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2019-2020 Luminaire Level Lighting Controls Market Assessment

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Executive Summary

This report presents the findings from the 2019-2020 Luminaire Level Lighting Controls (LLLC) Market Assessment performed for the Northwest Energy Efficiency Alliance (NEEA) by NMR Group, Inc., in partnership with Energy Futures Group (the NMR team).

Luminaire Level Lighting Controls (LLLC), as defined by NEEA, are a type of networked lighting control (NLC) system with integrated sensors and controllers in each luminaire that are wirelessly networked, enabling the luminaires within the system to communicate with each other and transmit data. The sensors and controllers in other NLC systems are external to the luminaires, and usually control groups of luminaires. LLLC and NLC products meet the requirements of the DesignLights Consortium (DLC).

This Market Assessment had four overarching research objectives (ROs), summarized below. NEEA designed these objectives to generate actionable findings which will guide the LLLC Program interventions intended to remove barriers and promote sustained adoption of LLLC in the commercial and industrial (C&I) lighting controls market.

Research Objectives:

1. Assess Selected Market Barriers and Potential LLLC Threats
2. Assess Potential LLLC Market Opportunity
3. Conduct LLLC Market Update
4. Research Code Requirements for Lighting Controls

Note: the study did not address any potential impacts of the COVID-19 pandemic on the barriers, opportunities, or market conditions for LLLC, given that the study was well underway before the pandemic began.

METHODOLOGY

To address these objectives, the NMR team performed four research tasks:

1. Reviewed existing resources, including reports, presentations, and other materials developed by NEEA and other organizations that addressed LLLC and lighting controls more generally;
2. Conducted 30 in-depth interviews (IDIs) with supply-side market actors, including manufacturers (5), manufacturer representatives (5), distributors (5), contractors (3), energy service companies (ESCOs) (4), and designers/specifiers (8). The NMR team also conducted four interviews with LLLC Program staff and implementation staff;
3. Performed a state-level review of building codes in all states within NEEA territory and the City of Seattle; and
4. Examined secondary data on commercial buildings to assess key characteristics of building stock and estimate the square footage served by various control strategies.

Table 1 maps these tasks to each of the four ROs.

Table 1: Relationships Among ROs and Research Activities

	Barriers / Threats	Opportunities	Market Update	Code Review
Task 1: Review Existing Research	●	●	●	●
Task 2: IDIs with Market Actors & Program/Implementer Staff	●	●	●	●
Task 3: Building Code Review				●
Task 4: Review Secondary Building Data				●

Defining Lighting Control Technologies and Technology Categories

The evaluation team worked with NEEA to establish specific definitions of each lighting control system being discussed in market actor interviews:[1]

- *Luminaire Level Lighting Controls (LLLC)* – A type of networked lighting control (NLC) system with integrated sensors and controllers in each luminaire that are wirelessly networked, enabling the luminaires within the system to communicate with each other and transmit data.
- *Room-based control solutions* (shorted to room-based controls in the report) – pre-packaged kits that were sold with the equipment necessary to wire fixtures in a single room. Room-based controls represent standalone solutions in which the fixtures cannot operate individually or communicate with anything other than the room controller.
- *Other NLC (besides LLLC)* – networked controls where sensors are installed separately from fixtures in a one-to-many relationship. The sensors usually control a group of fixtures.
- *Power over Ethernet (PoE)* in reference to lighting controls – a system where low-voltage power and control data are provided to fixtures via Cat 5 or 6 ethernet cables.

KEY FINDINGS AND RECOMMENDATIONS

The study yielded a total of five key findings. This section lists those key findings, the ROs to which the findings apply, the supporting evidence, and resulting recommendations. The findings refer to *market actors* as a category for widespread opinions that crossed supply-side market actor lines, but they call out individual market actor groups for opinions specific to one individual or market actor group. The Detailed Findings section addresses these and additional insights from each of the four ROs.

RO: 1

Key Finding 1: LLLC increase real and perceived costs over other control options, which can lead decision makers to exclude LLLC at any point in projects, from design to installation. In place of LLLC, decision makers most often choose room-based controls rather than non-LLLC networked lighting controls (other NLC).

The market actors interviewed for this study believe that choosing LLLC over other lighting control options increases real and perceived costs for equipment and programming. Coupled with concerns about realizing predicted energy and financial savings within acceptable timeframes, these costs served as the key barrier to increased LLLC adoption. Because of these cost-related concerns, decision makers (e.g., designers, installation contractors, and building owners) may exclude LLLC from projects through value engineering analyses or more basic cost-cutting decisions at any point in the process, from design to installation. On the positive cost side, some

[1] These represent condensed definitions. For the full definitions used during the interviews, plus a table detailing specific features each system has, please see the section of this report titled Defining Lighting Control Technologies and Technology Categories.

respondents noted that the sensor granularity of LLLC can reduce maintenance costs because, if one sensor fails, other nearby fixtures can pick up the slack, limiting the need to for immediate repair or replacement of the failed sensor. Also, several respondents noted that LLLC can decrease installation costs because sensors do not need to be installed as a separate step. Market actors believe that room-based controls are the major competitor to LLLC, rather than other NLC or Power over Ethernet (PoE) systems.

Recommendation 1: NEEA should continue to look for opportunities to collect empirical data from the field on the achieved energy savings and costs of LLLC installations relative to other controls options. This savings and cost assessment should consider the price of equipment, installation, programming, commissioning, and maintenance of LLLC compared to other NLC and room-based controls. To the extent possible, assessments should aim to provide site-specific findings for diverse building and space types, especially those identified by NEEA as priority markets. The outcomes of studies should provide concrete data on the costs and the energy and financial savings attributable to LLLC. The interviewees suggested that this information is key to encouraging more project decision-makers to seriously consider LLLC over other control options during design and installation.

RO: 1 RO: 2

Key Finding 2: Increased LLLC adoption – and the adoption of other types of NLC more generally – face numerous perceived and real non-cost barriers. However, the unique features of LLLC, such as luminaire-level programming and sensor density, can serve to overcome many of these barriers.

Market actors we interviewed noted that many end-users remain unaware of LLLC and that they cannot adopt the products if they do not know they exist. Interviewees said some of the end-users who are aware of LLLC are reluctant to adopt the controls because they believe LLLC are overly complicated. While it is the case that the initial setup of some LLLC requires programming of each sensor, other market actors stressed that the redundancy created by LLLC sensor density means that maintenance and reprogramming can be delayed if any individual sensor fails because other nearby sensors will pick up the slack. Interviewees highlighted this as an LLLC benefit not present in other NLC systems. Some market actors also pointed out that luminaire-level programming offers a great deal of flexibility for changing space use and end-user needs, as well as future integration with other lighting products and building management systems (BMS). This *futureproofing* includes the ability to adjust lighting for future tenants or incorporate Internet of Things (IoT) capabilities (e.g., asset tracking or wayfinding) at a later date. End-users may have lingering concerns about poor occupancy sensing performance from experiences with earlier generation products. However, LLLC sensor density, interviewees said, greatly improves the ability of the system to detect occupants and therefore decreases the chances of the lights turning off in an occupied room. As with many networked technologies, interviewees discussed that LLLC and other NLC systems present potential data security issues, which may require the involvement of information technology experts in the design and maintenance of the system. Finally, t interviewees explained that the perceived benefits of LLLC may vary by market actor and customer type. For example, a building owner may value the futureproofing capabilities, the maintenance staff may benefit from the sensor redundancy, specifiers may appreciate not having to physically locate sensors, and contractors may like not having to install sensors as a separate step.

Recommendation 2: The program should prepare persuasive arguments that go beyond energy savings for LLLC systems over other networked systems using external sensors. For example, the program could emphasize the flexibility and improved performance of LLLC over many other systems and the ability to easily adapt to future space and occupant needs. Using these arguments, NEEA should continue efforts to build awareness of LLLC benefits relative to other types of controls, but should also adopt tailored messaging that resonates with various market actors, customer types, and end-users. To document these benefits, NEEA should develop a robust accounting of available benefits and effective, tailored communication about those benefits.

RO: 3

Key Finding 3: Interview responses suggest that both the new construction and retrofit markets merit attention when exploring LLLC market opportunities, and that LLLC are most frequently installed in five of the six target markets identified for NEEA's LLLC Program.

Although opinions varied on the potential for LLLC adoption in new construction versus retrofit projects, market actors across groups reported that both new construction projects and retrofits were using LLLC systems. Some interviewees saw LLLC as an advantage in new construction because decision makers prefer the latest technology, and LLLC can more easily be integrated into architectural and lighting designs. Interviewees recognized one clear advantage for LLLC in retrofit situations: because the sensors are integrated into the fixture, the install does not require new wiring, thus saving time and money.

The research confirmed that LLLC are being installed in the office, warehouse, K-12 school, university, and hospital markets. However, the interviewees had mixed opinions on the potential of LLLC in the retail market. Distributors and ESCOs noted that there is a need for retailers to use lighting to showcase products, but also mentioned that LLLC can be advantageous for retailers if they choose to leverage the asset tracking and wayfinding IoT capabilities of some LLLC systems.

Recommendation 3: NEEA should continue to promote LLLC in both the new construction and retrofit markets, but tailor the messaging to the unique circumstances and needs of the two different types of installations. NEEA should continue to target office, warehouses, K-12 schools, universities, and hospitals in its LLLC Program. NEEA should conduct additional research into which sectors of the retail market fit best with LLLC systems and target only those retail sectors in the future.

RO: 1 RO: 4

Key Finding 4a: Some manufacturer representatives and distributors rejected the idea of requiring embedded sensors to define "luminaire level control" in code or other regulatory frameworks.

Key Finding 4b: Market actors – particularly manufacturer representatives and distributors – resisted the idea of prioritizing LLLC over other NLC systems when advancing the market for advanced lighting controls through incentives or other approaches.

LLLC can meet all lighting control requirements across all state codes but so can other control types, such as room-based controls and other NLC. Codes in Idaho, Washington, and Seattle have a specific LLLC compliance path, and Montana likely will as well when it adopts the International Energy Conservation Code (IECC) 2018.[2] Manufacturer representatives and distributors were critical of code language or incentive structures that favor LLLC-specific approaches, preferring the flexibility in price and system design provided by some NLC systems without embedded sensors. In addition, distributors with design experience reported a belief that they can achieve comparable performance and energy savings using non-LLLC NLC; one said that prioritizing LLLC over other NLC in codes or incentives is a mistake because NLC is effective and accepted in the market. Two manufacturer representatives reported conversations with code officials about the definition of LLLC in the Washington LLLC compliance pathway and have argued that the language should not require luminaires with embedded sensors. One manufacturer representative reported success in receiving approval under the LLLC compliance path using non-LLLC NLC.

Recommendation 4: NEEA, through their Codes Team, should continue working with market actors to increase awareness of LLLC as an optional code compliance pathway in concert with awareness-building on the added benefits provided by LLLC. Likewise, NEEA should have discussions with market actors and code official to assess how various actors are interpreting and executing the code in the field. NEEA might also consider discussing the benefits of more literal interpretations of the LLLC compliance path with code officials

RO: 2

Key Finding 5: ESCOs are not convinced that a major market opportunity currently exists for LLLC in such contracts.

Citing uncertainty about the ability of LLLC to yield the energy cost savings needed to meet project financing goals, ESCOs are not convinced that a major market opportunity currently exists for LLLC in lighting as a service (LaaS) and other performance contracts. The ESCOs interviewed did mention that while LLLC could have some benefits for LaaS, these benefits do not outweigh the current issues related to increased project costs and payback within typical contract lengths.

Recommendation 5: At this time, NEEA should refrain from dedicating resources to pursuing LaaS as a vehicle for promoting sustained LLLC adoption in the market.

[2] As of September 2020, the timing of this adoption remained uncertain.

Introduction

Background

This report presents the findings from the 2019-2020 Luminaire Level Lighting Controls (LLLC) Market Assessment performed for the Northwest Energy Efficiency Alliance (NEEA) by NMR Group, Inc., in partnership with Energy Futures Group (the NMR team). While this study specifically focused on LLLC products, it also pursued insights into the wider market for lighting controls to better understand how market actors understand and utilize different lighting control solutions within the regulatory frameworks and financial realities that characterize the commercial building market.

Luminaire Level Lighting Controls (LLLC), as defined by NEEA, are a type of networked lighting control (NLC) system with integrated sensors and controllers in each luminaire that are wirelessly networked, enabling the luminaires within the system to communicate with each other and transmit data. The sensors and controllers in other NLC systems are external to the luminaires, and usually control groups of luminaires. LLLC and NLC products meet the requirements of the DesignLights Consortium (DLC).

This Market Assessment provides findings from lighting market actors and other data sources that could inform the program's continued efforts to understand and quantify the lighting controls market and support market transformation. The study included the four research objectives (ROs) listed below. The NEEA market research and evaluation study manager and the NMR team developed the objectives to focus research activities on findings that would be of the greatest use to the program at this stage.

Research Objectives (ROs):

1. Assess Selected Market Barriers and Potential LLLC Threats
2. Assess Potential LLLC Market Opportunity
3. Conduct an LLLC Market Update
4. Research Code Requirements for Lighting Controls

Importantly, the study did not address any potential impacts of the COVID-19 pandemic on the barriers, opportunities, or market conditions for LLLC, given that the study was well underway before the pandemic began.

Report Organization

The remainder of the report is organized into three sections: (1) the Methods used to meet the Market Assessment ROs, (2) Detailed Findings, and (3) Conclusions and Recommendations. The NMR team has organized all findings and recommendations by RO. The report provides the full text of each RO in the detailed findings section.

METHODS

The NMR team employed four tasks to achieve the ROs of this study. Table 2 provides an overview of the main research tasks and how each task relates to the ROs.

Table 2: Relationship of Research Tasks to ROs

	Barriers / Threats	Opportunities	Market Update	Code Review
Task 1: Review Existing Research	●	●	●	●
Task 2: IDIs with Market Actors & Program/Implementer Staff	●	●	●	●
Task 3: Building Code Review				●
Task 4: Review Secondary Building Data				●

RESEARCH TASKS

Task 1: Review Existing Research

The NMR team began the market assessment with a review of existing data sources, including NEEA reports and outside research, covering LLLC technology and the lighting controls market. NEEA has previously conducted baseline research and market characterizations of the LLLC market, held focus groups with lighting decision makers, and assessed the potential energy savings provided by LLLC.[3] This foundational NEEA research and information from other sources informed the design of the questionnaires for market actor in-depth interviews (IDIs) and provided the NMR team with useful background information for addressing each RO.

[3] Studies are available at https://neea.org/search?query=LLLC.

Task 2: Market Actor and LLLC Program and Implementation Staff IDIs

The second research task involved the completion of thirty-four IDIs with market actors (30), NEEA LLLC Program staff members (2), and LLLC Program implementer staff members (2). The NMR team conducted the interviews between January and May of 2020. NEEA and implementation staff members and NMR team members worked together to compile lists of potential interviewees. Two of NEEA's funding utilities also provided lists of energy service companies (ESCOs) and commercial lighting contractors to help expand the interviewee pool. Finally, some interviewees referred us to other potential interview targets. The NMR team excluded individuals recently interviewed or contacted for other NEEA program or research efforts.

To recruit interviewees, NMR team members sent recruitment emails that introduced NEEA, explained the purpose of the study, assured the recipient that all responses would be kept anonymous, and offered a $100 incentive to all who completed the interview. Team members followed up with reminder emails and phone calls if the interview target did not reply to the initial email. After approximately five unanswered attempts, the NMR team dropped the target from the sample. The recruitment approach varied for two market actor groups. One utility sent emails to their partnering ESCOs and commercial lighting contractors that alerted them to the study and asked for their cooperation. It was particularly challenging for the NMR team to secure interviews with manufacturer contacts identified early in the study, so the contact pool was expanded and NEEA and NMR team staff members reached out to manufacturers to enlist their cooperation. The utility and NEEA staff outreach staff helped the NMR team achieve its desired number of completed interviews.

Table 3 lists the final number of interviews completed by market actor group and maps the market actor groups to the research topics addressed during their interviews. The NMR team used these interviews as the key data sources for ROs 1, 2, and 3; these interviews also provided data to satisfy parts of RO4. The NMR team used a variety of approaches to gather contact information for manufacturers, distributers, designers/specifiers, contractors, and ESCOs:

- Solicited contacts from NEEA staff and partner organizations and utilities;
- Gathered contacts from previous research; and
- Conducted new research to trace known LLLC manufacturers to their representatives within NEEA service territory.

LLLC Program implementation staff also assisted with outreach to contractors and ESCOs.

The NMR team also performed four interviews with members of the NEEA LLLC Program: two NEEA staff and two implementation staff. The staff interviews covered topics related to several ROs, but the NMR team specifically used these interviews to gain a better understanding of the LLLC Program's background, goals, and methods.

Throughout this report, unless explicitly noted, the findings reflect the insights, opinions, and commentary of the interviewees and not the NMR team. In contrast, the conclusions and recommendations reflect our interpretation of the findings and the suggested actions NEEA may want to take in response to those findings.

Table 3: Sample Composition, Schedule, and Research Goals for Market Actor IDIs

Target Group	Sample Size	Recruitment Approach	Key Research Topics		
			RO1 / RO2: Barriers, Threats, & Opps	RO3: Market Update	RO4: Code Requirements
Manufacturer Reps	5	Primary research by NMR Team	✓	✓	✓
Designers / Specifiers	8[1]	NEEA relationships, referral sampling	✓	✓	✓
Distributors	5	NEEA relationships, referral sampling	✓	✓	
Contractors / ESCOs	7	NEEA / funding utility relationships, referral sampling	✓	✓	✓
Manufacturers	5	NEEA relationships, NMR team relationships, referral sampling	✓	✓	
Program / Implementer Staff	4	NEEA relationships	✓	✓	
Total	**34**				

Notes: [1] One designer/specifier had transitioned to a role where they inspected lighting installations for eligibility under utility lighting programs. The NMR team interviewed this designer/specifier for their experience inspecting LLLC installations for rebate programs covering lighting controls.

Task 3 and Task 4: Building Code and Secondary Building Data Review

To achieve the objectives of RO4, the NMR team conducted a comprehensive review of building energy codes for the four states in NEEA territory, as well as for the City of Seattle, and used secondary building data from the 2014 NEEA Commercial Building Stock Assessment (CBSA).[4] The team augmented these data with information from the National Renewable Energy Laboratory (NREL) to fill any data gaps. CBSA contains information on many commercial building types, including those identified as priority building types by NEEA (e.g., offices, warehouses, schools, and healthcare) and the space types found within them. NREL provided data when the square footage and glazing area for specific space types were either not present or not captured under the same collection schema as other CBSA buildings. The NMR team's review of code materials identified energy code requirements for various lighting control strategies over several layers of data – state, building type (e.g., office, retail, school), and space type within building (e.g., enclosed office, corridor, classroom/training room). Once the NMR team gained an

[4] NEEA. 2014. Commercial Building Stock Assessment. Available at https://neea.org/data/commercial-building-stock-assessments. Note that NEEA has nearly completed a new CBSA but the results were not available in time for this study.

understanding of control requirements for building and space types, they used building data from CBSA and NREL to assess the typical square footage of new construction and major renovations within each subtype, as well as the percentage of that floor space required to have daylighting or occupancy controls.

Defining Lighting Control Technologies and Technology Categories

After consulting with NEEA staff, the evaluation team adopted the following equipment definitions for these interviews. Following this list, Table 4 details specific features of each system.

- *Luminaire Level Lighting Controls (LLLC)* – A type of networked lighting control (NLC) system with integrated sensors and controllers in each luminaire that are wirelessly networked, enabling the luminaires within the system to communicate with each other and transmit data.
- *Room-based control solutions* (shorted to room-based controls in the report) – pre-packaged kits that were sold with the equipment necessary to wire fixtures in a single room, including walls stations, cables, controllers and sensors. Room-based controls represent standalone solutions in which the fixtures cannot operate individually or communicate with anything other than the room controller. In practice, they are convenient products meant to provide simple code compliance across discrete spaces. Market actors reported familiarity with these products as defined and, as discussed later in the report, many market actors work with these products frequently.[5]
- *Other NLC (besides LLLC)* – networked controls where sensors are installed separately from fixtures in a one-to-many relationship. The sensors are external to the fixture and usually control a group of fixtures. Sensors can exercise control over fixtures wirelessly (with a wireless driver) or via a control wire.
- *Power over Ethernet (PoE)* in reference to lighting controls – a system where low-voltage power and control data are provided to fixtures via Cat 5 or 6 ethernet cables. NEEA began interviews with the assumption that PoE did not fit their definition of an LLLC system, but two manufacturers pushed back on this and described systems that would fit the definition of a wired LLLC system. The NMR team did not verify that these systems would meet the DesignLights Consortium (DLC) specifications for LLLC.

[5] Two examples of room-based control solutions can be found here and here. The product at the first link describes availability in both "network" and "standalone" architecture. In-depth interviews directed respondents to consider room-based solutions in their basic standalone set-up and assume that optional networking was not performed. Some interview respondents indicated that they frequently add networking capabilities to room-based systems, while others rarely did so.

Table 4: Controls Definitions for Market Actor Interviews

Control Capability	LLLC[1]	Networked Lighting Controls (NLC)	Room-based Control Solutions
Occupancy and daylight sensing	✓	✓	✓
Luminaire-mounted sensors	✓		
Networking of control devices	✓	✓	✓
Networking of luminaires	✓	✓	[2]
Individual luminaire addressability[3]	✓	✓	[2]
Zoning (via software)	✓	✓	[2]
High-end trim	✓	✓	[2]

Notes: [1] LLLC are a subset of the Design Lights Consortium DLC NLC Qualified Product List (QPL), available at www.designlights.org/lighting-controls. Note that NEEA's LLLC Program is focused only on qualified LLLC products designated for Interior application (not Exterior).

[2] Some room-based control solutions offer these additional capabilities, but the definition used in the interviews limited room-based control solutions to standalone equipment that provide lighting control to non-networked luminaires in a single room.

[3] 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.

DETAILED FINDINGS

This section provides in-depth findings from the Market Assessment that cover each of the four ROs. The NMR team used feedback from IDIs to develop findings for ROs 1, 2, and 3. The team used secondary research of internal and external data sources, detailed in the Methods section, as well as market actor IDIs to inform the findings reported for RO4.

Interviewees often provided useful feedback in different terms than those outlined in the ROs, or on related topics that have implications for the LLLC Program but are not explicitly stated in the ROs. Therefore, the NMR team addresses the specific term and topics for each RO in the Findings, but also provides additional feedback from the interviewees.

RO: 1

ASSESS SELECTED MARKET BARRIERS AND POTENTIAL LLLC THREATS

The first research objective focused on barriers to increased market adoption of LLLC products and identified specific topics to explore in market actor IDIs. The full text of the RO is as follows:

Conduct market research to assess the prevalence, magnitude, and characteristics of the following LLLC barriers identified in prior research:

a. *The impact of Value Engineering (VE) on the inclusion of LLLC and other NLC in new construction and renovation projects.*

b. *Specifiers' and design professionals' perceptions of the risks (and opportunities) of selecting LLLC or other NLC for their projects.*

c. *The potential threat of competing products, such as NLC, particularly Power over Ethernet (PoE) and room based NLC.*

LLLC Cost, Project Budgets, VE, and Return on Investment (ROI)

LLLC increase real and perceived costs over other control options, which can lead decision makers to exclude LLLC at any point in projects, from design to installation.

> ***"It comes down to cost and what we can project accurately as savings attributed to the equipment we install. We have found lack of payback in the range of our service terms for pretty much all controls. I put a lot of 'on-off' in, a lot of wall switches."***
> ***- ESCO (Who also meters energy)***

Every market actor group interviewed named cost as a key barrier to wider LLLC adoption. Likewise, market actors across groups voiced concern about the risk of not realizing the expected energy and cost savings from LLLC. Total controlled lighting wattages have dropped with widespread LED adoption. ESCOs and contractors explained that for some retrofit decision makers, the financial benefits and energy savings from switching to LEDs (without controls) meets their needs. Decision makers at various points in both new construction and retrofit projects perceive greater risk in increasing their budget to include LLLC and other NLC without a high level of certainty that the cost and energy savings will yield an acceptable ROI.

Value Engineering of LLLC occurs, but market actors more often spoke about general cost concerns.

Market actors across groups expressed differing views on the impact of VE, including whether they viewed VE and cost cutting in discrete terms. In the simplest sense, VE might refer to the removal of project features for budgetary reasons, but the interviews uncovered nuances in how market actors define or think about VE. Conversations gravitated toward the more fundamental issue that interviewees perceive LLLC to be among the most expensive lighting control options to fulfill the basic core functions of lighting controls, namely, to adjust light levels or reduce power based on daylight and occupancy. Many interviewees considered LLLC to include more functionality than, for example, room-based controls due to LLLC's connectivity and capacity to be leveraged for IoT functions. In design and engineering terms, VE refers to a detailed analysis on how to achieve cost-efficiencies in project design and construction that do not sacrifice the *functionality* of systems within the project.[6] Depending on the intended functionality of the lighting system and the building, the conversation about VE versus cost cutting in a project involved some ambiguity. Interviewees confirmed that VE occurs, but the belief among respondents that there is a lack of concrete data regarding the energy and cost savings of LLLC casts doubt on the level of detailed VE analyses occurring in the field.

Market actors believe that LLLC require higher software programming costs than other NLC systems.

While the concerns cited above apply to both LLLC and other NLC, interviewees consistently voiced the perception that luminaires with embedded sensors required increased programming labor (and therefore cost). The increased cost stems from the fact that each luminaire with an

[6] Cullen, S.W. 2016. "Value Engineering." *Whole Building Design Guide.* https://www.wbdg.org/resources/value-engineering

LLLC sensor needs some sort of individual programming attention, which adds labor costs that can affect project budgets and timelines. The level of programming needed on-site varies by LLLC product depending on a number of factors such as the degree of factory pre-programming, the programming interface used by the manufacturer, and other manufacturer-specific factors.[7]

The points below provide additional insights into the concerns about project costs.

> ***"The biggest [challenge] is staying ahead of the cost curve…The cost adder for the control--let's say the fixture was X dollars plus 25% to get the control in there. As cost of lighting has dropped over the years, the cost of controls has not kept pace at the same rate, so controls cost has become a larger cost adder." - Manufacturer***

- One manufacturer framed the larger issue of LLLC cost concerns as a by-product of the successful growth of LEDs in the market. As LEDs become the predominant lighting technology on the market, LED luminaire prices have dropped; however, the cost of controls and sensors has not decreased at the same rate as luminaires. This caused the incremental cost of adding sensors to fixtures (referred to in interviews as the "cost-adder" of sensors or the "delta" between normal and LLLC-enabled luminaire price) to increase. Even with decreasing luminaire prices, the choice to add sensors is further complicated if they increase luminaire cost by a greater percentage.
- A wide range of market actor interviewees indicated that adding LLLC to projects increases the time horizon of the ROIs provided by the lighting system beyond what is acceptable to many customers. Several interviewees mentioned this was an issue for controls more generally. ESCOs cited five or ten years as common service terms over which they negotiate reimbursement of the retrofit price with the cost savings from energy reductions; they have found it to be impossible to maintain these preferred timelines when factoring LLLC into budgets.
- Various market actors suggested that LLLC savings potential depends heavily on the space type and usage patterns of lights being controlled. Because LLLC are considered more expensive than other NLC systems or non-connected controls, ambiguity regarding how much actual savings are possible from controls in a given space type creates a perception of higher risk for LLLC.
- Multiple market actors, including ESCOs, mentioned retrofits as challenging environments for LLLC and NLC more generally because project decision makers tend to be sensitive to budget increases. Retrofitting with LLLC involves complete replacement of fixtures, whereas lower budget retrofits may just swap out lamps and possibly ballasts, excluding use of LLLC luminaires. Limited code requirements on retrofits also make it more difficult to bring advanced lighting controls into the conversation.

[7] NEEA conducts an annual study of the incremental cost of LLLC compared to standard controls. At the time of this report, NEEA was conducting its fifth study for publication in late 2020.

On a similar note, interviews with ESCOs and other market actors suggest that retrofit customers often view vastly decreased lighting wattage (by moving from fluorescent to LED) as a sufficient source of savings. They may lack the motivation to pursue additional savings via controls. The savings from the switch to LED are simple to quantify relative to the savings from adding controls, so there is a perception of risk when considering an added investment in controls.

Non-Cost Barriers to LLLC Market Adoption

Room-based controls are the major competitor to LLLC, rather than other NLC or PoE.

Because other NLC have several of the same cost concerns as LLLC, many decision makers opt for room-based controls over any advanced controls. Market actors across groups considered room-based controls to be the most commonly chosen control system, and, therefore, the key competition for LLLC. Room-based controls are less expensive than networked controls; are easy for end-users to understand, operate, and maintain; and, in most scenarios, offer occupancy and daylighting options that provide the same code compliance as LLLC. Interviewees report that PoE currently has a small footprint in the lighting controls market. Market actors differed in their opinions on whether PoE competes with or complements LLLC. Two manufacturers argued that their PoE products should be considered a wired LLLC because each luminaire has a sensor.

> ***"Knowing we live in a ROI world, a lot of times it doesn't pay to do the overarching whole building [networked] solution. Over 60% of the time we're using room based. Currently it's a more popular choice because you're getting savings and functionality, just not bells and whistles and no software to make future revisions. And a lot of times they don't care."***
> **- ESCO**

LLLC can better facilitate internet of things (IoT) features, offering a key competitive advantage over other NLC and room-based controls. However, the use of LLLC capabilities for IoT is not yet fully realized.

The embedded sensors of LLLC provide greater granularity over other NLC that can enhance IoT potential for things like asset tracking, wayfinding, and integration with building management systems. Additionally, room-based controls lack the robust IoT data collection and systems integration functionalities that LLLC can offer. However, the market actors raised two issues about IoT and advanced networking capabilities as a path forward for increasing the competitiveness of LLLC. First, according to interviewees, these IoT capabilities currently have a narrow range of market appeal – mostly tech savvy companies and customers who fit an early adopter mold, and large buildings and campuses with dedicated IT staff who are well-positioned to leverage the IoT capabilities. End-users with a dedicated IT staff likely represent a market subset that could play a key role in NEEA's efforts to promote sustained adoption of LLLC;

> ***"Were going to start to see non-lighting IoT being increasingly tied to lighting deployments. We see that as a big opportunity given lighting's footprint in buildings. Our networking capabilities are pretty limited today, so as our networking capacity increases and improves, that will open that door more."***
> ***- Manufacturer***

such end users may already be addressed through current outreach to target markets. Interviewees mentioned universities and large office complexes as specific buildings types likely to use dedicated IT staff that could influence lighting controls decisions. The second issue with leveraging LLLC for IoT functions is that the networks over which the LLLC operate and communicate currently have limited bandwidth, and LLLC must compete with other products for the existing capacity. One manufacturer mentioned hospitals as a building type where end-users can be hesitant to add connected lighting to networks that are already heavily used by critical equipment. That same manufacturer also stated that their LLLC product uses networks with bandwidth limitations that restrict the amount of information that can be transmitted over the network. In fact, in some cases, a manufacturer may design their product to operate on networks with lower bandwidth to avoid conflicting with critical equipment that must operate on faster networks. For example, hospitals will want to make sure that the lighting does not conflict with medical equipment on high bandwidth networks.

LLLC face several challenges from an end-user perspective, including low LLLC awareness, valuing simplicity in lighting controls, and perceiving LLLC as overly complex.

Manufacturer representatives, distributors, and contractors all mentioned that end-users value simplicity and sometimes perceive LLLC and other NLC as overly complex tools for managing lighting. Market actors noted that some end-users remain skeptical about automated controls due to negative experiences with less sophisticated occupancy sensing technology (see the discussion of Sensor Density for more on this). One ESCO spoke of an “annoyance factor” with occupancy sensing that can cause resistance from end-users. End-user concerns included the expectation that the lights will turn off on the user at inappropriate times, the occupancy sensing will not work as desired, or the sensors will need tweaking to increase “on times” (the amount of time a light stays on after reading movement). A specifier also mentioned that end-user concerns about occupancy sensing create a barrier to LLLC. They noted that end-users may be installing occupancy sensors because code mandates it, but they still hold negative opinions about the impact of controls on the occupant experience, so they invest the bare minimum in controls needed to satisfy code. End users may also feel uncomfortable with automated controls because they doubt that the lights will perform as expected without a wall switch. Some interviewees framed this issue in the context of the natural progression they have seen for other emerging technologies: product acceptance increases as more end-users gain awareness and experience with the technology, ultimately increasing their comfort.

Some manufacturer representatives and distributors rejected the idea of requiring embedded sensors to define "luminaire level control" in code or other regulatory frameworks.

In conversations about NEEA's working definition of LLLC, some manufacturer representatives questioned the point of requiring each luminaire to have embedded sensors for purposes of code compliance, a topic addressed in more detail in the Codes section. Some manufacturer representatives also stressed that a fully functioning LLLC system needs to be properly zoned, and they said that other control designs could achieve similar outcomes of individual addressability of each fixture, responsiveness to a sensor, and cost savings. For example, an external sensor could provide daylight and occupancy sensing to a group of fixtures, by controlling each fixture via a wireless driver or a wired connection. This install creates equipment cost savings by lowering the number of sensors in use. While each luminaire would not be able to sense and react individually, a manufacturer representative argued that one would not *want* them to do so in many cases.

Market actors – particularly manufacturer representatives and distributors – also resisted the idea of prioritizing LLLC over other NLC systems when advancing the market for advanced lighting controls.

Multiple distributors questioned the prioritization of LLLC over non-LLLC networked control solutions in incentive and other approaches to increase adoption of advanced lighting controls. Two distributors with experience working on lighting project specification said they were confident they could achieve comparable energy savings with other NLC systems at lower cost than LLLC. One distributor mentioned that a strategy that focuses on LLLC market adoption over other, less expensive networked control solutions could inadvertently exclude projects for which decision makers are open to a networked solution but not willing to make the larger investment in LLLC.

A perceived lack of LLLC availability in diverse fixture types and shapes increases the difficulty of choosing LLLC for some projects.

Manufacturer representatives, distributors, and manufacturers cited what they perceived as the lack of LLLC availability in a wide array of fixture types as a barrier to wider LLLC adoption. The dimensions of certain fixture types are not conducive to integral sensing and control equipment. Projects that want to use a wide array of fixture shapes *and* LLLC may require multiple control arrangements, which may lead decision makers to decide against LLLC for the project.

Proprietary LLLC software, and the security of that software, present real and perceived issues when deploying and maintaining LLLC systems in the field.

Manufacturer representatives and ESCOs brought up the proprietary nature of LLLC software as a potential barrier to more widespread adoption. When manufacturers use closed protocols for their software, their LLLC system cannot operate in concert with a different LLLC system, which limits the ability to use LLLC from different manufacturers in the same project. One ESCO also suggested that products advertising functionality on "open" protocols can be misleading. In reality, the cross-product functionality among different LLLC and networking products may be limited. Market actors also raised network security as a concern, which is especially relevant for leveraging advanced LLLC features, such as asset tracking and connecting to building management systems. Although improving, one manufacturer believed cybersecurity in connected lighting remained a concern due to inadequate attention to the issue among manufacturers. A mix of market actors mentioned the impact security concerns could have on the choice to forgo networked controls products and use simpler systems that do not present a security risk.

"There's a lot of value potential in integrating to other parts of the building network to add value to other systems but you are expanding the attack surface of that building network... As an industry we haven't done cybersecurity well, but it's getting more attention and that's good. But the general opinion is that these systems are not secure, and that's holding us back on some of the high value services and functionality we want to offer." - Manufacturer

RO: 2

Assess Potential LLLC Market Opportunity

The second RO shifted the focus from exploring barriers to addressing the market opportunities of a lighting as a service (LaaS) model:

Conduct market research to assess the potential of LaaS (or energy management as a service) as an approach for selling more advanced lighting control systems, including LLLC.

LaaS, a variation of an Energy as a Service (EaaS) contract, is a model in which a third party finances a lighting project and maintains the new equipment over a service term, guaranteeing improved energy performance (utility bill savings). The customer pays nothing up front, and instead pays back the third-party in monthly installments based on the amount of energy savings achieved.[8] While RO2 initially focused on LaaS, market actors named other opportunities that they felt were more likely to increase sustained market adoption of LLLC products.

[8] More information on Energy as a Service is available here.

ESCOs are not convinced that a major market opportunity currently exists for LLLC in LaaS contracts.

ESCOs agreed that using LLLC in projects can boost energy savings, but the added cost creates a significant barrier in making the contract economics work within typical LaaS contract lengths (term lengths of five to ten years). The entity financing the project must ensure that energy savings can pay for the project costs over the service term. Ambiguity around the actual achieved energy savings from upgrading to an LLLC system presents too much risk for the comfort of financing parties. In contrast, better documentation certainly exists on the energy savings when retrofitting a T8 fluorescent to TLEDs.

> ***"Based on our energy metering in the past, [LLLC is] problematic for lighting as a service given the economics we've seen on price versus added savings."***
> ***- ESCO***

One ESCO interviewed by the NMR team has transitioned to exclusively using LaaS and EaaS-style contracts in their work and performs energy metering on all their projects. In a limited sample of LLLC projects (<5 projects), the ESCO claims that LLLC have not created energy savings to match their budgetary impact (within the boundaries of the service agreement). However, this issue is not specific to LLLC; feedback from ESCOs indicates that other NLC and more standard controls can also complicate project economics for Laas / EaaS agreements.

Another ESCO respondent mentioned that there is a risk that software support or functionality for LLLC systems may erode over the length of a typical service term or add expenses that further complicate the economics of LaaS agreements. Likewise, unforeseen costs can arise if the software loses functionality (e.g., the manufacturer ceases to provide updates or adopts a new software platform that requires a new license purchase). Despite these issues, ESCOs see value in LLLC beyond energy savings. Because EaaS and LaaS agreements often involve a contractor or vendor providing system maintenance, LLLC can benefit the contractor by allowing remote access to troubleshoot certain issues or ascertain the nature of a problem before a service call.

LLLC have several marketable benefits over other control systems due to the increased sensor density.

The increased sensor density (also referred to as granularity) provided by an LLLC system is key to its ability to achieve greater energy savings than other control solutions. Interviewees across groups noted that the increased sensor density brings additional benefits that should appeal to a variety of market actors. Manufacturers and specifiers suggested that LLLC can simplify system specification because one does not need to decide where to physically locate sensors. For example, the installer does not have to measure the distance from windows to establish a daylighting zone or map out the occupancy coverage for various alcoves and corners. Sensor density also offers the benefit of redundancy over other NLC systems, which rely on one external sensor to control a group of fixtures; if that single sensor malfunctions, the NLC system will not run properly. Manufacturers and specifiers mentioned that because LLLC systems create a sensor-dense space, multiple sensors can fail and neighboring fixtures will pick up the slack, keeping the system operating properly. This feature can reduce maintenance costs because the LLLC sensor does not need to be replaced immediately for the system to function properly. One manufacturer also suggested that increased sensor granularity and overlap can enhance the occupant experience by improving the performance of occupancy sensing (e,g., reducing instances of the lights turning off), whereas one ceiling-based sensor may not always pick up movement at the outer edge of its range.

"One of the advantages is you can get a granular sensing approach. A more granular sensing approach means you have the possibility to do deeper, aggressive energy savings. From a user experience standpoint, typically with NLC or ceiling-based sensors, you may see a lot of false [not occupied] triggers in space. And people try to compensate that with higher timeouts, which means you're consuming more energy… but with LLLC, you get overlap. So the number of false triggers is drastically reduced, meaning the complaints the property manager gets from occupants are reduced and the facility manager does not need to disable sensors or behaviors."

- Manufacturer

LLLC have the ability to help *futureproof* buildings, which may be a key factor in their market potential.

When discussing the advantages offered by LLLC, many market actors mentioned the capacity for LLLC to provide both space flexibility and IoT potential on projects as a key market opportunity. This futureproofing concept followed two general lines of reasoning. The first way in which LLLC provide futureproofing is that LLLC can be reprogrammed to adapt to changing building layouts or tenant needs over time, offering flexibility to both building owners and tenants. For example, a new tenant may require physical floor plan changes that necessitate changes in control zones, which LLLC can adapt to far more easily with wireless control, embedded sensors, and software-based zoning. Because the customer or building owner initiating the project may not occupy the building, they need to be prepared to communicate these benefits effectively to potential tenants. Doing so can give these owners of buildings with LLLC systems a competitive advantage in the rental markets.

"I would say a key advantage is being able to futureproof your building by having the option of tying in to BMS systems or really doing a lot more with the fixtures as time goes on, even if you're not taking advantage of all of that initially."

- Distributor

The second way in which LLLC offer futureproofing is through their support for advanced IoT capabilities and integration into building management systems (BMS). LLLC fixtures contain the hardware needed to integrate into networked (WiFi-connected) *smart building* systems at any point after the initial installation. LLLC systems are being deployed in retail environments and airports (two examples from the market actor interviews) as part of advanced IoT systems for asset tracking and integrating data into sales strategies. Interviewees admitted that these advanced capabilities of LLLC have somewhat narrow appeal currently because IoT and networked smart buildings have not yet gained widespread market penetration. However, as the technology matures and the market for IoT functionality gains traction, the ability of LLLC to integrate with a broader suite of smart building systems may become a stronger selling point. Some market actors noted that LLLC could enhance building automation, and some ESCOs reported experience with tying LLLC into a BMS. For example, one manufacturer reported that some of their LLLC fixtures were being equipped with sensors for tracking temperature and humidity. These readings could then be transmitted to a building's HVAC system to help improve its operation.

RO: 3

Conduct LLLC Market Update

The third research objective was to develop a market update on the representation of LLLC within regional luminaire sales, what markets and building types LLLC are being sold to, who the key manufacturers of LLLC are viewed to be, and other important market details.

The text of the RO is below:

Conduct market research to:

- ***a.*** *Among luminaire manufacturers, identify and rank the top several companies in terms of their relative portion of LLLC luminaire sales.*
- ***b.*** *For each top manufacturer, describe the market channels through which they sell LLLC luminaires. A key purpose of (b) and (c) is to inform where the Program Implementation Contractor might focus sales data collection efforts.*
- ***c.*** *Identify which markets LLLC suppliers are targeting, where LLLC are most commonly being installed, and why.*
- ***d.*** *Estimate the portion of regional LLLC luminaires sold in each of six target markets (office, warehouse, K-12 schools, universities, hospitals, and retail).*
- ***e.*** *Estimate the portion of regional LLLC luminaire sales going to new construction / renovation versus retrofit:*
  - *i. … across all sales channels combined*
  - *ii. … within just the distributor sales channel This information will help NEEA Planning, because the program team is currently only collecting LLLC sales data from distributors. (As NEEA collects sales data from additional channels, NEEA Planning will eventually shift to using an average across all sales channels combined.)*

This RO proved to be the most difficult to address with the methodologies used for this assessment. Interviewees across groups demonstrated a lack of confidence in their ability to estimate metrics such as the proportion of all regional luminaire sales comprised of LLLC, the proportion of LLLC sold through various sales channels (e.g., distribution, direct to end-user, to builders and developers), and proportion of LLLC going to market segments of interest for NEEA. While market actors were unable to provide these market share estimates for NEEA, they still provided the following useful market insights.

In the supply chain, LLLC products follow similar trajectories as other lighting and controls products, moving through distributors on their way to end-users. However, it is mostly manufacturers and manufacturer representatives who execute the actual sales of products to various downstream market actors.

Manufacturers and manufacturer representatives reported selling products to electrical contractors, ESCOs, lighting design firms, and direct to end-users. The direct-to-end-user sales mentioned in interviews typically involved larger customers at the enterprise level – Fortune 100 companies and large chains. Other types of end-users mentioned included school districts and property developers. Both manufacturers and manufacturer representatives reported working with contractors, ESCOs and lighting designers to familiarize them with their LLLC products. The familiarity will in turn increase the likelihood that contractors, ESCOs, and lighting designers will recommend LLLC on their projects. Manufacturer reps also mentioned that architects are customers, and designers and specifiers most frequently cited architects as the group that they work most closely with on projects to make decisions on lighting systems.

Interview responses suggest that both the new construction and retrofit markets merit attention when exploring LLLC market opportunities, and that LLLC are most frequently installed in five of the six target markets identified for NEEA's LLLC Program.

The market actors generally found it easier to promote LLLC in new construction because builders and owners prefer to install cutting edge and attractive technologies, and LLLC can be worked into architectural and lighting designs. The sell for the retrofit market is sometimes more difficult because customers may be more budget constrained. Decision makers may be reluctant to take on the incremental cost of LLLC without stronger and more consistent documentation of achieved savings that fall within ROI horizons. LLLC do offer one clear advantage in retrofit situations over some other lighting control strategies: the sensors are integrated into the fixture so the install does not require new wiring, which can save time and money.

NEEA currently targets the following markets: office, warehouse, K-12 schools, universities, hospitals, and retail. Market actors concurred that LLLC are being installed in most of these markets and that these markets make good LLLC targets. The market actors offered mixed opinions about the potential for LLLC in the retail market, with some distributors and ESCOs pointing out that the granular sensing capabilities of LLLC will be used less often in retail because retailers are most concerned with showcasing their products. They prefer spaces to remain illuminated even when unoccupied. However, distributors also pointed out that some retail spaces would be a good fit for the asset tracking and wayfinding capabilities (see IoT discussion). For example, stores can track movement to understand foot traffic and locate certain products based on this data. As mentioned previously, these more advanced capabilities have not been widely adopted; but as awareness of these IoT benefits grows in the market, retail spaces could become more frequent LLLC destinations.

Market actors suggested that Acuity, Cree, and Signify have the largest presence in terms of sales among manufacturers in the LLLC market.

The market actors we interviewed frequently named Acuity, Cree, and Signify as the manufacturers with the largest presence in the LLLC market nationally, but interviewees could not rank them in terms of sales volume or estimate the percent of market share each held. Some interviewees also mentioned Cooper, Enlighted (controls only), Lutron (controls only), Hubbell, and RAB, but not as frequently. One interviewee mentioned that assessing the relative volume of LLLC available on the market for some companies was difficult because of differences in their product offerings. For example, some LLLC manufactures make luminaires while others make only controls or sensors.

RO: 4

Research Code Requirements for Lighting Controls

The fourth research objective researched and documented building energy code requirements for lighting controls in new construction and major renovation projects codes in Idaho, Montana, Oregon, Washington, and the City of Seattle. This information provided NEEA Planning with estimates of the percentage of floor space subject to different code requirements. It also included forward-looking criteria that Planning can use to track changes in code requirements, as well as changes in the amount of commercial floor space subject to those requirements.

Figure 1 lists the building energy codes reviewed by the NMR team and characteristics of those codes. Note that Oregon, Washington, and Seattle codes include occupancy sensor requirements exceeding those in 2018 International Energy Conservation Code (IECC), as well as secondary side-lit zones. These are absent from the Idaho and Montana codes.

Figure 1: Building Energy Codes Reviewed

	Idaho	Montana	Oregon	Washington	Seattle
Based on	IECC 2018	IECC 2018	ASHRAE 90.1 2016	IECC 2018 (amended)	WA 2018 (amended)
Effective Date	1/1/2021	Adoption date uncertain*	10/1/2019	2/1/2021	Adoption date uncertain*
Expected Effective Term	At least 3 years	At least 3 years	At least 3 years	3 years	3 years
Occ Sensor Requirements Beyond IECC 2018			●	●	●
Secondary Sidelit Zone			●	●	●
Reference	ID Building Energy Code	MT Building Energy Code	OR Zero Energy Ready Code	WA State Energy Code	Seattle Energy Code

Notes: *As of the preparation of this report, Montana was working towards adopting IECC 2018, but the adoption date remains uncertain and is not expected before January 2022. This research assumes that, as in Idaho, the Montana version of IECC 2018 will not have amendments impacting lighting controls. The adoption date also remains uncertain for the City of Seattle's code.

The NMR team recently finalized a memo dedicated to RO4 and codes research, which can be found here. This report highlights and summarizes the most important findings from that memo.

LLLC can meet all lighting control requirements across all state codes, but so can other control types, such as individual occupancy/daylight sensors, room-based controls, and other NLC.

Codes in Idaho, Washington, and Seattle include a compliance path that allows buildings to meet all lighting control requirements using LLLC because the luminaires include occupancy sensors, photosensors, and wireless configurability. Montana will likely follow suit when it adopts the IECC 2018, with the date now expected no earlier than January 2022. While the Oregon code does not specify an LLLC compliance path, the advanced technological features of LLLC can meet all of Oregon's lighting control requirements. Still, all lighting control requirements explored in this analysis can also be met using simpler technologies, generally viewed as less expensive to purchase or install. Other NLC can also meet code requirements.

The NMR team identified five different categories of lighting control requirements (Table 5) and classified each by the relative magnitude of potential savings if LLLC were installed to fulfill the requirement. The additional controls functionality of LLLC fixtures could generate varying levels of additional lighting savings compared to each of the five code-minimum control scenarios. Therefore, these scenarios can serve as baselines for NEEA Planning to calculate LLLC energy savings, taking into account the estimated percentage of new construction and major renovation floor area in each lighting control requirement category by state (Table 6).

Table 5: Lighting Control Requirement Categories

Code Requirement	Description	Relative Magnitude of Potential LLLC Savings
Daylight + Occupancy	Daylight zones in space types that are required to have occupancy sensors	Small potential savings from high-end trim capabilities and networked or zoned controls
Occupancy Only	Space types required to have occupancy sensors, excluding area in daylight zones	Medium potential savings from daylight control, high-end trim, and networked control
Daylight Only	Daylight zones in space types not required to have occupancy sensors	Medium potential savings from occupancy control, high-end trim, and networked control
Exempt	Spaces that code specifically exempts from any control requirements	Large potential savings from all LLLC capabilities; however, LLLC would be not applicable in areas designated as security or emergency areas that are required to be continuously lighted
Time Clock Only	Areas that are not specifically required to have occupancy sensors or daylighting controls but must at least have a time clock control	Large – from all LLLC capabilities

Table 6: Annual Percentage of New Construction and Major Renovation* Square Footage by Lighting Control Requirement Category

Code Requirement	ID	MT	OR	WA	Northwest
Daylight + Occupancy	35.0%	39.0%	49.9%	47.2%	45.7%
Occupancy Only	6.8%	25.6%	12.8%	14.6%	14.6%
Daylight Only	26.6%	25.9%	21.7%	27.6%	25.8%
Exempt	4.7%	6.2%	13.3%	5.3%	8.1%
Time Clock Only	27.0%	3.3%	1.8%	5.3%	5.9%
Total	100%	100%	100%	100%	100%

Notes: **The analysis is primarily based on 2014 CBSA data from buildings with a majority constructed in 2000 or later. The CBSA dataset covers nearly all target areas/ building types with space- and lighting-level data. Where there are gaps in CBSA (e.g., hospital/university space), the analysis incorporates NREL reference building information for the relevant climate zones. See Table 3 in the RO4 and codes research memo for details. The 2019 CBSA was not available in time for inclusion in this analysis.*

Confusion exists about the interpretation of what constitutes an LLLC for adhering to the Washington and Seattle LLLC code compliance pathway.

One manufacturer representative reported engaging with code officials about the optional LLLC compliance path in Washington, which includes specific language about using an LLLC system with sensing capabilities in each fixture and networking capabilities. The manufacturer representative argued that the code language should not be interpreted to require an LLLC product but rather to require an approach built on the *intent* of the system to allow for control capability with individual fixture *addressability*[9] without embedded sensors in each luminaire. This type of arrangement is possible via an external sensor and a wired or wireless control point in each luminaire, which the interviewee suggested could be enabled by a Digital Addressable Lighting Interface (DALI), a DMX interface, or even PoE.[10,11] In this way, an external sensor could provide data to each individual fixture. The manufacturer representative further argued – reflecting an opinion shared by other respondents – that an LLLC system should have some type of zonal programming to operate correctly and the ability of one individual fixture to sense in isolation is not as important as making sure the group of fixtures operates cohesively.[12] Despite not meeting the definitional requirements of LLLC, the manufacturer representative reported that code officials approved this *intent* approach, allowing installation of non-LLLC networked systems that used external sensors and fixture-level control to satisfy the LLLC compliance pathway. It is not clear how widespread this interpretation is in code enforcement circles, though a second manufacturer representative voiced agreement with this more flexible approach and reported having similar conversations about code compliance and LLLC. The potential for code officials to accept broadened parameters to satisfy code requirements such as the WA LLLC Compliance Pathway has implications for the ability of code to move the controls market toward wider LLL adoption.

[9] Addressability refers “the ability of a digital device to individually respond to a message sent to many similar devices.” https://en.wikipedia.org/wiki/Addressability.
[10] Wikipedia offers a fairly straightforward description of DALI (https://en.wikipedia.org/wiki/Addressability) and DMX (https://en.wikipedia.org/wiki/DMX51).
[11] PoE exists in a gray area based on several interviews, depending on the type of fixture used in the PoE system. PoE could be the backbone of a wired LLLC system if the fixtures have onboard sensors (as some manufacturers indicated was the case in their products) or could be the foundation for a non-LLLC NLC system if the fixtures do not have onboard sensors.
[12] The DLC specification for LLLC products requires zoning capability for occupancy sensing and high-end trim control strategies. Zoning capability is not required for daylight dimming control strategies.

Conclusions and Recommendations

Based on the findings reported above, the NMR team provided the following conclusions and recommendations for the NEEA LLLC Program moving forward. Each conclusion includes an indicator of the RO or ROs to which it most directly relates.

RO: 1

Conclusion 1: Market actors remain skeptical about the ability of LLLC to achieve adequate energy and bill savings to justify their installation over simpler room-based controls paired with LED technology in both retrofit and new construction. Interviewees cited both the incremental costs of the LLLC sensors and the programming costs. This skepticism limits the number of projects that include LLLC and can also result in their removal from a project even if included in the original design. On the positive side, embedding sensors can lower installation costs and the sensor granularity of LLLC can reduce maintenance costs because, if one sensor fails, other nearby fixtures can pick up the slack, limiting the need for immediate repair or replacement of the failed sensor.

Recommendation 1: NEEA should continue to look for opportunities to collect empirical data from the field on the achieved energy savings and costs of LLLC installations relative to other controls options. This savings and cost assessment should consider the price of equipment, installation, programming, commissioning, and maintenance of LLLC compared to other NLC and room-based controls. To the extent possible, the assessments should aim to provide site specific findings for diverse building and space types, especially those identified by NEEA as priority markets. The outcomes of studies should provide concrete data on the costs and the energy and financial savings attributable to LLLC. The interviewees suggested that this information is key to encouraging more project decision-makers to seriously consider LLLC over other control options during design and installation.

RO: 1 RO: 2

Conclusion 2: Increased LLLC adoption faces numerous perceived and real non-cost barriers, including lack of awareness; concerns about occupancy sensors, system complexity, and data security; limited availability of fixture types and shapes; and the potential incompatibility of proprietary software with other lighting products and BMS. Yet, LLLC include such advantages as providing flexibility and sensor density, which allows for *futureproofing*. Futureproofing includes greater adaptability to changing space and end-user needs and improved facilitation of IoT capabilities, such as wayfinding and asset tracking. Sensor density – an LLLC feature not present in other NLC solutions – reduces occupancy sensing errors. Sensor density also allows a system to function properly even if an individual sensor fails, improving performance and reducing maintenance cost compared to control solutions that require replacement upon sensor failure.

> **Recommendation 2:** The program should prepare persuasive arguments that go beyond energy savings for LLLC systems over other networked systems using external sensors. For example, the program could emphasize the flexibility and improved performance of LLLC over many other systems and the ability to easily adapt to future space and occupant needs. Using these arguments, NEEA should continue efforts to build awareness of LLLC benefits relative to other types of controls, but should adopt tailored messaging that resonates with various market actors, customer types, and end-users. To document these benefits, NEEA should develop a robust accounting of available benefits and effective, tailored communication about those benefits.

RO: 3

Conclusion 3: Although opinions varied on the potential for LLLC adoption in new construction versus retrofit projects, market actors across groups reported that both new construction projects and retrofits were using LLLC systems. Some interviewees saw LLLC as an advantage in new construction because decision makers prefer the latest technology, and LLLC can more easily be integrated into architectural and lighting designs. Interviewees recognized one clear advantage for LLLC in retrofit situations: because the sensors are integrated into the fixture, the install does not require new wiring, thus saving time and money.

The research confirmed that LLLC are being installed in the office, warehouse, K-12 school, university, and hospital markets. However, the interviewees had mixed opinions on the potential of LLLC in the retail market. Distributors and ESCOs noted that there is a need for retailers to use lighting to showcase products, but also mentioned that LLLC can be advantageous for retailers if they choose to leverage the asset tracking and wayfinding IoT capabilities of some LLLC systems.

> **Recommendation 3:** NEEA should continue to promote LLLC in both the new construction and retrofit markets, but tailor the messaging to the unique circumstances and needs of the two different types of installations. NEEA should continue to target office, warehouses, K-12 schools, universities, and hospitals in its LLLC Program. NEEA should conduct additional research into which sectors of the retail market fit best with LLLC systems and target only those retail sectors in the future.

RO: 1 RO: 4

Conclusion 4: Some manufacturer representatives and distributors rejected the idea of requiring embedded sensors to define "luminaire level control" in code or other regulatory frameworks. Market actors – particularly manufacturer representatives and distributors – resisted the idea of prioritizing LLLC over other NLC systems when advancing the market for advanced lighting controls.

LLLC can meet all lighting control requirements across all state codes but so can other control types, such as room-based controls and other NLC. Codes in Idaho, Washington, and Seattle have a specific LLLC compliance path, and Montana likely will as well when it adopts the IECC 2018.[13] Manufacturer representatives and distributors were critical of code language or incentive structures that favored LLLC-specific approaches, preferring the flexibility in price and system design provided by some NLC systems without embedded sensors. In addition, distributors with design experience reported a belief that they can achieve comparable performance and energy savings using non-LLLC NLC; one said that prioritizing LLLC over other NLC in codes or incentives is a mistake because NLC is effective and accepted in the market. Two manufacturer representatives reported conversations with code officials about the definition of LLLC in the Washington LLLC compliance pathway and have argued that the language should not require luminaires with embedded sensors. One manufacturer representative reported success in receiving approval under the LLLC compliance path using non-LLLC NLCs.

> **Recommendation 4:** NEEA, through their Codes Team, should continue working with market actors to increase awareness of LLLC as an optional code compliance pathway in concert with awareness-building on the added benefits provided by LLLC. Likewise, NEEA should have discussions with market actors and code official to assess how various actors are interpreting and executing the code in the field. NEEA may also consider discussing the benefits of more literal interpretations of the LLLC compliance path with code officials.

RO: 2

Conclusion 5: Citing uncertainty about the ability of LLLC to yield the energy cost savings needed to meet project financing goals, ESCOs are not convinced that a major market opportunity currently exists for LLLC in LaaS contracts. The ESCOs interviewed did mention that, while LLLC could have some benefits for LaaS, especially related to sensor granularity and IoT, these benefits do not outweigh the current issues related to increased project costs and payback within typical contract lengths.

> **Recommendation 5:** At this time, NEEA should refrain from dedicating resources to pursuing LaaS as a vehicle for promoting sustained LLLC adoption in the market.

[13] As of September 2020, the timing of this adoption remained uncertain.

Appendix A Sample Interview Guide

IDI Guide for Contractors/ESCOs

Interviewer Preparation

Interviewer: ____

Date of Interview: ____

Time Begun ____________________ Time Ended ___________________

Respondent Name: ____

Respondent Organization: ____________________________________

Respondent Title: ____

Phone Number(s): ____

E-mail Address: ____

We are conducting this interview on behalf of the non-profit Northwest Energy Efficiency Alliance (NEEA) to assess the market for lighting controls for commercial buildings in the Northwest. Your expertise on lighting technologies and markets will help NEEA better understand the market for lighting controls and aid in program planning. We anticipate the interview will take no more than forty-five minutes. As a thank you for your assistance, we will provide you with a $100 gift card after the interview. As a reminder, your responses will be kept anonymous – neither your name nor your company name will be associated with any of the responses you provide today.

Introduction

1-01: What is your role at [company] and how long have you been there?

1-01a: [PROBE if not covered in response to 1-01]: What is your role specifically in the lighting products or services market in the Northwest? What does a typical day in your role look like?

1-02: Are you ever involved in specifying lighting or lighting controls in your projects? [PROBE for details]

1-03: What geographic areas does your company serve? [PROBE: Is your business concentrated in one area?]

1-04: Does your company focus on any specific parts of the commercial building market? [e.g., Healthcare, Education, Office, Industrial, etc.]

1-05: Are you familiar with the term networked lighting controls? What about luminaire level lighting controls? [JUST LOOKING FOR SHORT ANSWER HERE]

[EVEN IF FAMILIAR WITH BOTH: For the purposes of this interview, I'd like to read two short definitions we will be using for networked lighting controls and luminaire level lighting controls: With networked lighting controls, sensors are installed as a separate step in the lighting system installation process, usually just to control groups of fixtures, rather than individual fixtures. Luminaire level lighting controls – also referred to as LLLC – are a type of networked lighting control where every fixture already has a built-in sensor and can be individually controlled. Both can be controlled and monitored via a computer or app interface. [PROBE to see if respondent has same or different sense.]

1-05a: Are these definitions different from others you've heard? [PROBE ON DIFFERENCES]

1-06: What level of experience would you say you've had with LLLC? [PROBE: Are you (1) very experienced, (2) somewhat experienced, (3) not directly experienced, or (4) not at all experiences with LLLC?]

1-07: What level of experience do you have with networked lighting controls that aren't LLLC? PROBE: Are you (1) very experienced, (2) somewhat experienced, (3) not directly experienced, or (4) not at all experiences with non-LLLC networked lighting controls?]

LLLC and Other Lighting Control Technologies

I'd like to ask about various lighting control technologies and get your thoughts as a Lighting Contractor in regard to LLLC:

2-01: Do you see more potential for LLLC in some building types over others?

2-01a: [PROBE] Which building types are more or less suited for LLLC, and why?

2-02: What differences do you see in the potential for LLLC adoption in retrofits versus new construction? [IF ONE BETTER THAN THE OTHER: Why?]

2-03: [IF RESPONDENT FAMILIAR WITH BOTH LLLC AND NLC] What do you think might help increase customer demand for LLLC?

2-03a: [IF RESPONDENT FAMILIAR WITH ONLY NLC] What do you think might help increase customer demand for networked lighting controls equipment and technology?

2-04: [IF FAMILIAR WITH LLLC:] From your perspective, what are the major brands/manufacturers of LLLC products?

2-05: Are you familiar with "pre-packaged room-based" lighting controls?

[IF YES]: I'd like to read a description. These are ready-to-go kits with everything needed to set up a room including controllers, sensors, wall stations, cables, and so on. The fixtures in these systems cannot operate individually or communicate with anything other than the room controller.

[PROBE to see if respondent has same or different sense.]

2-05a: [IF YES]: Have you installed any pre-packaged room-based systems?
[IF NO]: Why not?

2-05b: [IF YES]: Are there particular scenarios for which pre-packaged room-based controls are best suited?

2-05c: Do you see room-based systems as complimentary or competitive with LLLC? How do you think decision makers at customer firms will decide whether to choose room-based controls or LLLC?

2-06: [IF INVOLVED IN SPECIFYING LIGHTING/CONTROLS] How do you select which type of control equipment to use in a given space type? [PROBE for specifics on traditional, room based, LLLC, NLC, POE, other]

2-07: How do you see lighting controls technology evolving in the next few years?

2-08: [ESCOs ONLY]: Are you familiar with the concepts of Lighting as a Service/Energy Management as a Service, where customers pay an ongoing subscription fee for management of lighting and other energy end-uses?

[IF YES:]

2-08a. Does your company offer these services?

IF YES, CONTINUE, IF NO, SKIP TO 2-08d:

2-08b. How long have you offered them?

2-08c. What do you do for customers as part of the lighting services? [PROBE: Lighting controls installation, programming, follow-up service and troubleshooting, maintenance, energy monitoring (probe if any service contracts include LLLC).]

2-08d. What do you think about the fit of LLLC with lighting as service contracts?

2-08e.For your company, is lighting as service growing, staying about the same, shrinking? [PROBE on why]

2-08f. What types of companies besides ESCOs are offering lighting as service? [PROBE IF KNOWS OF OTHERS: Are these companies relative newcomers to offering this service?]

2-08g. What are your predictions for the broader market for Lighting as a Service? [PROBE: What are the drivers of these market changes?]

Perceived Advantages and Disadvantages of LLLC

3-01: Describe any projects you've worked on that used LLLC? [PROBE: Building type, size, new/renovation/retrofit, why customers purchased LLLC, what went well, what didn't go well]

3-02: What if any advantages might LLLC offer over other lighting control systems? What about disadvantages compared to other types of systems? [PROBE: room-based controls, POE, other NLC]

3-02a [ESCOs ONLY]: Do LLLC products offer any advantages or disadvantages compared to other types of controls from the perspective of Lighting as a Service operations?

3-03: How do other lighting control systems compare to LLLC in terms of the installation process and programming?

3-04: What about anything you've heard regarding ease of use by occupants? [PROBE: Where did you hear this?]

3-05: How about quality of lighting? [PROBE: Where did you hear this?]

3-06: What have you heard regarding how LLLC compare to other lighting control systems with respect to maintenance requirements? How about with regard to IT system issues? [PROBE: *If they report issues:* How did they resolve those issues?]

3-07: [If not already addressed] Are there situations that require lighting controls where you would not recommend an LLLC? Please describe.

3-8: Assuming LLLC will work technically in a new construction or major renovation project, who ultimately makes the decision whether or not to include LLLC? [PROBE IF NEEDED: Owner? Developer?] What other people influence this person's decision and in what way?

And who ultimately makes the decision to include LLLC in a retrofit project in an existing building? [PROBE IF NEEDED: Owner? Facilities manager? Tenant?] What other people influence this person's decision and in what way?

3-9: What percentage of commercial projects integrate the lighting control with other building system controls (i.e., building management control systems designed for the whole building, but including lighting controls)?

Market Actor Awareness and Demand for LLLC

4-01: How aware are your customers of LLLC products?

4-01a: For customers who are aware of LLLC, what misconceptions or confusion do you encounter?

4-01b: How clear do you think customers are about the differences between Networked Lighting Controls and LLLC? [Why do you say that?]

4-01c: Do you typically mention LLLC to the customer, or do they raise the subject?

4-01d: Do you find it hard to explain LLLC to customers? [PROBE: Why?

4-02: How many of your projects have used LLLC? What percentage of your total projects does this represent?

4-02a: How many used non-networked controls, NLC, or room-based controls (as examples)? [Percentages are fine if they don’t have numbers]

____ Non-networked controls (such as discrete occupancy and daylight sensors)

____ Networked Lighting Controls (not luminaire level)

____ Pre-packed room-based lighting controls (using earlier definition)

____ Other (specify)

4-03: In the last 5 years, how many new construction projects have you worked on that included LLLC products? Retrofit projects?

4-04: When value engineering becomes necessary on projects, which design components have you seen impacted?

4-04a: How often are LLLC dropped from a project due to value engineering? [IF NOT AWARE OF LLLC SPECIFICALLY:]

4-05: How can value engineering of lighting design features be reduced?

LLLC and Code Requirements

5-01: LLLC is now an optional code compliance pathway in Washington. Do you think that’s an effective method for building LLLC market share? [PROBE: what about the idea of LLLC being required by code?]

5-02: Please rank how often the following control strategies are chosen in commercial new construction lighting projects to comply with building energy codes, from most to least common:

_____ Non-networked controls (such as discrete occupancy and daylight sensors)

_____ Luminaire Level Lighting Controls (LLLC)

_____ Networked Lighting Controls (not luminaire level)

_____ Room-based (as defined earlier)

_____ Other (specify)

5-03: What, if any, aspects of the energy code requirements for lighting controls do you find difficult to interpret or follow?

Programmatic Possibilities for Increasing LLLC Adoption

6-01: NEEA has a program that is working in a lot of different ways to support and encourage the selection, purchase, and installation of LLLC systems. What types of activities do you think would be most effective for NEEA? [PROBE: possible suggestions if not mentioned: training, awareness building, case studies]

> 6-01a [IF TRAINING MENTIONED]: Who should be targeted with trainings [suggestions: contractors, designers, reps]? What type of training would be most helpful [in-person, webinar, reference documents]?

> 6-01b [IF AWARENESS BUILDING AND/OR CASE STUDIES ARE MENTIONED] Who are the most effective targets for these efforts—who would yield the largest impact on LLLC sales?

Conclusion

7-01: Is there anything else you would like to say about LLLC that we have not covered?

[Thank them for their time, and collect contact information to send incentive]