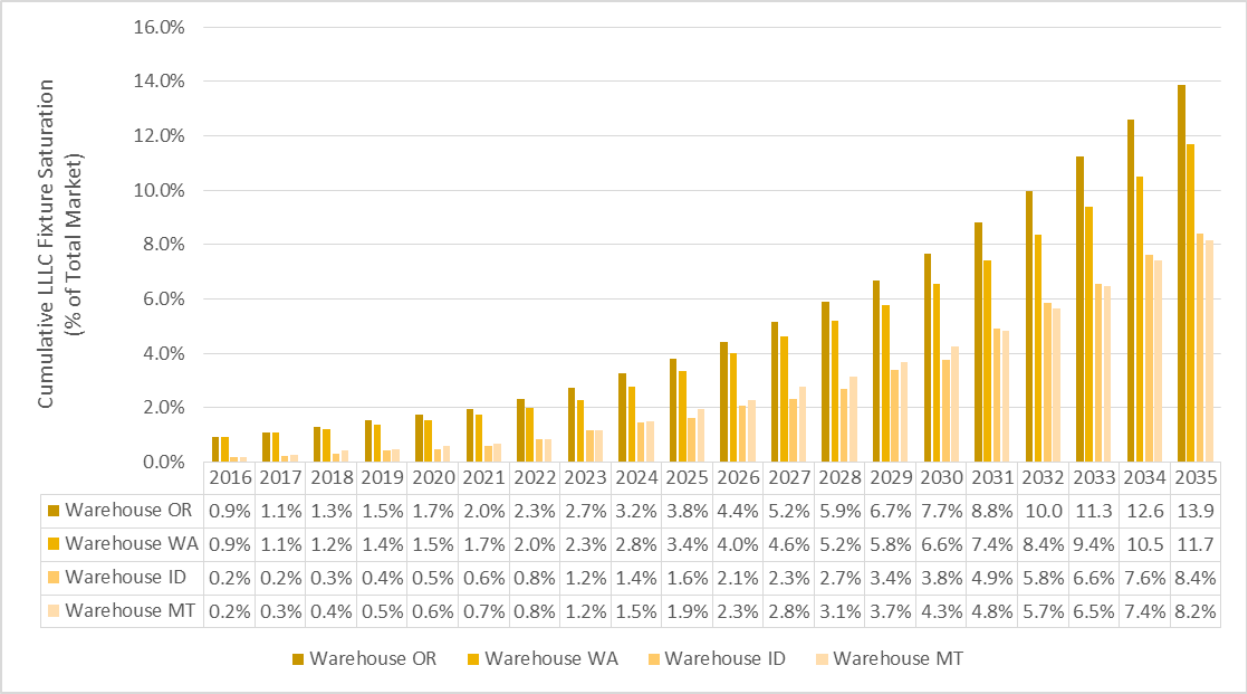
	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Medium Off OR	0.6%	0.7%	0.9%	1.1%	1.4%	1.6%	1.9%	2.2%	2.6%	3.0%	3.5%	4.1%	4.8%	5.6%	6.6%	7.4%	8.4%	9.5%	10.8	12.1
Medium Off WA	0.6%	0.7%	0.9%	1.1%	1.3%	1.6%	1.9%	2.2%	2.6%	3.1%	3.7%	4.4%	5.3%	6.1%	7.1%	8.3%	9.4%	10.6	12.0	13.4
Medium Off ID	0.0%	0.1%	0.1%	0.3%	0.4%	0.5%	0.7%	0.9%	1.1%	1.5%	1.9%	2.2%	2.6%	3.2%	3.9%	4.5%	5.8%	6.3%	6.9%	8.1%
Medium Off MT	0.0%	0.1%	0.1%	0.2%	0.4%	0.4%	0.7%	0.9%	1.2%	1.5%	1.9%	2.4%	2.9%	3.4%	4.2%	5.0%	5.7%	6.5%	7.5%	8.6%

Figure 26. Cumulative LLLC Fixtures Saturation by State – Small Office Percent of Total NC/MR Market



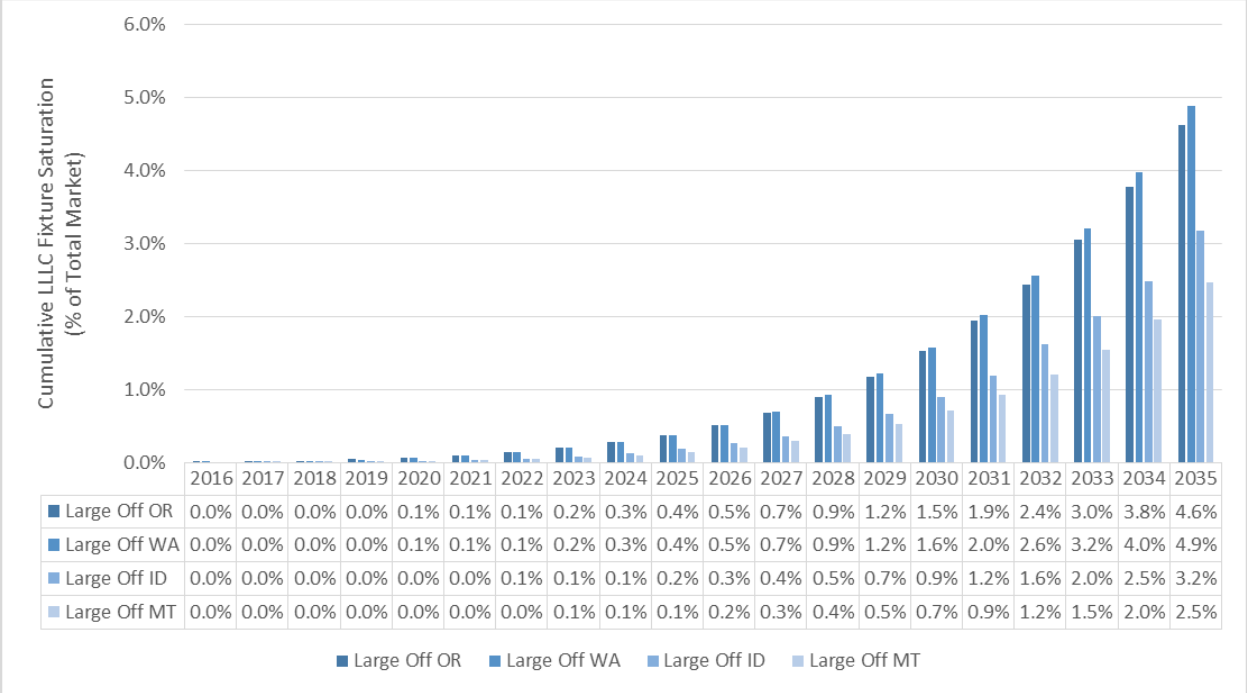
	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Small Off WA	0.6%	0.7%	0.9%	1.1%	1.3%	1.6%	1.9%	2.2%	2.6%	3.1%	3.7%	4.4%	5.3%	6.1%	7.1%	8.3%	9.4%	10.6	12.0	13.4
Small Off ID	0.0%	0.1%	0.1%	0.3%	0.4%	0.5%	0.7%	0.9%	1.1%	1.5%	1.9%	2.2%	2.6%	3.2%	3.9%	4.5%	5.8%	6.3%	6.9%	8.1%
Small Off MT	0.0%	0.1%	0.1%	0.2%	0.4%	0.4%	0.7%	0.9%	1.2%	1.5%	1.9%	2.4%	2.9%	3.4%	4.2%	5.0%	5.7%	6.5%	7.5%	8.6%
Small Off Region	0.5%	0.6%	0.8%	1.0%	1.2%	1.4%	1.7%	2.0%	2.4%	2.8%	3.3%	3.9%	4.6%	5.4%	6.3%	7.3%	8.4%	9.5%	10.7	12.0

Figure 27. Cumulative LLLC Fixtures Saturation by State – Warehouse Percent of Total NC/MR Market



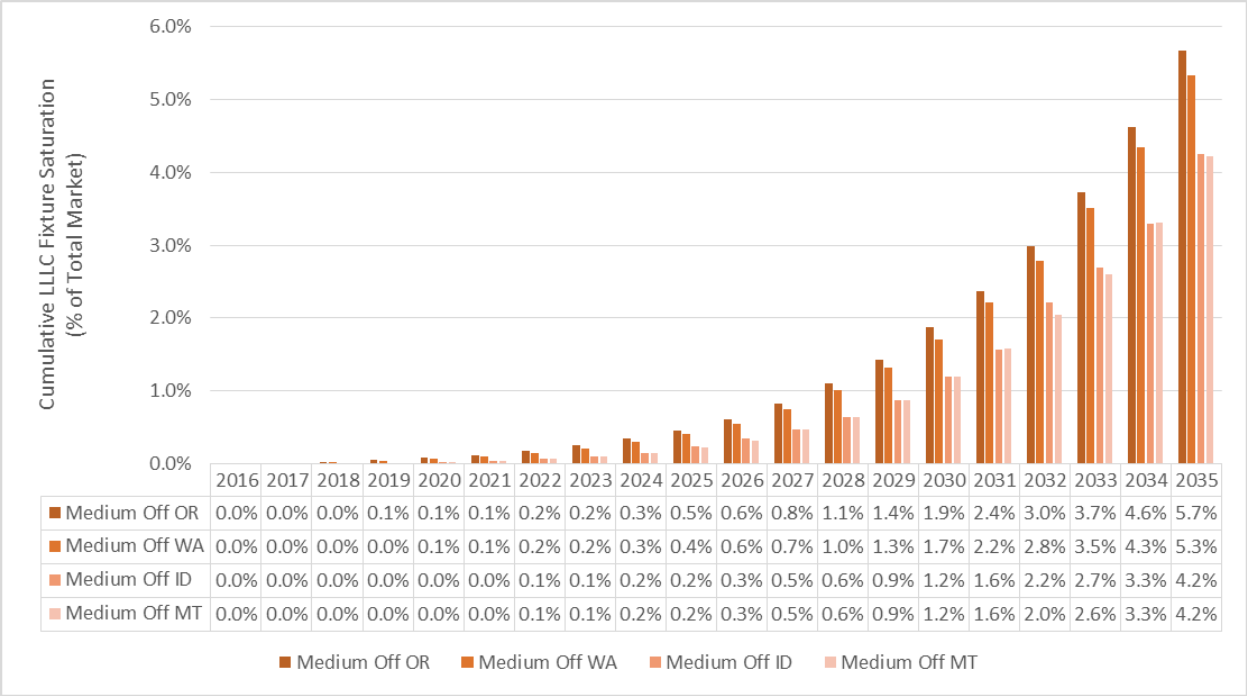
	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Warehouse OR	0.9%	1.1%	1.3%	1.5%	1.7%	2.0%	2.3%	2.7%	3.2%	3.8%	4.4%	5.2%	5.9%	6.7%	7.7%	8.8%	10.0	11.3	12.6	13.9
Warehouse WA	0.9%	1.1%	1.2%	1.4%	1.5%	1.7%	2.0%	2.3%	2.8%	3.4%	4.0%	4.6%	5.2%	5.8%	6.6%	7.4%	8.4%	9.4%	10.5	11.7
Warehouse ID	0.2%	0.2%	0.3%	0.4%	0.5%	0.6%	0.8%	1.2%	1.4%	1.6%	2.1%	2.3%	2.7%	3.4%	3.8%	4.9%	5.8%	6.6%	7.6%	8.4%
Warehouse MT	0.2%	0.3%	0.4%	0.5%	0.6%	0.7%	0.8%	1.2%	1.5%	1.9%	2.3%	2.8%	3.1%	3.7%	4.3%	4.8%	5.7%	6.5%	7.4%	8.2%

Figure 28. Cumulative LLLC Fixtures Saturation by State – Large Office Percent of Total Retrofit Market



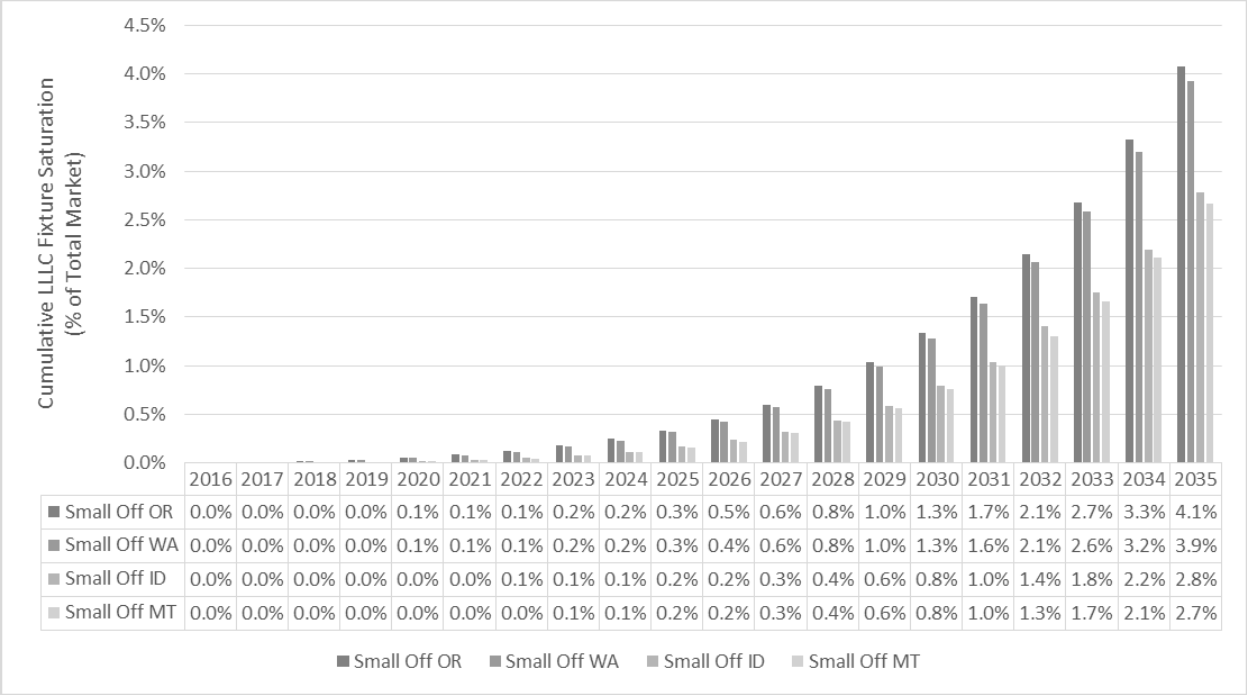
	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Large Off OR	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.1%	0.2%	0.3%	0.4%	0.5%	0.7%	0.9%	1.2%	1.5%	1.9%	2.4%	3.0%	3.8%	4.6%
Large Off WA	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.1%	0.2%	0.3%	0.4%	0.5%	0.7%	0.9%	1.2%	1.6%	2.0%	2.6%	3.2%	4.0%	4.9%
Large Off ID	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.1%	0.2%	0.3%	0.4%	0.5%	0.7%	0.9%	1.2%	1.6%	2.0%	2.5%	3.2%
Large Off MT	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.1%	0.2%	0.3%	0.4%	0.5%	0.7%	0.9%	1.2%	1.5%	2.0%	2.5%

Figure 29. Cumulative LLLC Fixtures Saturation by State – Medium Office Percent of Total Retrofit Market



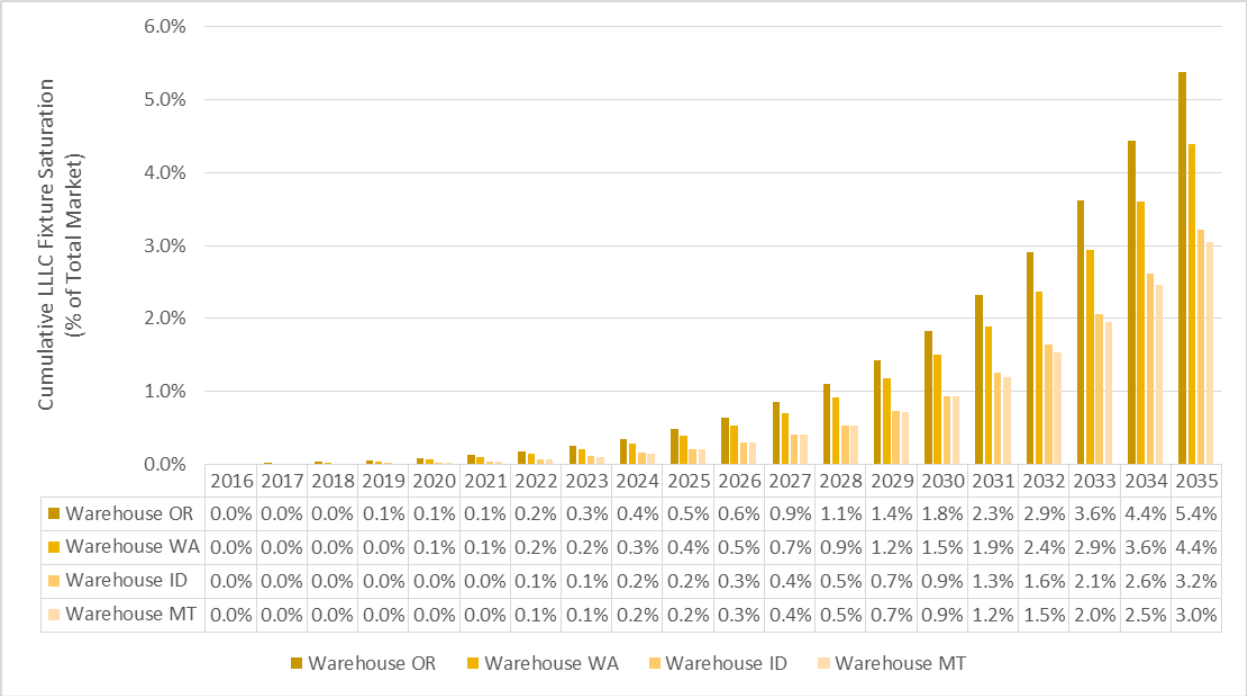
	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Medium Off OR	0.0%	0.0%	0.0%	0.1%	0.1%	0.1%	0.2%	0.2%	0.3%	0.5%	0.6%	0.8%	1.1%	1.4%	1.9%	2.4%	3.0%	3.7%	4.6%	5.7%
Medium Off WA	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.2%	0.2%	0.3%	0.4%	0.6%	0.7%	1.0%	1.3%	1.7%	2.2%	2.8%	3.5%	4.3%	5.3%
Medium Off ID	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.2%	0.2%	0.3%	0.5%	0.6%	0.9%	1.2%	1.6%	2.2%	2.7%	3.3%	4.2%
Medium Off MT	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.2%	0.2%	0.3%	0.5%	0.6%	0.9%	1.2%	1.6%	2.0%	2.6%	3.3%	4.2%

Figure 30. Cumulative LLLC Fixtures Saturation by State – Small Office Percent of Total Retrofit Market



	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Small Off OR	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.1%	0.2%	0.2%	0.3%	0.5%	0.6%	0.8%	1.0%	1.3%	1.7%	2.1%	2.7%	3.3%	4.1%
Small Off WA	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.1%	0.2%	0.2%	0.3%	0.4%	0.6%	0.8%	1.0%	1.3%	1.6%	2.1%	2.6%	3.2%	3.9%
Small Off ID	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.1%	0.2%	0.2%	0.3%	0.4%	0.6%	0.8%	1.0%	1.4%	1.8%	2.2%	2.8%
Small Off MT	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.2%	0.2%	0.3%	0.4%	0.6%	0.8%	1.0%	1.3%	1.7%	2.1%	2.7%

Figure 31. Cumulative LLLC Fixtures Saturation by State – Warehouse Percent of Total Retrofit Market



	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Warehouse OR	0.0%	0.0%	0.0%	0.1%	0.1%	0.1%	0.2%	0.3%	0.4%	0.5%	0.6%	0.9%	1.1%	1.4%	1.8%	2.3%	2.9%	3.6%	4.4%	5.4%
Warehouse WA	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.2%	0.2%	0.3%	0.4%	0.5%	0.7%	0.9%	1.2%	1.5%	1.9%	2.4%	2.9%	3.6%	4.4%
Warehouse ID	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.2%	0.2%	0.3%	0.4%	0.5%	0.7%	0.9%	1.3%	1.6%	2.1%	2.6%	3.2%
Warehouse MT	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.2%	0.2%	0.3%	0.4%	0.5%	0.7%	0.9%	1.2%	1.5%	2.0%	2.5%	3.0%