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Luminaire Level Lighting Control (LLLC) Market Characterization

Developed For

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Section 1 Executive Summary

In July 2022, Minnesota Department of Commerce approved a market transformation portfolio as proposed by Center for Energy and the Environment (CEE) and known as the Efficient Technology Accelerator (ETA). This proposal included an initial portfolio of projects, including one focused on Luminaire Level Lighting Control (LLLC).

LLLCs are connected systems of light fixtures with embedded controls and a dedicated sensor per luminaire that provide granular control over lighting levels and functions in a space. Unlike conventional lighting control systems that control a group of fixtures wired to a common controller, LLLCs have control devices embedded within individual fixtures. Sensors typically include motion and daylight, which allow for increased energy savings at the fixture level. The LLLC system typically communicates wirelessly though wired LLLC configurations are possible. Individual fixture control allows for flexibility in design and reconfiguration of spaces. Sensing can also offer increased comfort and productivity, longer lifespan of lighting systems, and smart building applications like occupancy tracking and indoor navigation. LLLCs may also be used to meet requirements included in energy codes.

In February 2023, CEE contracted with Cadeo to conduct a baseline market characterization designed to build on existing market intelligence through four research activities:

- In-depth interviews with supply chain actors operating in Minnesota, including manufacturers, manufacturers' representatives, and distributors.
- Web-based survey of contractors who install lighting controls in Minnesota.
- Virtual focus group and in-depth interviews with Minnesota-based lighting and lighting controls specifiers.
- In-depth interviews with key building contacts in Minnesota, including building maintenance managers, third-party property managers, facility managers, and other key decision makers.

These research activities provided insight into the status of Minnesota's lighting control market, including understanding barriers, opportunities, and leverage points for market intervention to drive broad adoption of LLLC. This information will inform CEE staff as they intervene in the market to create lasting market transformational change.

In this report, the Cadeo research team presents a market characterization overview, followed by detailed findings for each research activity.

1.1 Overview of Technology and Current Market State

LLLCs are a networked lighting control approach where each luminaire (light fixture) in a lighting system is equipped with on-board controls, including embedded sensors and load controllers. Unlike traditional lighting control systems, LLLC places control capabilities directly within each luminaire, allowing operators to maximize the benefits of multiple lighting control strategies.

LLLC systems can save energy by optimizing light output through high-end trim (the ability to reduce maximum light output) and granular occupancy and daylight sensing. In addition to their energy-saving benefits, LLLC systems can also improve lighting quality and user experience. With the ability to fine-tune lighting settings, occupants can experience better visual comfort through reduced glare and optimal illumination for specific tasks or preferences. Additionally, LLLC systems simplify maintenance and

troubleshooting, allowing for remote monitoring, diagnostics, and targeted maintenance actions. LLLC systems also offer long-term flexibility and scalability, making them a good choice for sustained energy-efficient lighting because they can be easily modified as space needs and occupants change.

LLLC systems have existed for nearly a decade, but the technology has improved significantly in recent years. Most major lighting and controls manufacturers now offer an LLLC system, either through their own proprietary offerings or with other original equipment manufacturer (OEM) partners. The DesignLights Consortium (DLC)[1] maintains a Qualified Products List (QPL) of Networked Lighting Controls (NLC) systems, which includes systems with LLLC. As of July 2023, the QPL included 48 systems with LLLC capabilities, offered by 36 manufacturers. Market-leading LLLC manufacturers nationally, as confirmed through this research effort for Minnesota, include Acuity, Lutron, and Cooper.

In summary, this research identified the following key LLLC market conditions:

LLLC systems are widely applicable. Supply chain and specifier interviews identified offices (including corporate campuses and open office spaces in particular), schools, and higher-education campuses as the ideal applications for LLLCs. Specifiers and contractors also mentioned warehouses and industrial settings as good applications, but supply chain interviewees noted that some of these facilities may have concerns about safety.

Advanced controls remain rare. The research team assessed the frequency of installation of LLLCs as compared to other control strategies through the contractor survey. The survey results indicate that standalone (non-networked, not fixture-embedded) occupancy sensors and photocells are the most commonly installed control equipment in Minnesota today. Among the projects reported by contractor respondents, 77% had no lighting controls and an additional 17% had standalone controls (including occupancy sensors, photocells, and timeclocks). The remaining share of projects had a mix of LLLCs (1%), NLCs (0.5%), and non-networked light fixtures with embedded sensors (4%). These results indicate that LLLCs are rarely installed in Minnesota, while standalone controls are typical for projects that include controls.[2]

Competing solutions are available. Given their similarity in features, LLLCs likely compete most often with other types of NLCs and with non-networked light fixtures with embedded sensors. Supply chain and specifier interviewees described achieving advanced control capabilities by installing NLC systems with individually addressable fixtures but without embedded sensors.[3] Non-networked fixtures with embedded sensors may provide an alternative to LLLCs. Interviewees described LLLC systems' scalability—i.e., the ability to upgrade system software to enable more features—as one of the technology's advantages.

1.2 Market Actor Roles and Supply Chain Dynamics

This project examined the roles of each market actor[4] and the relationships between them to identify potential areas for intervention or leverage points for increasing the likelihood that LLLCs are adopted in a project. Paths to purchase and project processes vary greatly, and market actor roles vary accordingly.

[1] DesignLights Consortium (DLC) is a non-profit organization that promotes energy-efficient lighting products and technologies and operates as a collaboration between utilities, energy efficiency organizations, and regional energy efficiency programs.
[2] See Section 3.2.3 Market Share of LLLCs for detail on how the team analyzed market share.
[3] Addressable fixtures have communication components that allow each fixture to be controlled individually. This is an NLC configuration that is distinct from LLLC, which additionally includes sensors in each fixture.
[4] This study uses the term "market actor" to mean any professional involved in lighting and controls projects. The study also refers to "supply chain actors," which include manufacturers, manufacturers' representatives, and distributors.

1.2.1 Project Processes

LLLCs can be installed either during lighting retrofit projects or during new construction or major renovations and typically follow one of two processes: design-bid-build or design-build.

In retrofit projects, a building owner typically hires a contractor to provide retrofit services. This contractor is responsible for designing and installing the lighting equipment required by the owner.

In new construction and major renovation projects following a design-bid-build process, a building owner hires an architect to design a building and provide a complete set of design and construction documents, including lighting and controls specifications. Lighting control systems are typically specified by the electrical engineer who may be employed by or contracted to the architect. Next, a pool of general contractors submits bids to provide the construction services. When the owner selects a winning bidder, the general contractor hires subcontractors (e.g., an electrical contractor) to support the completion of the building. Some projects follow a design-build process in which the architect and the general contractor are hired under one contract rather than each being hired separately by the building owner.

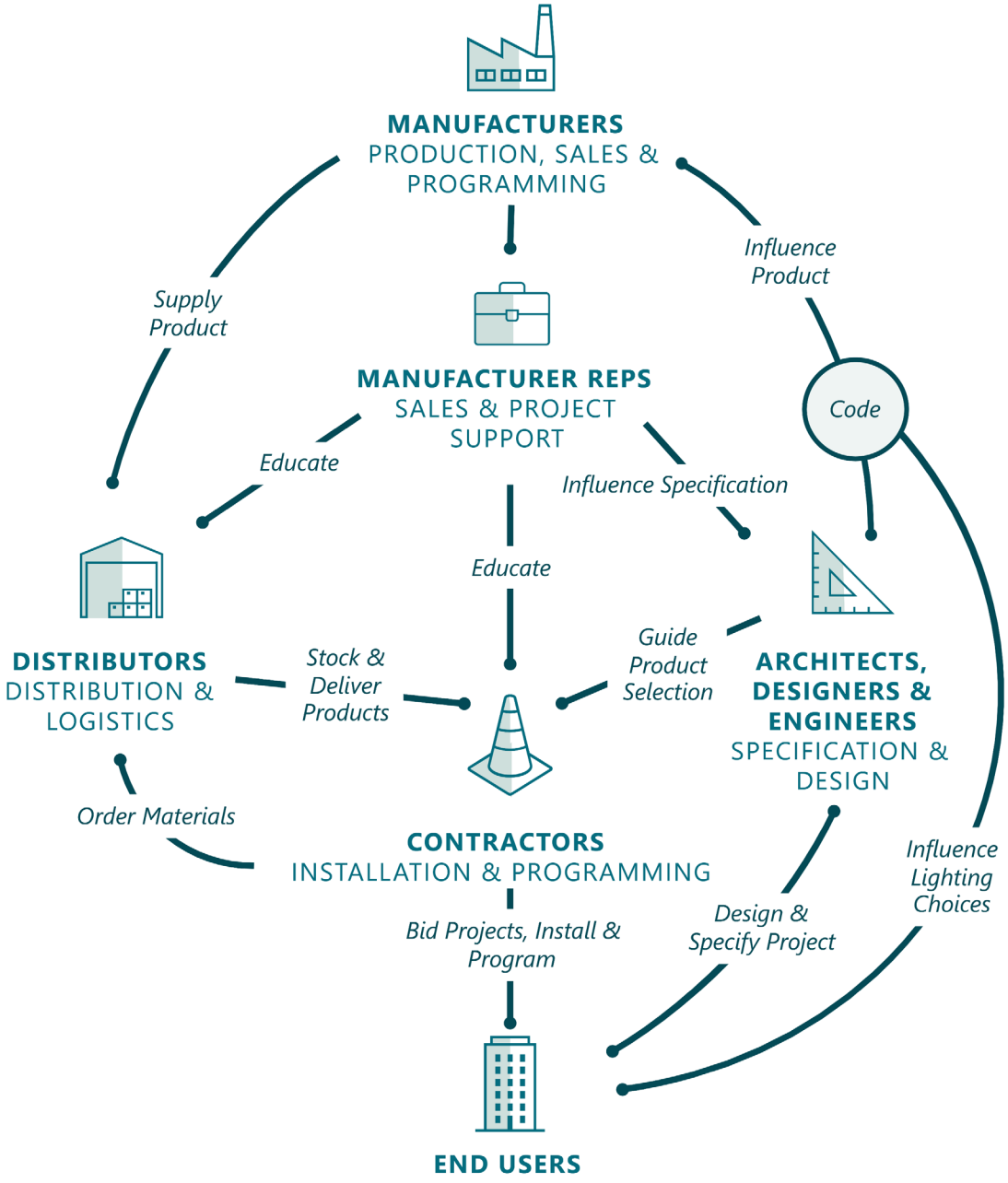
In all cases, additional market actors are involved in these projects:

- **Lighting and controls manufacturers.** These companies develop, manufacture, and sell lighting and controls products. In some cases, they also assist with specification, installation, and/or programming of the control systems.
- **Manufacturers' representatives**. These are independent sales agencies that manufacturers hire to provide local/regional sales functions. They typically work on a commission basis, with commissions paid by manufacturers for sales. Representatives (reps) are a key source of information for lighting designers and electrical engineers, often assisting in specification. They also provide product education to other market actors, including owners, architects, and contractors. Reps tend to be up-to-date and knowledgeable about the product lines and capabilities.
- **Distributors.** These market actors play a logistical role in fulfilling product orders. Sometimes when a contractor orders a product, the manufacturer ships that product to a local distributor. In some cases, distributors keep products in stock. In addition to their fulfillment role, some distributors also have lighting project sales teams that typically focus on selling lighting retrofit projects with energy savings as a selling point.

Specification is a critical decision-making step in any project and the prime opportunity to influence lighting and controls decision making. The specification role includes selecting and specifying the system requirements and can be performed by different market actors depending on project type. Electrical engineers typically specify controls on new construction and major renovation projects, often with input from a manufacturer rep. On retrofit projects, the electrical or lighting contractor would most likely specify controls, often with input from a manufacturer rep. As such, manufacturer reps are a key source of information and influence in project decisions. Reps tend to be up-to-date and very knowledgeable about their specific product lines and product capabilities. Distributors can also influence project specifications, typically for simpler retrofit projects, and often through a lighting project team or energy team.

In most projects, end-use customers interact with an interconnected ecosystem of influential market actors, as shown in Figure 1. See Appendix B for descriptions of market actor roles and relationships of influence as well as differentiated diagrams of market roles for new construction and retrofit projects.

Figure 1: Lighting Control Market Roles and Relationships



1.3 Market Barriers and Opportunities

This research identified several market barriers that prevent or delay the widespread adoption of LLLC in Minnesota. The Minnesota lighting and controls market also has several strengths that CEE can leverage to encourage the adoption of LLLC. The sections that follow describe these barriers and opportunities.

1.3.1 Market Barriers

The research team identified the top five market barriers to LLLC adoption. See Section 6 Conclusions and Recommendations for a more detailed description of barriers and opportunities specific to the various market actor groups included in this study.

Overcoming product first cost remains a challenge. The upfront cost for purchasing LLLC equipment, installing a lighting system with LLLCs, and programming the LLLC system is often higher than alternative approaches to lighting and controls. Many interviewees and survey respondents mentioned material costs as a reason for not including LLLCs in both retrofit and new construction projects, noting that if they use LLLCs, the cost of materials will compare poorly with their competitors who do not use LLLCs. Market actors acknowledged that wireless LLLC systems can save labor costs when compared to traditional wired controls. They also acknowledged that the lifetime cost of owning an LLLC system, accounting for energy and maintenance savings, is often lower than alternative lighting systems. However, the perception that LLLC is an expensive solution remained a persistent theme in interviews and surveys.

End users do not fully understand or embrace the value of LLLC. End users generally do not understand the benefits they would receive from an LLLC system compared to other lighting and controls options, and they do not always embrace the benefits LLLC offers. This lack of understanding and appreciation of the value, combined with the perception that LLLC is expensive, may depress demand for this technology. Especially in retrofit projects where end users can be more directly involved in weighing costs and benefits of various options, end users will find it difficult to accept higher first costs (even when offset by labor savings) for a system whose benefits they do not understand or appreciate.

Contractors lack the ability to sell LLLC. In retrofit projects, the contractor often has the greatest opportunity to communicate the value of LLLC to their end user customers. However, our data indicate contractors do not feel prepared to conduct this conversation. Contractors need a full understanding of the benefits to end users as well as LLLC's time and labor savings in order to recommend a higher-cost technology to end users.

Contractors lack the technical skills needed to implement LLLC. Additionally, most contractors lack the technical skills and familiarity with LLLC systems that would be required to achieve successful installations. Contractors reported that most projects encounter challenges with programming. Contractors also reported that they find it challenging to learn the unique details of different manufacturers' control systems. On average, they have little to no training on these systems, and most contractors are not prepared to install and program LLLCs with confidence.

Contractors encounter issues when programming LLLC systems. Lack of training, as discussed above, may be the root of many programming challenges contractors face. But in some cases, real product issues are hindering project success. Some contractors reported encountering issues like settings being erased unexpectedly and bugs in control system software.

Contractors lack awareness of utility incentives for LLLC. Less than half (39%) of the contractors surveyed were aware of utility rebates for LLLCs in the area they work in. This likely means that utility incentives are an underutilized tool for promoting the adoption of LLLC and offsetting concerns about high upfront cost in the retrofit market.

1.3.2 Market Opportunities

Manufacturers and manufacturer reps are promoting LLLC, among other controls approaches, and most believe that the future of lighting controls is in wireless and embedded controls such as LLLCs. However, nearly all manufacturers that offer an LLLC system also offer other controls options, and supply chain actors do not consider LLLC a default option. Two respondents also mentioned they appreciate the support they already receive from CEE on promoting efficient lighting. CEE has an opportunity to bolster and amplify the attention that manufacturers and reps are already devoting to LLLC in Minnesota to drive the market further toward LLLC.

Specifiers are poised to champion LLLC. Specifiers are aware of LLLC, understand the value, and have positive opinions of the technology. These market actors are poised to act as champions of LLLC, and CEE can leverage early adopters' success with the technology to build confidence among other supply chain actors. Specifiers are particularly influential in the new construction and major renovation segments of the market because they prescribe the lighting and controls requirements that contractors must implement.

Code requirements encourage LLLC. LLLC is perceived as an efficient tool for achieving energy code requirements, such as square footage of space controlled by a single motion sensor. This presents an opportunity for raising awareness and comfort with LLLC through the promotion of LLLC as an effective tool to meet code requirements.

Contractors have a positive opinion of embedded controls. Contractors prefer working with embedded controls, or systems in which the controls components are integrated into the lighting fixture. While embedded controls include products other than LLLCs, this positive sentiment indicates contractors will be willing and able to adopt and promote LLLCs when they gain familiarity and comfort with the systems. However, only 15% of the contractors who have worked with LLLCs reported they like to work with LLLCs, with most (77%) saying they only "somewhat like" to work with LLLCs.

Contractors are interested in receiving training on LLLC. Half (50%) of contractors expressed interest in receiving training about LLLC, with an additional 34% of contractor respondents "unsure" of their interest level. Their desire to learn more about LLLC systems provides an opportunity to address skill and knowledge gap barriers.

Utility incentives are a widely recognized tool for promoting LLLC in retrofits. All market actors view utility incentives as a valuable tool for encouraging LLLC adoption. Despite their low awareness of incentives for LLLC, most contractors surveyed (65%) believe rebates are important in encouraging selection of LLLC systems, particularly for retrofit projects.

1.4 Recommendations

Based on our research findings, the Cadeo team offers the following recommendations for CEE to consider in designing its LLLC market interventions. Market transformation efforts need multiple tools for intervening in the market, and these recommendations present a variety of options for market intervention approaches. CEE may determine that certain interventions need a near-term focus while others can be delayed, resulting in a staged approach to introducing multiple intervention strategies.

CEE should strengthen partnerships with leading firms in Minnesota that sell, design, specify, install, and program lighting control systems. Supply chain actors, specifiers, and contractors all influence end user decisions around lighting controls. For CEE's market intervention to succeed, it will

need to partner with these professionals to influence market practices and support continuous learning and adaptation to market conditions over time. To influence the retrofit market, CEE should prioritize building relationships with leading electrical contracting firms, lighting retrofit firms, and lighting consulting firms as well as exploring partnerships with manufacturer rep agencies that represent LLLC systems. To influence new construction and major renovation activity, CEE should prioritize building relationships with manufacturer rep agencies that represent LLLC systems, and leading architecture, engineering, and lighting design firms. Building these partnerships should be a near-term priority for CEE, because partnerships will strengthen and enhance all subsequent market interventions.

CEE should invest in educating contractors on (1) technical skills for installing and programming LLLCs and (2) understanding and communicating the LLLC value proposition in retrofit projects. Contractors indicated interest in receiving more training on LLLC. Professional organizations and supply chain market actors, particularly manufacturers' reps, may be effective partners in education. Hands-on training is of particular importance for contractors to learn technical skills, and the greatest need for technical training is in programming LLLC systems. One distributor interviewee noted that medium- to larger-sized contractors are more interested in training than smaller firms. Supply chain interviewees believe that once contractors gain familiarity and comfort with LLLC technical skills they will be strong champions of the technology. Therefore, it is also critical for contractors to understand how to communicate the value of LLLC to their retrofit customers. All market actor and end user groups studied in this effort highlighted the need for contractor education, indicating that this need affects multiple aspects of the LLLC market, and CEE should consider it a priority area for intervention.

CEE should consider direct and indirect strategies for educating end users and building owners on the value of LLLC. Lack of awareness and a poor understanding of the benefits of LLLC among building decision makers can be a barrier to wider LLLC adoption. In particular, cost is a critical decision driver, and the cost savings associated with LLLC technology (via labor savings at installation and via energy savings upon occupying the space) may be compelling enough to influence purchasing decisions. Efforts to drive improved awareness and increased promotion through the supply chain will indirectly bridge this knowledge gap by improving specifier and contractor knowledge and understanding of LLLCs and its benefits. However, CEE should also consider direct strategies for building awareness among end users to increase the market acceptance of LLLC, particularly among high-leverage building decision makers such as commercial property managers who influence a portfolio of buildings.

CEE should develop and disseminate clear, targeted, and compelling value proposition messaging to assist market actors in communicating the value of LLLC. For example, CEE could develop case studies that illustrate the cost savings that can be achieved through LLLC systems, featuring different building types that would allow diverse building decision makers to relate their own facilities to the value proposition. As another example, interviews with supply chain actors revealed some hesitancy and misunderstanding around LLLC technology in warehouse and manufacturing settings, with interviewees mentioning that such facilities cannot risk malfunctioning lighting controls causing unsafe conditions. However, another interviewee indicated that properly implemented LLLCs can *reduce* safety hazards. CEE can build greater market acceptance of LLLC by finding ways to ensure systems are programmed correctly and operation is verified thoroughly. CEE's efforts to build understanding of LLLC's value propositions will also add credibility to manufacturer messaging.

CEE should support standard terminology around LLLC definitions across programs and key stakeholders. Interviewees revealed inconsistent understanding of the term Luminaire Level Lighting

Control (LLLC). Once interviewers explained the characteristics of LLLC technology, all respondents were at least somewhat familiar with the concept. This indicates a lack of consistent terminology for LLLC, which can create confusion that prevents adoption. Currently, market actors tend to speak about all forms of embedded controls as a category, lumping LLLC together with other approaches. Market actors may miss opportunities to highlight LLLC as the most beneficial approach, when relevant, if they don't distinguish between LLLC and other control strategies. CEE can encourage consistency by using consistent terminology in all marketing and educational materials. This will help market actors differentiate between LLLCs, with their rich set of energy and non-energy benefits, and other approaches to wireless or embedded controls that may provide less value.

CEE should support Minnesota utilities in offering simple-to-use, financially compelling rebates for LLLC. LLLC systems are eligible for lighting controls rebates in some areas of Minnesota, but awareness of LLLC rebates is low, particularly among contractors: 60% of surveyed contractors were unaware of rebates for LLLCs. Competitive stand-alone rebates for LLLCs may improve awareness and adoption of the technology. While respondents agreed that simplicity is paramount for rebates to be most effective, various rebate designs for LLLCs can be effective, including stand-alone rebates for LLLCs or LLLC rebates as part of a broader lighting controls rebate offering.

CEE should consider (1) promoting (through educational or media channels) LLLC as a tool for meeting energy code requirements and (2) seeking opportunities to improve energy code enforcement. Recent changes in Minnesota's energy code are already driving specifiers to consider LLLC more frequently, but improved awareness of LLLC as a tool for meeting code requirements would strengthen the impact of this shift in professional practice. Furthermore, specifiers indicated that lack of energy code enforcement means Minnesota is not maximizing the impact of the transformative effects of the code. The issue of non-compliance with energy code is particularly common on retrofit projects that may not involve an engineer in design and specification.[5] A new construction or major renovation project is more likely to be designed to meet code, but even in these projects, interviewees said there may be either no inspection for energy code compliance or a cursory inspection that does not confirm controls are programmed correctly.

[5] Minnesota Energy Code is applicable in some lighting retrofit scenarios. This study did not include a review of code applicability, but future research could investigate the opportunity to improve code compliance in applicable retrofit settings.

Section 2 In-Depth Interviews with Supply Chain Market Actors

This section presents the results of in-depth interviews with supply chain market actors conducted in April, May, and June 2023. The research team spoke to eight manufacturer's representatives, six lighting manufacturers, and five lighting and electrical distributors. The sections that follow describe Cadeo's research approach and review detailed market insights from the interviews. The top findings from the interviews are:

- Respondents expect LLLC adoption to grow, but low contractor awareness and technical skills (including familiarity with the specifics of installing and programming LLLC systems) must be addressed to increase the pace of adoption and to encourage broader adoption. Secondary barriers include end user awareness and familiarity, high costs, and lack of code enforcement.
- End users lack the knowledge to request LLLCs, making it essential for specifiers and contractors to feel confident recommending and installing LLLCs.
- Contractors need hands-on training either from manufacturers and reps or from educational entities or utilities. Smaller contractors are likely to need the most support, while larger contractors are more likely to pursue training on new technologies. Specifier training is also needed but could focus more on the benefits of LLLCs.
- Market actors believe rebates are critical for increasing LLLC adoption, but market awareness of rebates is low and program requirements can be cumbersome.

2.1 Approach

During April, May, and June 2023, Cadeo completed a total of 19 30-minute in-depth phone or video-conferencing interviews with supply chain actors operating in Minnesota, including manufacturers of lighting controls, manufacturers' representatives, and lighting and electrical distributors offering lighting controls. The interview effort sought to:

- Understand and confirm supply chain dynamics and the customer's "path to purchase."
- Understand barriers, opportunities, and leverage points for market intervention.
- Understand current marketing and training efforts around LLLCs.
- Establish the readiness level of contractors in Minnesota to bid out and install LLLCs.
- Identify market leaders in LLLC sales and what they are doing differently from others.
- Test LLLC value propositions and determine value proposition differences between submarkets when possible.
- Understand awareness and importance of existing utility rebates.
- Understand market share of LLLC vs. other lighting control or non-control strategies.

Table 1 shows the number of respondents in each market actor category.

Table 1: Market Actor Category (n=19)

Category	Count	Percent of Total
Manufacturer Rep	8	42%
Manufacturer*	6	32%
Distributor	5	26%

*Among manufacturer respondents, five out of six worked for manufacturers that offer DLC-listed LLLC products.

The Cadeo team took detailed notes during the interviews, and calls were recorded to facilitate thorough analysis. The research team used qualitative analysis techniques to identify patterns, themes, and key findings from the collected data. For more detailed information about the approach, please see Appendix A.

2.2 Findings

The interviews covered a wide range of topics. This section summarizes findings in each topic area.

2.2.1 LLLC Awareness

Fourteen of 19 respondents were familiar with the term "LLLC" or "Luminaire Level Lighting Control." The five respondents who were not familiar with the term "LLLC" indicated an understanding of the concept after the interviewer provided a brief description. "Embedded controls" was the most common alternative terminology interviewees mentioned. One large manufacturer plans to better align with codes by transitioning its marketing and technical materials from using "embedded controls" to using "LLLC" exclusively.

After gauging general awareness, interviewers asked respondents whether they make, sell, stock, design, or install LLLCs. As Table 2 shows, most manufacturers (five of six) and manufacturer reps (six of eight) reported working with LLLCs on a regular basis, and all respondents had prior exposure to LLLCs. A smaller portion of distributors reported working with LLLCs (two of five), but all possessed general familiarity with the technology.

> *"We have been pivoting to [the term LLLCs] due to codes. We have previously used the term 'embedded controls' but we're trying to synergize, so everyone is using the same terminology. We're making an effort to say LLLCs in training and in literature."*
>
> ***– Manufacturer***

Table 2: Market Actor Familiarity (n=19)

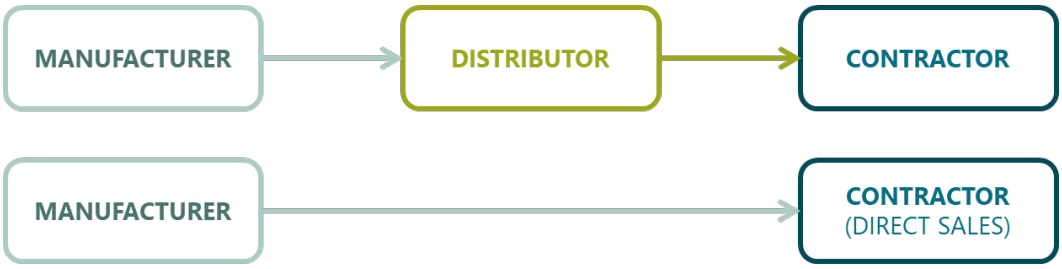
Category	Familiar with term "LLLCs" or "Luminaire Level Lighting Control"	Familiar with concept once defined	Regularly work with LLLCs
Manufacturer Reps (n=8)	6	8	6
Manufacturers (n=6)	5	6	5
Distributors (n=5)	3	5	2
All Respondents (n=19)	14	19	13

2.2.2 Supply Chain Dynamics

Supply Chain Path

According to interviewees, lighting controls follow multiple supply chain paths, as shown in Figure 2. These paths represent the flow of product from one market actor to another.

Figure 2: Controls Supply Chain Paths



The manufacturer-distributor-contractor path is the traditional supply chain path for lighting and associated equipment. Interviews confirmed that lighting control products also typically follow that traditional path. However, in some cases, manufacturers supply lighting controls directly to the contractor.

Supply Chain for LLLCs vs. Other Controls

Half of respondents said LLLCs move through the supply chain consistent with other types of lighting controls. The other half of respondents mentioned that while the supply chain path does not differ, stocking difficulties and longer lead times are differentiating factors. These slowdowns occur particularly for LLLC systems that include components from two different manufacturers. In such cases, the control manufacturer typically ships components to the fixture manufacturer that assembles the fixtures with embedded controls. In this process, the likelihood of facing fulfillment delays due to shipping or coordinating logistics between the two suppliers is higher than if products were provided by a single manufacturer or if controls and lighting products were fulfilled separately, as in traditional control systems. However, this barrier does not affect all LLLC systems. Manufacturers noted that in cases where one supplier provides both the lighting and controls components of an LLLC system, fulfillment delays are less likely than for separate lighting and controls packages because the process involves fewer players. Additionally, as a newer and less widely adopted technology, LLLCs are less likely to be readily available and fully stocked on distributor shelves as compared to traditional control products. However, some

manufacturers proactively keep some LLLC fixtures available in North America to minimize shipping delays.

Representative comments included:

- *[regarding fulfillment of LLLC products in cases where two different manufacturers supply the fixtures and the controls components] "Typically, there's more complexity. You've got the control component and the fixture component. The fixture manufacturer might have the fixtures, but then if they [i.e., the fixture manufacturer] get control parts from a different manufacturer, there might be a delay." – Rep*
- *[regarding fulfillment of LLLC products in cases where the same manufacturer supplies the fixtures and the controls components] "The supply chain is simpler for LLLCs because so many components are embedded (you order a luminaire with embedded controls)." – Manufacturer*
- *"I don't think our market is mature enough in controls, or at least stock ready. Nobody has gone all in on having that local stock. Almost all of it is project driven and directly ordered from a manufacturer." – Rep*

2.2.3 Barriers, Opportunities, and Leverage Points

Market Expectations

Seventeen of 19 respondents predicted the lighting market will shift toward greater adoption of wireless and integrated controls within the next five years. However, only four respondents specifically mentioned LLLCs, whereas most simply referred to wireless and integrated controls. Additionally, supply chain contacts only provided general market predictions and did not specify the extent to which they expect the controls market to grow. Controls are one of the few areas of recent innovation in the lighting industry and manufacturers are actively investing in making them more user-friendly and easier to install. One distributor said, *"all R&D dollars are in controls currently."* Additionally, manufacturers are streamlining their offerings and eliminating individual products in favor of multi-use fixtures. These products have selectable technical specifications, such as wattage and color temperature, and they work well in concert with LLLCs and other networked lighting control systems to increase the flexibility and customizability of a lighting system.

Respondents also expect code will accelerate the shift toward controls as Minnesota moves toward adopting requirements currently in place in California and other coastal jurisdictions. A few respondents were optimistic that prices will decrease or rebate amounts will increase, further encouraging the adoption of controls.

Challenges with Lighting Control Innovations

According to supply chain contacts, the biggest perceived barrier to lighting control innovations in general is a lack of familiarity and awareness among both contractors and end users. These respondents describe contractors who are reluctant to embrace new or unfamiliar technology and as a result are unlikely to recommend innovative lighting controls to customers. Respondents consider electrical contractors to be more risk averse than other trades. End users typically have limited knowledge or experience with lighting controls and are unlikely to request specific technology or features, making it essential for contractors and specifiers to promote lighting controls to their retrofit customers and educate customers on code requirements. Furthermore, end users often find controls overly complex and

seek simpler solutions. Only two respondents mentioned cost as a barrier to lighting control innovations in general, though cost is frequently mentioned as a barrier to LLLCs specifically.

Market Challenges

LLLCs specifically encounter challenges with low contractor and end user familiarity and awareness and face additional barriers including higher costs and a lack of understanding of value. The top perceived barriers to LLLC adoption include:

- **Contractor and end user discomfort and unfamiliarity.** As with other lighting control innovations, contractors are hesitant to adopt and promote LLLCs, while end users lack the knowledge and understanding needed to request them. This can prevent inclusion of LLLCs, especially on retrofit projects. According to the supply chain contacts, contractors do not understand and market the value associated with simple installation and resulting labor savings.
- **High costs.** The high initial costs of LLLCs often deter would-be adopters in retrofit projects, particularly when contractors fail to effectively communicate the value and energy savings over time. Rebates may ease some of the initial costs but typically aren't enough to win over building owners on a tight budget. Supply chain contacts report that even proponents of LLLCs may not include them on projects in order to win bids, and LLLCs are often removed from projects to cut controls costs.
- **Lack of understanding of value.** According to supply chain contacts, end users struggle to understand the true value and return on investment of LLLCs, and some find them superfluous and unnecessary. End users lack understanding of LLLCs' benefits, energy savings, and ease of use. Contractors who are comfortable and confident with promoting and installing LLLCs could more effectively educate customers on these benefits.
- **Lack of specifier awareness.** Four supply chain contacts (two reps, one distributor, and one manufacturer) mentioned a lack of specifier familiarity and awareness as a barrier to LLLCs. However, these respondents mentioned specifiers as an afterthought, whereas almost all respondents mentioned contractor awareness as a top barrier.

> *"Costs have always been a deterrent. Utilities' rebates don't match up to the costs for nice systems like this. The delta between the cost of luminaire and cost of controls was too big historically for the controls devices to be adopted."*
>
> ***– Distributor***

Encouraging LLLC Installation

Respondents provided the following recommendations for increasing LLLC installation and acceptance, listed in order of frequency:

1 | Contractor and specifier awareness-building and education.
2 | Lower costs through rebates.
3 | Improve end user awareness and understanding of value.
4 | Code education and enforcement.

According to supply chain contacts, contractor awareness and education is critical to encouraging adoption of LLLCs.[6] Because most end users lack the knowledge to request LLLCs, they rely on guidance from contractors to steer their lighting decisions. Respondents believe well-educated contractors will lead the way with LLLCs and be most effective in promoting them to the general population. However, hands-on training is necessary to support this. Though respondents mentioned specifiers less frequently, some respondents also considered specifiers influential.

Lower costs and improved rebates also emerged as an important factor for encouraging LLLC adoption. The high upfront costs deter potential adopters who often fail to recognize the long-term value of LLLCs. More abundant, larger, or more easily calculable rebates could also encourage adoption by lowering initial costs and giving end users an incentive to act. As one rep said, *"It's a huge motivator. It's like anything on sale."*

> *"Toughest part is still convincing people to go ahead and do it. People are still hesitant about it… It's like with LEDs in the past. We spent a hell of a lot of time convincing people to use LED. Now, all that hard work paid off and everybody is using LEDs and nothing else."*
>
> ***– Rep***

Supply chain contacts also advocated for improving end user awareness and understanding of the value of LLLCs. Multiple respondents noted that while they expect end users will be much happier with LLLCs in the long term, they struggle to communicate this to consumers focused on initial costs. Long-term energy savings are one of the biggest and most easily demonstrated benefits, but flexibility and improved occupant comfort also provide value over more rudimentary lighting solutions.

- *"So as a business owner, as much as I would love to be environmentally friendly, most people are looking at the bottom line first. Showing the long-term payoff is a bigger draw." – Distributor*

Supply chain contacts also view energy code as a key driver in a shift toward LLLC. Respondents expect LLLC adoption will help meet the changing code requirements and expect that eventually LLLCs may be more broadly mandated in code. However, some respondents mentioned a lack of code compliance and enforcement, particularly outside of larger cities in Minnesota. For smaller retrofit projects, compliance with energy code is not always required.[7] These findings suggest that code changes should be paired with market actor education and ideally more rigorous enforcement.

- *"We don't have third party reviewers to ensure the lighting controls are purchased or installed as they were designed. I don't see that hardly ever. By and large, inspectors aren't flagging them, so contractors aren't being pushed to deviate from the norm." – Rep*

Recommended/Not Recommended Applications

The flexibility and versatility offered by LLLCs led supply chain contacts to recommend them for a variety of applications and customers. Office spaces and corporate campuses were mentioned most frequently, followed closely by schools and higher education campuses. Additionally, two respondents mentioned warehouses and one respondent mentioned retail stores, churches, and dairy barns as ideal applications. Two reps and one manufacturer said they recommend LLLCs to every customer. Respondents also

[6] This is particularly relevant for retrofit projects in which contractors recommend products to their customers, but can also affect new construction projects where contractors may choose to use LLLCs to meet design intent.
[7] Minnesota Energy Code is applicable in some lighting retrofit scenarios. This study did not include a review of code applicability, but future research could investigate the opportunity to improve code compliance in applicable retrofit settings.

recommend LLLCs to meet specific end user needs, including flexibility or instances where end users need to gather data about the space or its occupants.

Supply chain contacts highlighted several unique applications:

- *"Here in the Midwest, there are a lot of big dairy barns… With lighting and wireless controls, you can create a long day for your cows. They turn lights on from 6 am to 11 pm – they eat more, drink more, and give off more milk. Then they dim all the lights down and the cows go to sleep. Another application is for milking zones; cows in zone 1 know when the lights come up, it's time to go get milked." – Rep*
- *"I've seen it at Target and other big retailers. They love it because they can see if people are walking down the aisles. The lighting controls provide info about theft and moving product around to sell more." – Manufacturer*
- *"A big market for these kind of controls has been in churches. Giving them a wireless controls system they can use within their existing systems is a great feature, and we've been successful selling this type of product in the church marketplace."- Rep*

Best Applications	Challenging Applications
✓ Offices/Corporate campuses	× Small spaces with very few fixtures/single zone spaces
✓ Schools/Higher education	× Projects with severe budget constraints
✓ Warehouses	× Military sites
✓ Retail stores	× Hospitals
✓ Dairy barns	× Industrial sites
✓ Churches	

Although LLLCs are generally considered suitable for most applications, real or perceived safety and security concerns can impede LLLC adoption. Two supply chain contacts noted military and government projects often restrict installation of LLLCs because strict security protocols limit wireless technology.[8] Respondents also mentioned hospitals as a challenging application because specific safety procedures needed to account for power failure or malfunctioning equipment make it difficult to integrate LLLCs. Additionally, factories or sites with heavy machinery raise concerns about unexpected lighting failure that could potentially cause injury. This is most often due to end user concerns or strict safety protocols that restrict technology like LLLC. It can also reflect a reluctance to recommend LLLCs out of an abundance of caution.[9]

Additionally, a few respondents reported they refrain from recommending LLLCs for spaces that don't need granular controls, like small offices or single zone areas. They are also less likely to recommend LLLCs for projects with budget constraints. One manufacturer said, *"If I can recommend it, I will. But if*

[8] Note that not all LLLCs are wireless, but these interviewees considered only wireless LLLCs in their comments.
[9] The contractor survey and specifier research recognized warehouses and factories as great applications.

budget or cost is a restraint, it will be the only time I won't recommend it. Or it might be overkill. Like if it's a really small office with only a couple of fixtures, then the cost of putting in these LLLCs won't really be justified."

2.2.4 Marketing and Training

Most distributor and rep respondents have received some training on LLLC, most commonly from manufacturers. Distributors also mentioned receiving training from reps, though less frequently. However, reps often play a role in facilitating training sessions.

Supply chain contacts advocated for hands-on training for all points in the supply chain, with contractors the highest priority group. Distributors and reps said hands-on training would be most useful for increasing LLLC sales. One rep mentioned the Illuminating Engineering Society as a training resource, particularly for engineers, and utilities as a potential training resource for contractors and other market actors. Respondents also see value in general education from a non-manufacturer or sales perspective not specific to one manufacturer's line.

Although interviewers did not specifically ask about contractor training in this section, multiple respondents highlighted a need for contractor education to build comfort and familiarity with installing LLLCs as well as illustrating LLLCs' time and labor savings. According to supply chain contacts, two rep agencies in Minnesota, the Rouzer Group and JTH Lighting, are leading the way with LLLC education by hosting showroom demonstrations and hands-on training aimed at contractors.

2.2.5 Contractor Readiness

Supply chain actors reported that while some contractors already have the technical skills to successfully implement LLLCs, as a group, contractors need more exposure and experience to gain confidence. Supply chain contacts expect that as contractors gain exposure to these systems, they will realize LLLCs are easier to install and will recognize the associated labor savings. The reps who have facilitated contractor trainings report positive results and say contractors prefer LLLCs once they get comfortable with installation. A few respondents mentioned that larger firms seem more eager to learn about LLLCs, likely due to a need to stay competitive and offer the newest, best technology.

- *"You might pay 10% extra for this type of system, but it's going to save you 30% on labor. Anything that's labor-savings related, [contractors'] ears are going to perk up." – Distributor*
- *"We've developed very loyal contractors because once they use it and understand it, they keep going back to it." – Rep*
- *"The medium- to larger-sized contractors are more interested… Smaller guys are fine doing their smaller spaces with analog controls." – Distributor*

2.2.6 Market Leaders

Universities and large corporate campuses request LLLC most frequently. Outside of these customer types, respondents say it is rare for customers to request LLLC and instead rely on recommendations from contractors, engineers, and designers to guide their decisions.

Supply Chain Leaders

Respondents did not identify any Minnesota-based market leaders in LLLC but recognized the following leading manufacturers:

- Lutron
- Acuity
- Cooper Lighting
- Current (formerly GE)[10]

Additionally, two respondents mentioned HGA as an influential design firm, although they are not involved with LLLC specifically. HGA is a large national architecture and engineering firm, with an office location in Minneapolis.

Respondents described specifiers and electrical engineers as the most influential actors in the lighting space. Supply chain contacts view engineering firms as risk averse and believe they will promote established, proven technology over newer, more innovative systems. Respondents noted that educating specifiers and engineers about the reliability and value of LLLC may be necessary to overcome this tendency. Emphasizing the capability to design with LLLC as a competitive advantage while emphasizing the risk of installing older or less granular technology could encourage greater acceptance of LLLC among specifiers.

- *"Some of them are hesitant to stick their neck out on a new technology. Rightly so. But just educating them. They're inundated with so much information from so many vendors pushing their product. So, developing relationships with them, them trying it out and having a success – that's the key there." – Rep*

2.2.7 Value Propositions

Interviewers asked supply chain contacts about the most important benefits of LLLC for end users, contractors, and specifiers in order to identify the most resonant value propositions. Table 3 breaks down how respondents mentioned the perceived benefits to each (in order of frequency). Supply chain respondents perceive fewer benefits to specifiers.[11]

Table 3: LLLC Benefits to End Users, Contractors, and Specifiers

Benefits to end users	Benefits to contractors	Benefits to specifiers
Flexibility	Ease of installation	Ease of design
Energy savings	Labor savings	Reputation and competitive advantage of using cutting edge technology
Data and informational capabilities	Ease of maintenance	
Ease of use		
Improved occupant comfort and ability to change lighting settings		

[10] The respondent mentioned GE, which has changed the name of its lighting business to Current. It is possible the respondent had a different product in mind.
[11] However, specifiers mentioned numerous benefits, including design and installation flexibility, easier integration with other systems, and meeting end user needs (See the section on LLLC Benefits in Specifier Focus Group and Interviews).

2.2.8 Rebate Awareness and Importance

Rebate Knowledge

Only 6 of the 19 respondents, including 2 manufacturers, 2 reps, and 2 distributors, had prior experience with rebates for LLLCs or knew any specific details. Those with prior experience say rebates can be highly motivating but are often cumbersome, restrictive, or confusing. In some cases, even large rebates are not enough to justify the high upfront costs of installing LLLCs. Additionally, respondents view new construction rebates as less persuasive in comparison to rebates for retrofit projects. According to respondents, new construction rebates tend to be lower dollar amounts and cover a smaller portion of the incremental cost.

Rebates for LLLCs and Controls Generally

The most common request from respondents regarding rebates is greater simplicity in calculating and applying for rebates. Recommendations for improving rebates included:

- Offering an adder for LLLCs.
- Reducing the project detail required.
- Allowing non-DLC-listed products to be eligible.
- Offering rebates statewide.

Respondents had mixed opinions regarding whether separate incentives for LLLCs would be beneficial. Some respondents see a general controls rebate (including LLLCs) as more influential because the total dollar amount can convince customers to adopt controls. Other respondents thought an LLLC-specific rebate would increase interest in LLLCs. When asked whether a dollar per fixture or per watt add-on for LLLCs would be of interest, most respondents said this could be beneficial but emphasized that simplicity and ease is their top priority and is most likely to encourage LLLC adoption. A few respondents expressed concern that a separate rebate for LLLCs would be convoluted.

Two respondents mentioned they appreciate the help they get from CEE and wish they received similar support throughout the state.

"You know CEE is really helpful and gives us flyers to go out and promote." – Rep

"With CEE, they hold our hand. […] Other areas in Minnesota, it's not that easy." – Distributor

Section 3 Contractor Survey

This section presents the results of the contractor survey conducted in May 2023. The sections that follow describe Cadeo's approach and review detailed market insights from the survey. The top findings from the survey include:

- A majority of contractors (31 out of 39) have not received any training on LLLCs. Although 13 respondents reported having installed LLLCs, only 8 of them had received any training.
- At least half would be interested in training to improve their comfort with installing LLLCs, with hands-on training being most desirable.
- The main challenge contractors face with controls is issues with programming and configuration, and they most often turn to manufacturers and reps for technical support.
- Low customer awareness and high costs are the biggest barriers to LLLC installation.
- Most contractors are not aware of any rebates for LLLCs, but most believe rebates would encourage LLLC adoption.
- LLLCs were reported to be used on approximately 1% of respondents' lighting installation projects.
- Contractors report that the most valuable benefits of LLLC systems for them are lower installation costs and faster installation.

3.1 Approach

Cadeo conducted a web-based survey with lighting and lighting controls contractors in Minnesota in May 2023. Potential respondents were recruited using a CEE-provided list of 650 contacts known to be involved in lighting projects in Minnesota, largely Xcel Energy service territory, most of whom had done at least one project with CEE in the past. From that list, 39 contractors participated in the survey. The contractor survey included the following objectives:

- Understand/confirm supply chain dynamics and the customer's "path to purchase."
- Understand barriers, opportunities, and leverage points for market intervention.
- Understand current marketing and training efforts around LLLCs.
- Establish the readiness level of contractors in Minnesota to bid out and install LLLCs.
- Identify market leaders in LLLC sales and what they are doing differently from others.
- Test LLLC value propositions (i.e., which non-energy benefits are the most relevant and important) and determine value proposition differences between submarkets when possible.
- Understand awareness and importance of existing utility rebates.

For more detailed information about the approach, please see Appendix A.

3.2 Findings

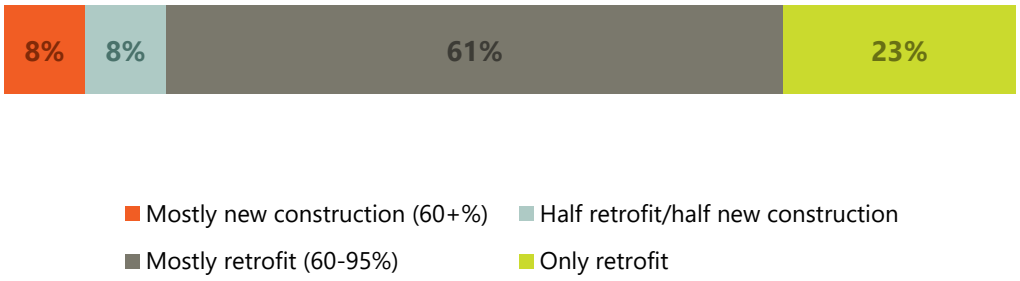
The survey covered a wide range of topics. This section summarizes those findings.

3.2.1 Respondent Characteristics

All contractor respondents work on commercial projects that include lighting controls and most (85%) offer lighting design services, such as consulting on lighting layout, appearance, and function of a space. On average, retrofit projects accounted for 80% of their lighting installations over the last three years,

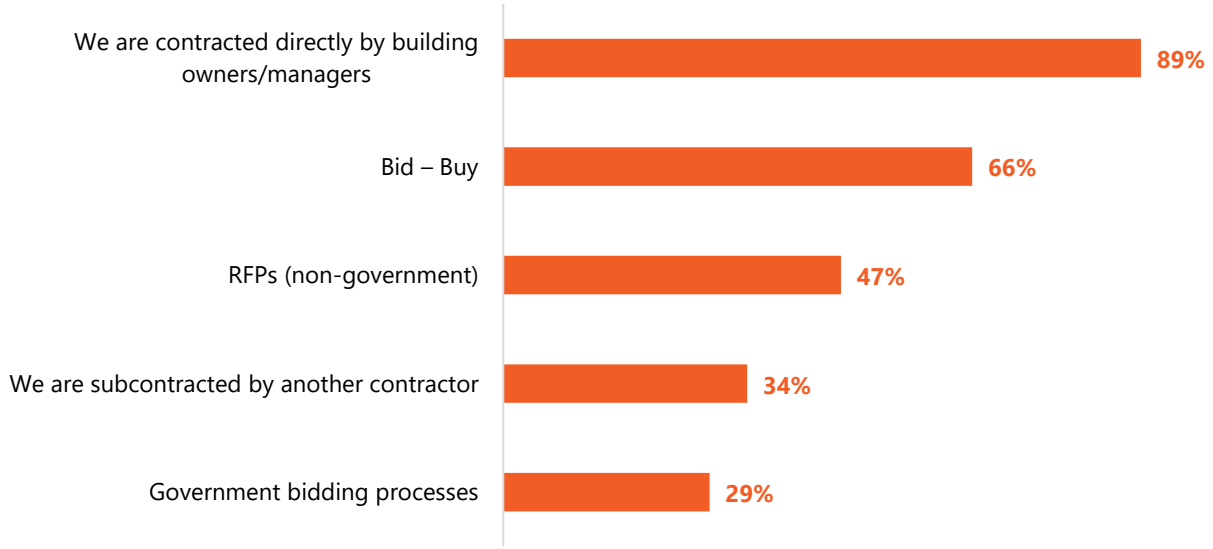
while new construction accounted for the remainder. Only three respondents (8%) said they work on new construction projects the majority of the time, and another three (8%) respondents reported working on an equal number of new construction and retrofit projects (Figure 3).

Figure 3: Portion of Lighting Installation Projects in New Construction vs. Retrofit (n=39)



When asked about the types of project processes they participated in, most respondents said they were contracted directly by building owners/managers (89%) or participated in bid-buy processes (66%) (Figure 4). Contractors said an in-house estimator most often estimates the labor for lighting and lighting control projects (68%), followed by distributors (16%).

Figure 4: Types of Project Processes (Multiple Responses Allowed, n=38)



3.2.2 Awareness of LLLCs

Slightly more than half of contractors (62%) reported having heard of LLLCs. The survey asked the question, "Have you heard of LLLCs, which stands for Luminaire Level Lighting Controls?" before providing a definition of LLLCs. A few questions later, the survey provided a definition of LLLCs to ensure that respondents understood the technology correctly when answering subsequent questions.

3.2.3 Market Share of LLLCs

The survey provided the following definitions for NLCs, light fixtures with embedded sensors, and LLLCs:

- **Networked Lighting Controls (NLCs**)—A connected combination of sensors, network interfaces (gateways/hubs/timeclocks), user interfaces (keypads/touchscreens) and controllers (relays/dimmers/panels).
- **Light fixtures with embedded sensors**—Not part of a networked lighting control system.
- **Luminaire Level Lighting Control (LLLCs)**—Networked systems of light fixtures with embedded controls and a dedicated sensor per luminaire. Sensors are typically occupancy and/or daylight sensors, and often use wireless communication. Because controls are housed within, additional relays/dimmers/control panels are not required like in other NLCs.

We asked contractors to select all the lighting control strategies they had installed in the last three years. Almost all (89%) respondents installed standalone photocells and standalone occupancy sensors in the last three years. Slightly more than half installed lighting controls that were not part of a networked lighting controls system or standalone timeclocks. Less than half installed LLLCs or networked lighting controls (NLCs) (Table 4).

Table 4: Portion of Contractors Installing Each Control Technology in Prior Three Years (Multiple Responses Allowed, n=38)

Control Technology	Portion of Contractors
Standalone Photocells	89%
Standalone Occupancy Sensors	89%
Light Fixtures with Embedded Sensors	66%
Standalone Timeclocks	53%
Luminaire Level Lighting Control (LLLC)	37%
Networked Lighting Controls (NLC)	34%

Respondents estimated the number of projects they installed that were associated with each of the following:

- No Controls/Manual Switch Only
- Standalone Controls (Non-Networked Sensors/Photocells/Timeclocks)
- Networked Lighting Control Systems (NLCs)
- Light Fixtures with Embedded Sensors
- Luminaire Level Lighting Control (LLLC)

The following three tables show the results for (1) all respondents, (2) respondents who primarily work on new construction, and (3) respondents who work primarily on retrofit. As Table 5 shows, no controls or only manual switches account for 77% of lighting installations. Standalone controls are the second most common installation. Only 124 projects included LLLCs, accounting for 1% of total installations.

While this data provides a good view into current market practice for controls installation, it has some limitations. Although this survey used random sampling and had an adequate sample that included a variety of contractor types and experiences with controls, we did not ask about the size of projects and as a result we cannot weight technology distribution by project size. Additionally, because most respondents work on both new construction and retrofit, we cannot determine which types of projects included LLLCs. Finally, 1% may be a slightly conservative estimate because the survey question asked about projects in the last three years and findings from all sections indicate a trend toward greater adoption of LLLCs. Therefore, it is possible that current (2023) market share could be slightly higher if it has grown over this three-year period.

Twelve respondents reported installing LLLCs. Eleven of these respondents primarily work on retrofit projects and on average used LLLCs on 9 projects, though the number of LLLC projects ranges from 1 to 80 per respondent. Only one respondent who installed LLLCs primarily works on new construction. That respondent reported 16 projects that included LLLCs. This does not indicate that LLLC systems are more commonly used in retrofit projects, but rather reflects that most survey respondents work primarily on retrofit projects.

Table 5: Number of Lighting Projects Associated with Each Type of Controls
All Respondents (n=39)

Type of Control	Number of Projects	Percentage of all Projects
No controls/manual switch only	9,306	77%
Standalone controls (non-networked sensors/ photocells/ timeclocks)	2,031	17%
Light fixtures with embedded sensors	456	4%
Luminaire Level Lighting Control (LLLC)	**124**	**1%**
Networked Lighting Controls (NLC)	64	0.5%
All Lighting Projects	11,981	100%

Note: The percentages do not sum to 100% due to rounding.

Of the respondents who primarily work on retrofit projects, slightly more than half reported using embedded controls and one third had used LLLCs and NLCs. However, the survey did not ask respondents to segment their answers by retrofit versus new construction, so we cannot draw any conclusions about how the prevalence of controls types may differ between project types.

3.2.4 Supply Chain Dynamics

The 14 contractors who previously installed LLLCs most often purchase LLLCs directly from a manufacturer (9), but some also reported purchasing LLLCs from electrical distributors (5) or other distributors (3). This result is somewhat surprising, given that supply chain interviews indicated that direct sales by manufacturers are somewhat rare. It is possible that some respondents conflated working with a manufacturer rep with ordering directly from the manufacturer.

The suppliers (n=14) from whom contractors most often purchase LLLC equipment are displayed in Table 7. Table 7 also displays the companies contractors believe are most successful with LLLCs in Minnesota.

Table 7: LLLC Market Leaders in Minnesota (Multiple Responses Allowed)

Type	Commonly Supply LLLC Equipment (n=14)	Successful with LLLCs in Minnesota (n=38)
Manufacturer		
Keystone	✓	✓(2)
ESL Vision[12]	✓	
Legrande	✓	
Linmore	✓	
Sensor Worx[13]	✓	
Maxlite		✓
Lutron		✓(2)
Leviton[14]	✓	✓
Distributor		
Viking Electric	✓(3)	✓(2)
Graybar Electric	✓	
Premier Lighting	✓	✓(2)
Rexel Energy	✓	
Voss Lighting	✓	
Energy Saving Devices		✓
Don't know	✓	✓(30)

3.2.5 Contractor Readiness

Slightly more than half of contractors (62%) have heard of LLLCs, but the majority (79%) have not received training any training on LLLCs (Table 8).

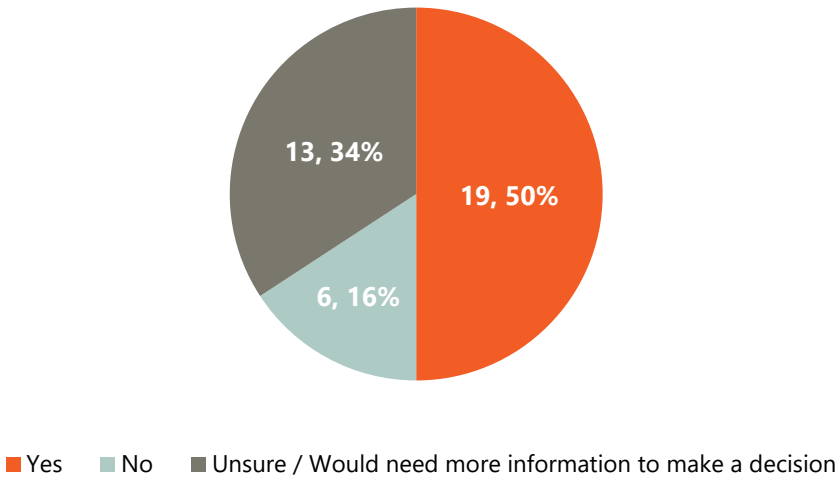
[12] ESL Vision is not on the DLC QPL.
[13] Sensor Worx is not on the DLC QPL.
[14] Leviton is not on the DLC QPL.

Table 8: Contractor Awareness and Training

Status	Count	Percent
Heard of LLLCs (n=39)	24	62%
Received any training on LLLC equipment (n=38)	8	21%

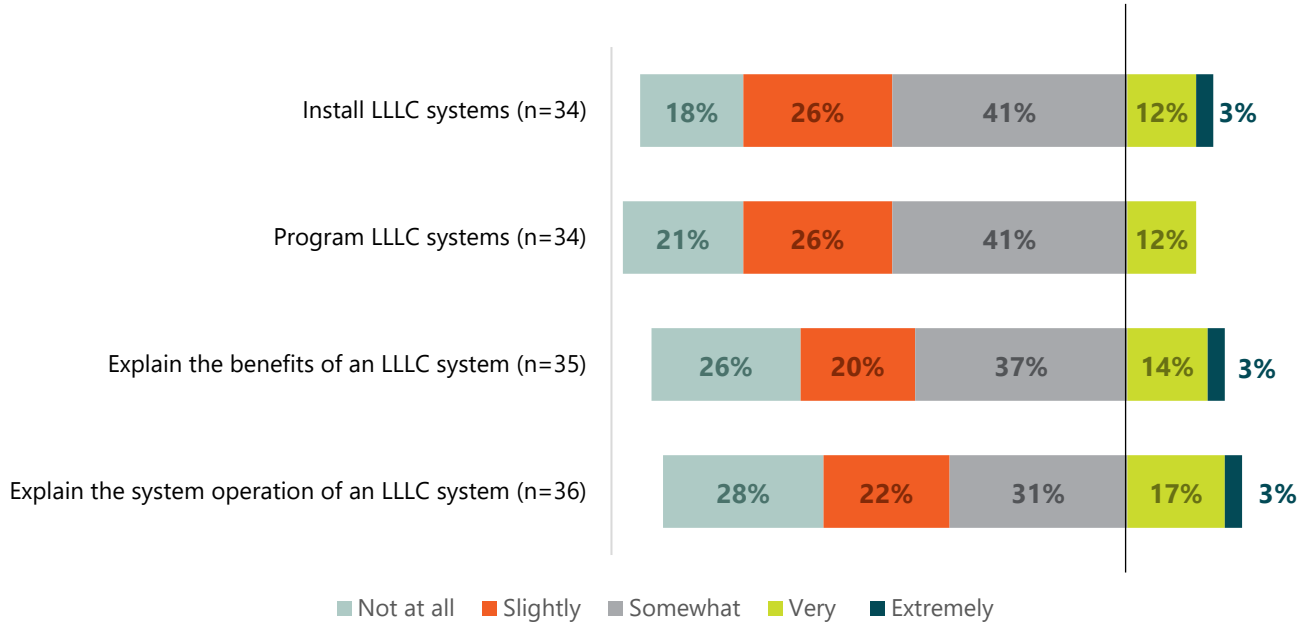
At least half of contractors would be interested in LLLC training (Figure 5). Thirteen respondents said they need more information about the details of the training before deciding. Only six contractors said they would not be interested in LLLC training. Of the eight participants who reported previous training on LLLCs, most received online training or company-sponsored on-site training (5). Three respondents attended a training event at a distributor or other supply chain entity.

Figure 5: Interest in Training to Improve Confidence with LLLCs (n=38)



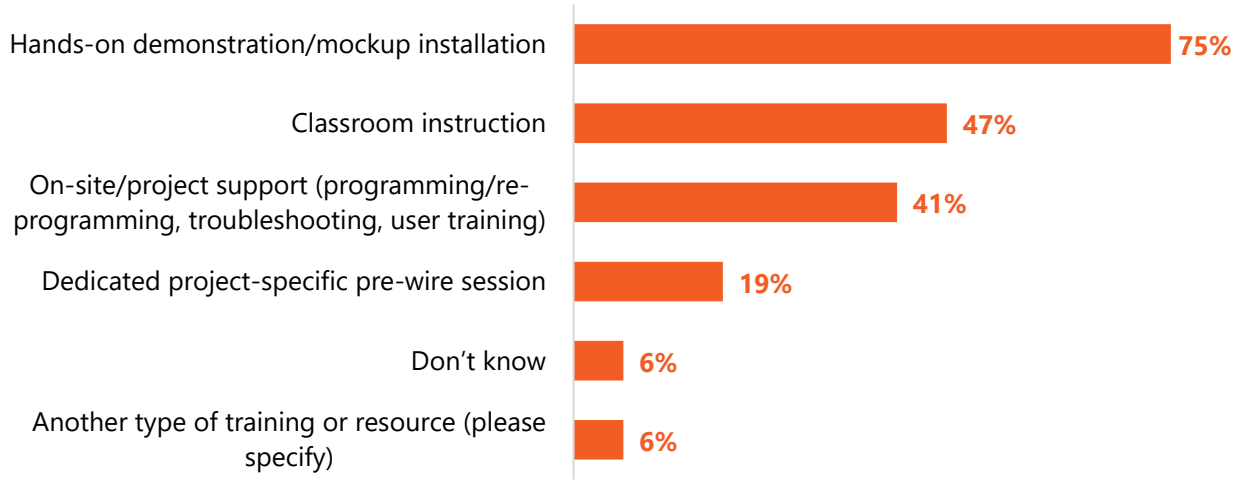
Few contractors feel "very" or "extremely" prepared to explain the benefits (17%) and system operation (20%) of an LLLC system to a customer (Figure 6). An even smaller percentage feel very prepared to install (15%) or program (12%) LLLC systems. Roughly one quarter of respondents do not feel prepared to interact with LLLCs in any capacity.

Figure 6: Contractor-Reported Level of Preparedness



Contractors want hands-on demonstrations and mock installations to improve their confidence with LLLCs. Respondents also said classroom instruction and on-site or project support would be beneficial resources (Figure 7)[15].

Figure 7: Preferred Types of Training and Resources for Improving Confidence with LLLCs (n=32)



[15] Two respondents wrote that they would like Zoom/webinar trainings.

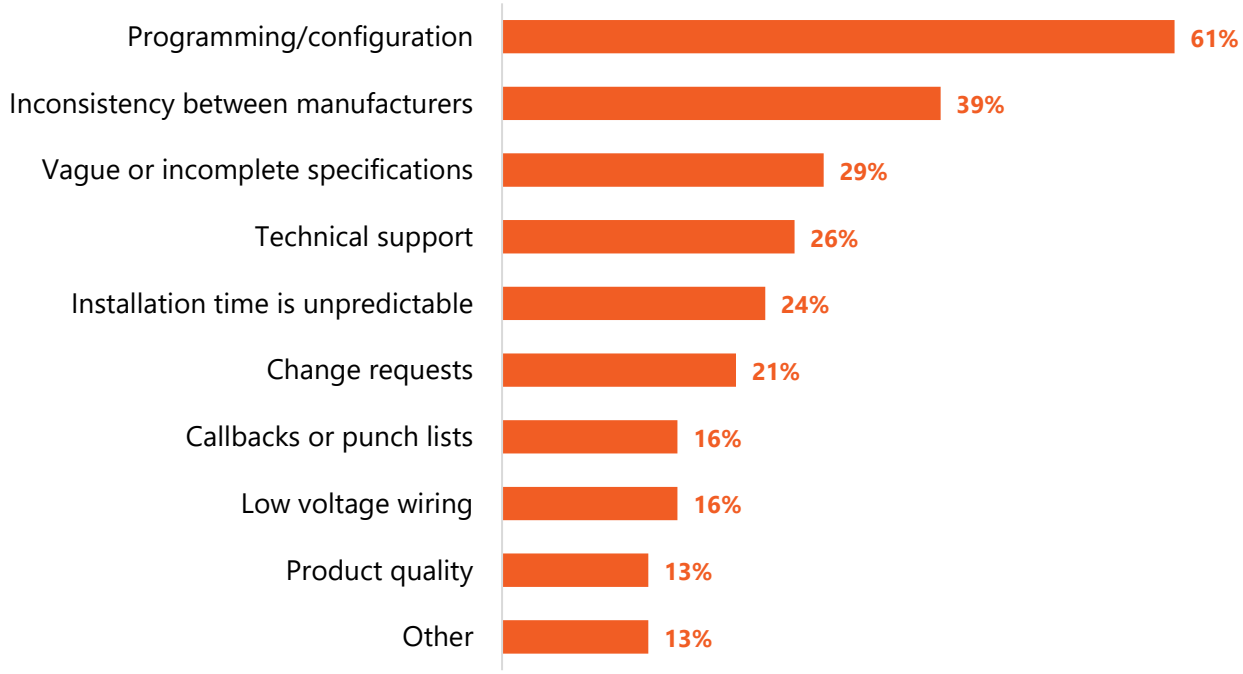
3.2.6 Controls Challenges and Available Resources

As Figure 8 shows, over half of contractors run into problems with lighting control installations at least occasionally.

Figure 8: Frequency of Problems with Lighting Control Installations? (n=38)

The main challenge contractors face with controls is problems with programming and configuration (Figure 9). However, inconsistency between manufacturers and vague or incomplete specifications are also relatively common challenges. These findings suggest contractors' challenges with programming and configuration stem from both a learning curve issue in which they must develop fluency with every system and a lack of guidance due to incomplete specifications.[16]

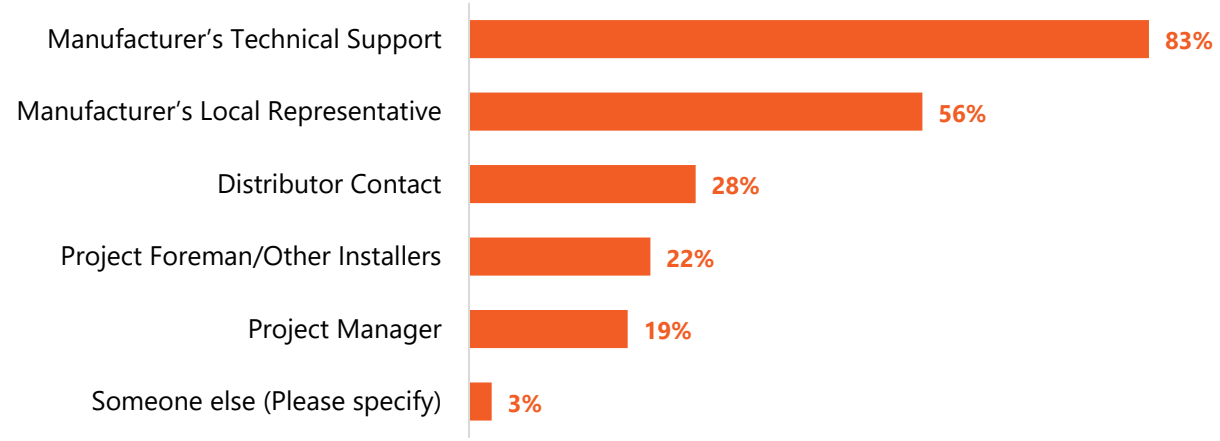
Figure 9: Contractors' Biggest Challenges with Installations Involving Lighting Controls in General (n=38)



[16] Contractors also indicated challenges with programming/commissioning, compatibility with existing systems, longer lead times, and additional costs for sensors.

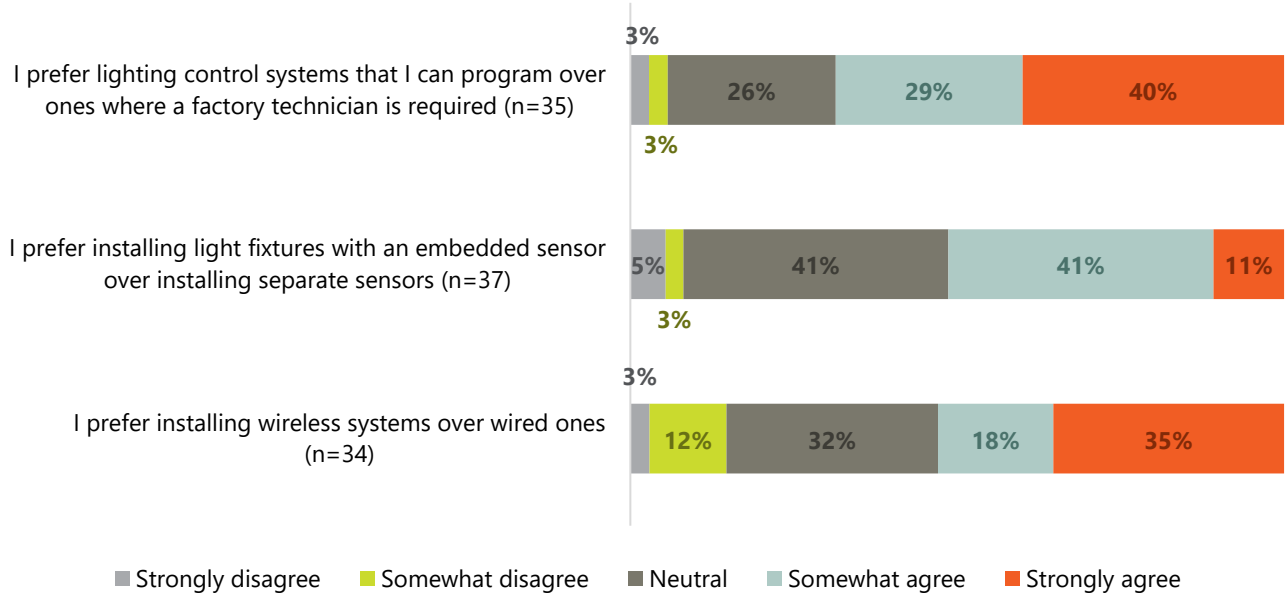
When contractors encounter problems in lighting control installation and programming, they typically turn to the manufacturer's technical support or a manufacturer's local representative (Figure 10). One contractor reported that CEE reps have been helpful with troubleshooting.

Figure 10: Where Contractors Turn for Help Troubleshooting Problems in Lighting Control Installation and Programming? (n=36)



Most contractors prefer lighting control systems they can program over systems requiring a factory technician. Additionally, slightly more than half show a preference for installing wireless systems and light fixtures with an embedded sensor (Figure 11).

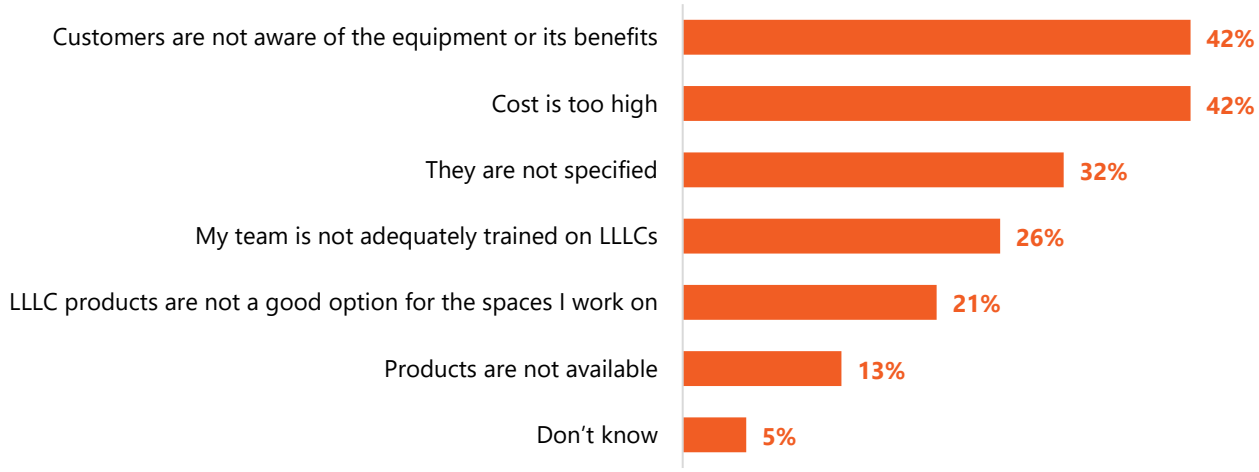
Figure 11: Lighting Installation Preferences



3.2.7 Barriers and Opportunities for LLLCs

Contractors report that low customer awareness and high costs are the biggest barriers to LLLC installation (Figure 12), followed by the fact LLLCs are not specified in design documents.

Figure 12: Reasons LLLCs are Not Used on More Projects Today (n=38)

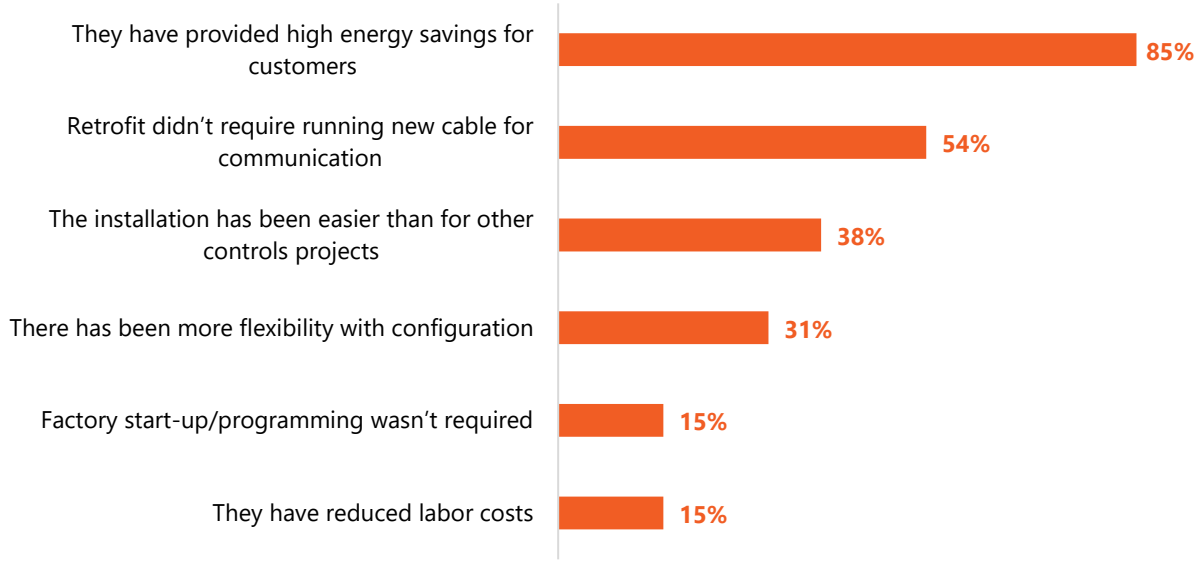


The 13 contractors with prior experience with LLLCs say the main challenges they face with sourcing LLLC equipment are shipping and supply chain issues (6) and high costs (6). Three respondents also said the product is not available where they source their equipment. Respondents also shared the following challenges:

- Commissioning.
- Compatibility with existing system.
- Lead times on materials.
- Additional cost for the sensors.
- Finding someone to explain the operation and configuration.

When asked to select all the ways in which their LLLC projects were successful, most contractors (11) said they provided substantial energy savings for customers. Seven reported that the retrofit didn't require running new cable for communication. Five reported the installation was easier than for other controls projects and there was more flexibility with configuration. Only two respondents said they reduced labor costs, and two said the factory start-up/programming wasn't required (Figure 13).

Figure 13: How LLLC Projects Have Been Successful (n=11)



Twelve of the 13 contractors with experience installing LLLCs reported they "liked" (2) or "somewhat liked" (10) working with LLLCs. When asked to elaborate on their response, contractors indicated the main advantages are simplicity and value, while the main disadvantages are complications or technical issues.

Respondents listed the following pros and cons to explain their response. Each response below is associated with one individual respondent, none were repeated by multiple respondents. These responses illustrate that contractors have mixed opinions and experience with LLLCs:

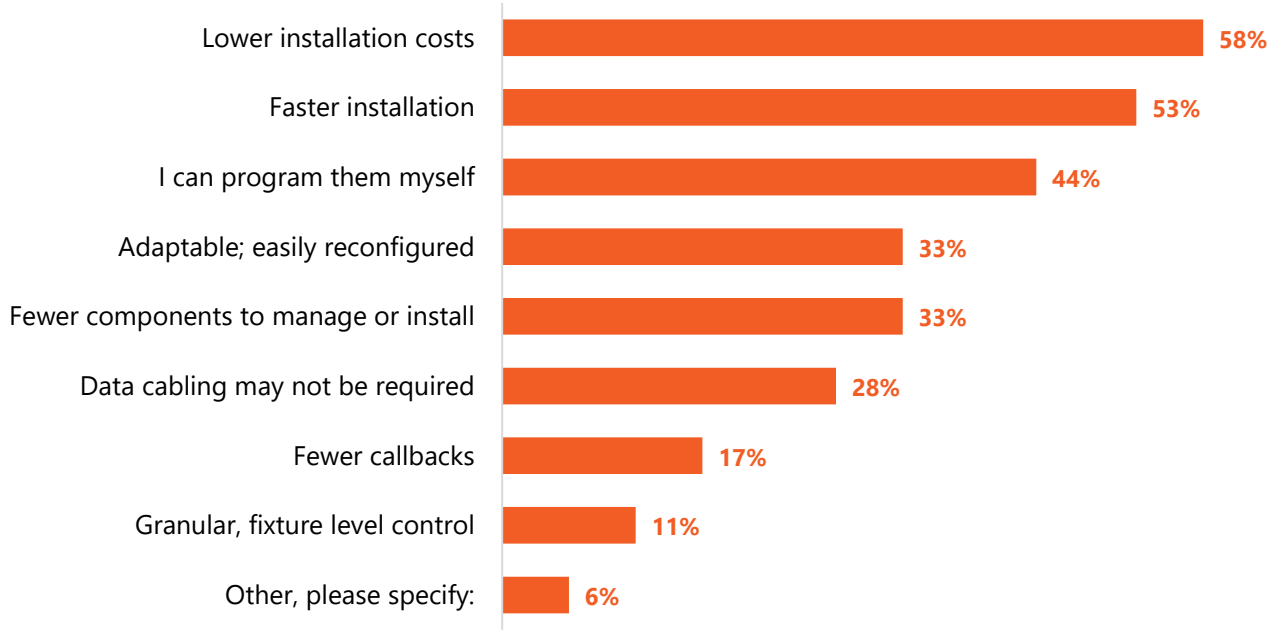
Pros	Cons
✓ "Installation is easy and offers labor savings over wired systems."	× "At times there are too many options and getting the fixtures set correctly can be a pain."
✓ "Simpler to sell & install. Versatile."	× "Complications are always present."
✓ "Using LLLC products is a great way to add value to lighting projects."	× "Directions aren't always clear, and programming sometimes is lost, requiring a callback."
	× "I feel there are still a lot of kinks to be worked out on the manufacturing side. I would have a lot more confidence specifying once those bugs in the systems are more reliable."
	× "Savings don't always offset the up-front cost of equipment."
	× "Not completely comfortable yet."
	× "Takes time to learn and do well."
	× "We have had some firmware issues."

Contractors with LLLC experience report the most common applications for LLLCs are office spaces (8) and warehouses (8), followed closely by schools (6). Three respondents also mentioned industrial and manufacturing areas. Three participants also reported installing LLLCs in parking lots and garages.

3.2.8 LLLC Value Propositions

Contractors report that the most valuable benefits of LLLC systems for them are lower installation costs and faster installation. Respondents also value the ability to program LLLCs themselves as well as easy reconfiguration and fewer components to manage or install (Figure 14). One respondent wrote "happier customers" would appeal to him as a contractor.

Figure 14: As a contractor, what benefits of LLLC products are, or would be, the most valuable to you? (n=36)



3.2.9 Rebate Awareness and Importance

Fewer than half of respondents (39%) are aware of utility rebates for LLLCs in the area they work in (Table 9), although most respondents (55%) believe rebates are very or extremely important in encouraging selection of LLLCs (Table 9). The respondents all work at least somewhat in Xcel territory and therefore would have access to utility rebates.

Table 9: Rebate Awareness and Importance

Survey Question	Response	Count	%
Are you aware of any utility rebates for LLLCs in the area you work in? (n=38)	Yes	15	39%
	No	15	39%
	I don't know	8	21%
How important are rebates in encouraging selection of LLLCs? (n=38)	Extremely important	15	39%
	Very important	6	16%
	Somewhat important	12	32%
	Not too important	1	3%
	I don't know	1	11%

Section 4 Specifier Focus Group and Interviews

This section presents the results of a specifier focus group and in-depth interviews conducted in June and July 2023. The sections that follow describe Cadeo's research approach and review detailed market insights from the specifier research. The key takeaways from this effort are:

- All six specifiers were familiar with LLLC, had prior experience with LLLC, and expressed positive opinions. The specification community appears very familiar with LLLC, though this is a small sample.
- Specifiers see energy code as a major driver of LLLC adoption. Code is pushing specifiers toward LLLC more often, and code requirements (e.g., sensor every 600 sq ft in open office) make highly granular sensing logical, with LLLC ensuring compliance.
- The biggest challenge specifiers face is communicating design decisions and the rationale behind code requirements to building owners and end users.
- Specifiers see flexibility as a major benefit of LLLC, including:
    - Design flexibility: LLLC guarantees adequate sensor coverage and reduce wiring needs.
    - Installation flexibility: LLLC systems are much easier to modify or correct on-site.
    - User flexibility: Users can modify settings as needed.
- Specifiers offered the following key considerations for encouraging LLLC adoption:
    - Contractor education.
    - Better tools for communicating value.
    - Enforcing code compliance: Two respondents said improving code education.
    - Ongoing specifier education.

4.1 Approach

We planned to conduct two focus groups with lighting and controls specifiers, including lighting designers, engineers, and other lighting professionals who play a specification role on projects. However, as specifiers were hard to reach, we conducted one focus group and two additional in-depth interviews. The specifier focus groups and interviews included the following objectives:

- Understand specifier awareness of and impressions of LLLC solutions.
- Explore how code requirements affect lighting control specification and inclusion of LLLCs specifically.
- Understand the barriers and opportunities to including LLLCs in projects and investigate the overall considerations behind lighting control specifications for new construction and major remodeling. How do these considerations support or hinder inclusion of LLLCs?
- Understand how control specifications are affected by the needs of specific submarkets, and how these affect the attractiveness of LLLC specifications.
- Understand how value engineering affects lighting control specification generally and LLLC specifically.

For more detailed information about the approach, please see Appendix A.

4.2 Findings

The focus groups and interviews covered a wide range of topics. This section summarizes findings in each topic area.

4.2.1 Participant Characteristics

Specifiers included a variety of different specification-focused roles:

- Electrical engineer specializing in lighting controls working for an engineering firm (2)
- Independent lighting controls consultant (1)
- Specification salesperson, engineer, or controls specialist working for a manufacturer representative (3)[17]

While all specifiers had experience designing control systems and writing specifications, they provided different perspectives on the project process. Participants working for a manufacturer representative have fewer product options to work with and only specify equipment from the brands they represent. Independent consultants and engineers, on the other hand, will choose the best product to suit their client's project needs, regardless of brand.

4.2.2 Awareness of and Experience with LLLC Solutions

Familiarity and Terminology

All six specifiers understood LLLC technology and concepts. Four out of six specifiers were familiar with the term "LLLC," but all were familiar with the concept and had previously used LLLCs on projects. All specifiers expressed positive opinions of LLLCs, highlighting their flexibility and versatility.

Specifiers indicated a lack of consistency in the terminology surrounding LLLCs. While the four focus group participants were familiar with the term "LLLC," they agreed this is not the most commonly used term. Specifiers reported that "embedded controls" is used most often, but other terms like "individual controls" are also prevalent. They indicated the terminology is unspecific and leads to confusion: *"Do they mean individually addressable fixtures, or personal ability to control the lighting in one person's workspace?"* A few respondents mentioned hearing "embedded sensors in each luminaire" or "embedded fixture with integral controls." All indicated some level of confusion and frustration with the inconsistent language used to describe LLLC.

LLLC Benefits

Although specifiers typically incorporate LLLCs into projects to fulfill code requirements, LLLCs can also help specifiers meet specific end user's needs, including easy reconfiguration and people-counting capabilities. Respondents mentioned that LLLCs provide several key benefits to specifiers, contractors, and end users:

- Design flexibility: LLLCs guarantee adequate sensor coverage and reduce wiring needs compared to traditional wired control systems.
    - *"It increases coverage, whether it's required for code or if it's just convenience and good for your use case."*

[17] These specification sales professionals do not serve the same role as engineers and consultants that specify controls as part of a design team. However, because they participated in the focus group, their views are included in this reporting.

- Installation flexibility: LLLC systems are much easier to modify or correct on-site compared to traditional wired control systems.
    - *"Benefit from a controls person's perspective, it's ease of installation and ease of reconfiguration… The contractor doesn't have to go back up into the ceiling to modify. It's the get-out-of-jail-free card to modify the system without having to do rewiring. The cost is higher for the equipment, but when the contractors realize how much easier it is, they get on board too."*
- User flexibility: Users can modify settings.
- Easy integration with other building systems.
    - *"Also, they talk a lot about integration with other systems—you could work with the security designer and say, hey, I already have the sensors, what if my sensor tells your camera to start recording? It's a wealth of information."*

Specifier Skills

Currently, specifiers don't believe they need any new skills to incorporate LLLCs into their designs. However, they anticipate that they will need new skills in the future if code or customers begin to demand that all building systems become interconnected and communicate with one another. One respondent said maintaining simplicity is a critical skill: *"That's the potential challenge. Being able to refrain from overcomplicating the controls for something like an office or classroom."*

4.2.3 Barriers and Opportunities

Specifier Challenges

The biggest challenge specifiers face is communicating with building owners and end users. While specifiers believe that designing to meet code and lighting power density requirements is relatively simple, they find that explaining design decisions and the rationale behind code requirements to customers is particularly challenging. Many end users are resistant to both the complexity and added cost of lighting controls and struggle to understand why they are required by code. Multiple specifiers mentioned occupancy sensors as a feature that end users dislike. Specifiers emphasized a need for developing documents that clearly communicate design intent to customers.

Specifiers also described finding it difficult to strike a balance between designing to meet code and creating a user-friendly solution that owners can embrace and contractors can install. One specifier mentioned that younger contractors seem more comfortable with programming and doing the setup themselves. Though many contractors show a preference for embedded controls, specifiers said they are unlikely to use them unless they are included in the specification.

Additionally, cost is a top consideration for every project and higher up-front costs (as compared to other solutions) often steer customers away from implementing LLLCs. Customers typically do not understand or value the long-term energy savings and lower maintenance costs associated with LLLCs and specifiers face challenges demonstrating this.

Although all specifiers reported their projects with LLLCs were ultimately successful, one respondent mentioned problems with programming and that some LLLC products were not in-field serviceable, meaning the products are not designed to be repaired on site, requiring the entire luminaire to be replaced in the event of failure. Another respondent shared the same sentiment: *"Most manufacturers are going to replace the whole fixture, not repair the device within the fixture."*

Likelihood of Specifying LLLCs

All respondents said they are likely to specify systems with LLLCs and expect the number of LLLC projects to increase. Incentives are often used to fund projects, and designing in a way that qualifies for incentives is critical. Incentives can also motivate specifiers to use LLLCs.

Project Types and Applications

Specifiers report classrooms and open office spaces are ideal applications for LLLC installation because schools and offices see value in LLLCs' ease of reconfiguration. Specifiers viewed LLLCs as the most logical solution for many open offices because of energy code requirements for occupancy zones no larger than 600 square feet.

In contrast to the findings from the market actor interviews, multiple specifiers said warehouses are an ideal fit for LLLCs and can improve safety: *"For warehouses, not having to change wiring is a huge benefit. […] there's huge install savings in a warehouse retrofit. Also, the fact that you have multiple sensors is also a huge advantage. If one sensor misses you and you're down an aisle, from a safety perspective the multiple sensors are a big advantage."*

Specifiers mentioned that projects in existing buildings can be more challenging than new construction projects. Renovation projects require careful consideration of existing infrastructure and a determination of how much can be modified while preserving functionality. In some cases, wireless controls can eliminate the need for extensive rewiring and allow for more flexible placement of switches. In contrast, new construction projects provide a clean slate for implementing lighting controls. One specifier described maintaining consistency in renovation projects by using products from a single manufacturer and working to integrate controls with existing building automation systems.

Encouraging LLLC adoption

Specifiers offered the following key considerations for encouraging LLLC adoption:

- Contractor education.
- Better tools for communicating value.
- Improving code compliance through increased enforcement and code education.
- Ongoing specifier education.

Three respondents highlighted a need for contractor education to improve contractors' comfort with installing and promoting LLLCs. Echoing the findings from the supply chain and contractor research, specifiers said many contractors have limited exposure to LLLCs and are not fully comfortable working with them. While one specifier mentioned that newer or younger contractors tend to be more receptive to learning about LLLCs, another said newcomers often feel overwhelmed and struggle to stay abreast of new technology.

> *"For contractors… any sort of new thing is big and scary for them. Once they start to get things installed and sensors set up, I think they'd be pretty excited about it. Especially since so much is user-friendly. But it's getting that bridge made from looking at the new tech and thinking there is no way I'll be able to get this programmed to feeling confident."*
>
> ***– Specifier***

Developing better tools for communicating with customers, particularly regarding the value of LLLCs, is another key recommendation from specifiers. All respondents reported challenges communicating the value of LLLC systems with customers and end users and three mentioned that streamlined materials that easily communicate intent and design options would be highly valuable and could help convince customers to use LLLCs. One respondent said, *"You can't convince an owner without any documentation."* Although all respondents predicted that changes to energy code will drive LLLC adoption, two respondents said improving code education and compliance is critical to increasing LLLC installations because code is not adequately enforced or inspected.

Respondents also mentioned the importance of ongoing specifier education as new technology emerges. One respondent said specifiers have access to all the resources needed to learn about new lighting developments, but they must take the initiative to seek them out. According to one specifier, while some specifiers are naturally curious, others lack the initiative or drive to continue their education and may fall behind on new developments.

4.2.4 Value Engineering and Other Threats to LLLCs

Value engineering (VE) is the practice of altering a design with the goal of reducing project costs. This can happen via contractors offering alternative approaches or equipment that meet the design intent with the goal of reducing project costs, or it can occur if all bids come in too high and the specifier has to alter the design to re-solicit bids in an attempt to garner a lower price. Five out of six specifiers expressed frustration with VE. As one specifier noted, *"There's no value, there's no engineering… I can't stand it."* Specifiers believe that VE often leads to inferior designs and products to cut costs and satisfy customers' immediate requests while ignoring the long-term needs met by LLLCs and other advanced controls. Specifiers say LLLCs are more likely to be eliminated (rather than added) in VE but believe this is a mistake and end users and contractors fail to see the added value. *"They lose some functionality and granularity."* While specifiers see VE as a problem, they also noted that it does not happen often.

One specifier mentioned that customers often ask for an inferior product or brand, and they must find a way to tactfully communicate that this is the wrong decision: *"If I add that cost for embedded controls on each of the fixtures, it's more expensive than the powerpacks. But then you lose that flexibility, and in the long run you're also going to spend more for labor."*

Lead times can also result in LLLCs being removed from projects. One specifier said, *"One of the big things is lead times and ship dates. Everybody wants everything possible for the best price. And sometimes the best product has a really long lead time, so you may need to go with something else."*

Finally, even in cases where LLLCs are successfully installed, it is possible that end users will not use them to their greatest advantage. One respondent mentioned that often the design and construction team will install controls to meet code, but the specifier knows the customer will never use or connect them once the specifier leaves. This respondent mentioned this is particularly common in hospitals.

4.2.5 Energy Code and LLLCs

Energy Code Impact on Lighting Controls

Designing to meet energy code requirements is a fundamental aspect of specifiers' jobs. Specifiers report that code is pushing them toward LLLCs more often and code requirements make highly granular sensing logical in some spaces. LLLCs provide a means to achieve compliance with these code requirements.

Codes drive nearly all specifiers' design decisions. However, communicating the necessity of meeting code to customers can prove challenging because end users and building owners generally do not understand the purpose of certain lighting control features and why they are required by code: "*Some things have become over-designed. Like, to an end user, it may seem like way more than they need, but it's all designed to help them meet code.*" Specifiers expect codes to become more stringent and difficult to meet in the future: *"Codes aren't getting easier; they're getting more complex."*

LLLCs for Code Compliance

According to specifiers, LLLCs offer the flexibility necessary to meet code, particularly in areas where multiple lighting control strategies and plug load controls are required. Respondents viewed LLLCs as superior to traditional control systems for this reason.[18]

> *"LLLC offers that flexibility to meet the code. […] In most of these systems, it's not difficult to add a plug load controller and tie it into the occupancy sensors – in a wired system it would be difficult to do that. The digital flexibility helps meet code requirements as well as the end user requirements."*
>
> ***– Specifier***

Respondents find LLLCs more economical, simpler, and easier to design because they eliminate the need for occupancy coverage layouts and come as a comprehensive package. *"It's more economical for our design time. It's simpler, in my opinion."*

[18] Note that some benefits discussed here are associated with wireless LLLC systems, but not all LLLC systems are wireless. Further, there are other types of wireless controls that are not LLLCs.

Section 5 Building Decision Maker Interviews

This section presents the results of in-depth interviews with building decision makers conducted in June and July 2023. The sections that follow describe Cadeo's research approach and review detailed market insights from the interviews. The key takeaways from the interviews are:

- Most decision makers in commercial buildings rely primarily on the advice of others when selecting new lighting equipment.
- While many want to incorporate new technology as much as possible, they find it difficult to navigate the many options and rebates available on the market.
- Issues with staff capacity and funding often impede lighting upgrade projects, especially for larger portfolios with competing priorities for staff's time or operating budgets.
- Only 30% of our participants had heard of LLLCs prior to the interview, and none had any experience with them.
- LLLC benefits that were the most valuable to participants were extending the life of lighting equipment, better control over energy use, and ease of use.

5.1 Approach

We completed interviews with 17 building decision makers (contacts). Potential respondents were identified from CEE contact lists, primarily consisting of property managers and public entities who had worked with CEE previously and supplemented by other contacts from Cadeo. These in-depth interviews with key building contacts were designed to understand:

- Awareness, attitudes, and behaviors toward LLLCs (and lighting controls in general).
- Barriers and opportunities.
- Current experience with LLLCs (when applicable).
- The process for identifying and specifying LLLCs in projects.
- Value propositions for LLLC (including non-energy benefits of LLLC).

All interviews were conducted via video or phone call. For more detailed information about the approach, please see Appendix A.

5.2 Findings

The 17 building contacts represented a range of backgrounds, with responsibilities ranging from one large building to a portfolio of hundreds of buildings. Five participants worked in commercial real estate, 11 in the public sector, and 1 worked for a large non-profit. The building types represented included:

- Commercial office spaces.
- Non-profit offices and facilities.
- Retail, including strip malls.
- Medical, including hospitals.
- Public school buildings (classrooms, administrative offices, garages, athletic facilities).
- City and county municipal buildings (fire, police, jails, office, libraries, parks and recreation facilities, animal control facilities).

The interviews covered a wide range of topics, and this section summarizes findings in each topic area.

5.2.1 Awareness, Attitudes, and Behaviors

Current Lighting Control Systems

Fifteen of the 17 interviewees reported currently having lighting controls (of any kind) in their buildings. The two who did not currently have controls both worked in the public sector, one for a municipality's housing and redevelopment authority, and the other worked for a school system's ice rink arena.

When asked if they had ever considered installing lighting controls, interviewees provided varying responses. A contact working for the housing authority said most lighting equipment in their buildings is quite old and they have not considered adding lighting controls. He added that although his organization has done some LED retrofits, they do not know the *"pros and cons"* of lighting controls.

The school ice rink arena manager stated that while they had considered them, they faced budget constraints that reduced their options. Additionally, he said that they had concerns about investing scarce funds into new technology that may get destroyed by a loose puck, saying that *"everything needs to be smash proof."*

While their reasoning was different, both highlighted challenges related to funding, labor capacity, and knowledge of technology available.

The type and amount of lighting controls varied among the 15 participants with systems in place. Thirteen reported having occupancy sensors, making them the most common type of existing controls (Table 10).

Table 10: Interview Participants' Current Lighting Control Strategies (n=17)

Lighting Control System	Count
Occupancy Sensors	13
Daylight Sensors	7
Scheduled Lighting	7
High-End Trim	3

One participant (in the commercial real estate sector) knew that they had lighting controls but did not know exactly what strategies or in which buildings because they managed a large portfolio and struggled to recall building specifics. They assumed it was likely they had all the above, but did not want to misspeak, so their response is not reflected in the counts in Table 10. It is not uncommon for property managers to be unaware of all their lighting control systems, thus the counts in Table 10 may only reflect what they are personally aware of.

Eight contacts reported having multiple control strategies, and three had all four systems. As expected, all participants who reported having high-end trim also had other strategies. In several instances (6), occupancy sensors were the only lighting control strategy installed.

Desired Characteristics for Lighting Control Systems

Building contacts reported the characteristics they would want from their ideal lighting control system. Responses varied, but all answers included some combination of the nine features listed in Table 11 below.

Table 11: Characteristics of an Ideal Lighting Control System (Multiple Responses Represented)

Capability	Count	Exemplary Quote
Motion Control	6	*"Just shut off when people leave the room."*
Increased Controllability (Compared to Current System)	4	*"Even just a dimmer control would be wonderful. Having a way to control the amount of light to whatever degree we want it to would be a nice option."*
Remote Control	4	*"There seems to be more and more smart controls—like apps and remote controls for property managers and maintenance guys. We just haven't been able to take that step because of the cost."*
Scheduling	4	*"Schedules for on off times. We have emergency lighting that needs to be controlled on different schedules."*
Fully Automated	3	*"[My ideal system would be] for everything to be fully automated and to never see lights on when it is unnecessary."*
User-Friendly	2	*"Well, something that is user-friendly where I could say: 'at this time, I know that these lights will go on.' Just having the control to be able to do that sort of thing. No one really knows what's going on with different lights, and there are unused timers—it's just a mess."*
Daylight Harvesting	2	*"It would be nice if the lighting control system had the ability to adjust to the lighting outside—on a bright sunny day, let the lights dim."*
Integration with Security Cameras	1	*"I know these are out there, but in a perfect world, I would love lighting controls that would have more sensors and cameras that turn on and off outside with the lighting system as well. For security purposes for our residents, but also because it would allow us to capture what may be going on outside the building and know too if sensors are too sensitive and going off for a branch in the wind or something."*
Provide Building Data	1	*"More advanced data related to being able to home in on specific fixtures or being able to measure projects, like here's the energy we were using before we replaced everything with LEDs…Something where we can get more detailed in evaluating specific fixture's performance and energy use."*

Most building contacts acknowledged that the features they described were available but said that they either could not invest in new equipment or did not have the time or capacity to take on the new lighting project. One participant summed up their ideal system by saying: *"Save us money ultimately."*

Lighting Control Programming

A majority of building contacts said that the contractor or electrician who installed their lighting controls systems also programmed the controls. In a handful of instances, the controls were programmed in-house

by the building engineer or maintenance manager. One contact said that the public works director of their municipality programmed their controls.

Of the 15 participants with existing controls, 9 reported no concerns about the programming. The others listed a range of concerns, which fell into the following categories:

- Issues with a contractor
- Ensuring the settings are appropriate
- Ease of changing settings as needed

No one was concerned about the technology itself. Most concerns revolved around making sure that the contractor understands their lighting needs and that controls are programmed in a timely way. One contact mentioned dealing with contractors who were *"bad apples"* who failed to program their system and they ultimately hired another contractor to make their sensors work. Other building contacts worried about knowing how to program the settings in the first place, and how to best communicate their needs to the contractor programming them: *"After they are programmed, we might find that they don't work, or don't stay on long enough, or sensors aren't pointing in the most effective position…communicating our needs to the person programming them can be challenging."* Similarly, another contact had concerns about the process of changing configurations afterward if they received occupant feedback like the lights were not staying on long enough or that they were too bright, etc.

Familiarity with Luminaire Level Lighting Control (LLLC)

Twelve of the 17 (71%) building contacts were unfamiliar with LLLC, even after being provided with a brief description. Only 5 of the 17 building contacts had heard of LLLC previously, all of whom worked in the public sector.

5.2.2 Decision Making Processes

Causes for Lighting Equipment Replacement

Respondents described a wide variety of processes for obtaining lighting equipment upgrades and replacements. The reasons behind the upgrades, such as how and when replacements occurred, generally fell into the following categories:

- **Based on available rebates or incentives.** Lighting systems are substantial investments and for many building representatives any lighting equipment upgrades were timed to take advantage of as many rebates and incentives as possible.

  "*The last time [lighting equipment was replaced], it was because we had learned from the school electrician that there were a lot of rebates available for switching to LEDs.*"
- **When equipment wears out.** The cost and inconvenience of major system upgrades means that key decision makers will only upgrade and replace equipment as needed. In some instances, the decision to replace equipment is based on city- or county-wide lighting audits to determine which buildings were most in need of upgrades, meaning that facility staff did not have decision making authority. For others, the facility staff could decide to replace equipment when an old system failed. One contact stated that they still had lighting equipment dating to the 1970s and 1980s that they planned to continue to use until they no longer could.

  "*In multi-family buildings, it doesn't happen unless there is a refresh of a space, or a rehab of units. But we generally try and maintain what we have for as long as we can.*"

- **If better technology becomes available**. Many building owners recognize the benefits to their building that come from having the latest technologies. Some building contacts stated that they upgraded their systems when new technology became available, while another reported evaluating their lighting systems every five years to determine if better technology was available.
- **During remodeling or rehabilitation projects.** In some buildings, typically commercial real estate, building representatives said that they only updated lighting systems while doing other major repairs or remodels, often as tenant improvement projects.

Influences on Lighting Equipment Choice

Once end users make the decision to replace equipment, the next step in the process is to choose the equipment. When asked how they make these decisions, building contacts overwhelmingly said that they relied on the advice of others (12), either contractors, vendors, or consultants. In many instances, this was attributed to the sheer volume of options and their lack of personal knowledge of the lighting market.

> *"We would rely on a consultant to help figure that out. And maybe a designer if it is a big common area. The lighting world is pretty opaque in terms of what's out there, so I really rely heavily on consultants to let me know what's out there."*

Outside of trusted third parties, contacts also listed variables that affected the equipment they decided to install. Two building contacts said that they try to look for something as similar as possible to what they already had in place: "*A lot of times a one-for-one swap out with whatever LED product is similar if possible. Otherwise, there are lots of fixture replacements to make maintenance easier down the road.*" Other respondents indicated that they try to adopt whatever new technology is available.

We asked building contacts about other sources of information that they used to weigh their options. Almost all participants (15 of 17) reported relying on their contractors. In five instances, contacts relied on these professionals exclusively to help make decisions: *"We go with our main contractor and stick with them across all our buildings."* Table 12 presents the other information sources participants used.

Table 12: Lighting Control Equipment Information Sources

Information Sources	Count
Contractors/Vendors	15
Designers/Consultants/Architects	5
In-house Maintenance Crew	2
Internet	2
Peers	2
CEE	2
Sustainability Coordinator	1
Trade Shows/Conferences	1

Most contacts relied on someone they trusted to give them information, and only very few reported doing outside research, such as online or attending trade shows.

> *"It's pretty straightforward—if it's recommended by people I trust, then I'm good."*

Equipment Bid Review Process

Only two building contacts did not require a bid review, neither of which worked in the public sector. The other 15 participants required bids, though some only in certain circumstances. Nine always review multiple bids. One contact suggested that this was not necessarily a requirement as a strategy to help navigate the many options available. *"There is a wider range of options on the lighting side, so we find that it's harder to navigate. How does something look or perform? When is it available? We tend to take a while to decide on lighting systems."*

Six building representatives said that multiple bids were only required when project cost exceeded a threshold, explaining that *"[because] lighting tends to be a lot cheaper [than other projects], and we've been able to eek smaller projects out of our operating budgets. But for larger projects, we have a full bid process."*

Building contacts described a variety of challenges they face reviewing bids and selecting lighting systems and controls. The most common responses tended to focus on supply chain actors and factors, including:

1 | Challenges navigating all the options and rebates available: "There is a wider range of options on the lighting side than on the heating side, so we find that it's harder to navigate. How does something look or perform, and when is it available? It tends to take longer to decide on. And it can take a while to get the lighting levels correct in common areas."
2 | Lack of contractor availability: "People don't want to work with us. They just don't get back to us. We'll send them a bid package and then never hear anything. People must either be really busy or just really don't want to work with the government. And I understand both."
3 | Lack of specifier or contractor knowledge: "The biggest challenges are any gaps in knowledge that there may be with their architects or engineers. Which is why we first got involved with CEE."

Other, less common, challenges are:

- Bids coming in higher than available budget.
- Time commitment of the review process.
- Having older buildings and running into unexpected issues during big projects.
- Maintenance crew understanding of the new technology.

Many interviewees had recently completed an interview about HVAC system upgrades. In multiple instances contacts compared the lighting and HVAC decision making processes and their challenges.

> *"The challenges are similar to what was experienced with HVAC, but with lighting, the contractors are more helpful with applying for rebates, which they don't do for HVAC. And generally, they are much easier to work with for lighting than with HVAC. Maybe it's because they know us better? So maybe it's really about relationships."*

Several respondents commented that working with lighting contractors and electricians was easier than working with other contractors.

5.2.3 Barriers and Opportunities

Perceived Benefits of Lighting Controls

The interviewers asked the 15 participants who reported having lighting controls currently what benefits, if any, they had seen since installing them. Their answers varied, and many participants listed several benefits, but all benefits fell into the following categories, detailed in Table 13 below.

Table 13: Perceived Benefits of Lighting Controls

Benefit	Count	Exemplary Quote
Energy Use	7	*"We're seeing a 12-15% drop in energy usage by installing these building automation systems. And LEDs might be a no-brainer, but without the automation then the energy savings aren't sustainable."*
Financial	6	*"The cost of utilities has really skyrocketed in the last few years. It's now the biggest cost, so everything helps."*
Maintenance Crew	5	*"[The lighting control] helps save us so much time. It reduces trips for the engineers to the building by not having to physically be there to turn off lights, because they can use an app. They have saved us in both energy use and time."*

In addition to the commonly cited benefits, one participant in the commercial real estate sector said that one of the biggest benefits they received from lighting controls was the public perception around being more sustainable. One participant, who works for a large public school system, said that they saw benefits in student comfort by having more flexibility and lighting characteristics through controls. *"The impact is mostly being seen in the student comfort, allowing us to give more lighting color options for students and better dimming controls for teachers. It's especially helpful in the special needs classrooms where some students are more sensitive to light."*

One participant said that they had not really noticed any benefits: *"[We] haven't really noticed anything. Bill may be slightly less? Pretty much the same as before though."* One participant was not asked about the benefits of their lighting control systems because they were only involved in procurement and were not involved in operations.

Perceived Drawbacks of Lighting Controls

Eight of the 15 participants with lighting controls said they did not see any drawbacks to their systems. Six of the participants listed a handful of issues that they or members of their maintenance team had experienced. One participant was not involved in the day-to-day lighting operations and was not asked about drawbacks.

Of the six who had noted drawbacks, two said that they were concerned about the lighting controls failing or breaking. However, in both cases they said that that concern did not outweigh the benefits they were seeing: *"Sometimes they break, but not so much. For the most part they're beneficial."*

One participant discussed the pace of technology being an issue that they have dealt with*: "I think some of the technology we have is a bit outdated and we can no longer get support on one of the systems that we*

have." This made him hesitant to update again too soon so he did not continuously find the building in the same situation.

One participant said that their crew preferred a more manual system, but that that was just because they weren't as familiar with the more high-tech controls: "*Some people dislike the occupancy sensors—not end users, but coworkers [on the maintenance team]—who prefer simple switches instead of lights that [turn themselves] on and off. But I think it's the kind of thing that people get used to.*" That same participant also said that they had some challenges in getting the controls calibrated just right: "*Initially, it takes a little more effort to get them calibrated correctly. Deciding how long it needs to stay on, is the sensor pointed correctly, etc.*"

Two participants seemed to conflate the drawbacks of lighting controls with those of LEDs as they have replaced legacy lighting with LEDs at the same time as they installed controls. In one case occupants thought LED light was too harsh, in another, the interviewee stated that they had to change the LED bulbs more regularly: "*The outside lights are brighter than the old ones used to be. And people have looked at the new bright LEDs as too light outside.*"

Despite these drawbacks, participants often noted that they did not outweigh the benefits they were seeing.

Opportunities to Improve Lighting Control Systems

Eight of the 15 participants who currently have controls said they saw an opportunity to improve their current lighting control system. Most said that while they were happy with what they had, they anticipate new technology that they will want to update their systems with eventually. Some said that they hoped for new technology for specific purposes, with one participant saying, "*It would really depend on connectivity between our buildings. If they could all tie together that would be amazing.*"

The other seven replied no, they did not see opportunities for improvement. This group also said they were happy with what they had, they just did not imagine needing more: "*I mean, it is always a work in progress, but we are really happy with the system we have in place.*"

LLLC Opportunities

Researchers asked all 17 participants to rate LLLC features as either valuable, somewhat valuable, or not at all valuable. Their responses are shown in Table 14.

Table 14: Benefits from Networked Lighting Control Systems (n=17)

	Valuable	%	Somewhat Valuable	%	Not Valuable	%
Control Energy Use	15	88%	1	6%	1	6%
Extend Equipment Life	14	82%	2	12%	1	6%
Easy Changes	12	70%	3	18%	2	12%
More Flexibility	7	41%	5	29%	5	29%
Remote Monitoring	7	41%	5	29%	5	29%
Building Data	7	41%	4	24%	6	35%

Fifteen of the 17 building contacts (88%) considered controlling energy usage valuable. Extending the life of the lighting equipment was considered valuable by 14 of the 17 (82%) building contacts. Several respondents noted that these benefits were valuable because they resulted in cost savings.

Twelve of the 17 building contacts (70%) said facilitating easy changes in lighting settings or configuration was valuable, 3 said this was somewhat valuable, and only 2 said it was not at all valuable. One of the participants who had said not at all valuable said, "*Easier than what? For us, it's not important but maybe for a rec center director it would be more important.*" This participant worked for their city and in procuring light systems for municipally owned buildings.

When asked about the value of providing building data for other applications, like informing HVAC systems of occupancy, 7 of the 17 (41%) said valuable. One of those respondents who said somewhat valuable remarked that "*It could be, but I don't see us getting there for a long time. So many more entry-level energy management priorities.*" Six participants said it was not at all valuable. Issues with staff capacity seemed to be a driving factor for that reasoning as well. As one participant said, "*We just don't even have the bandwidth to have anyone do anything with that information.*"

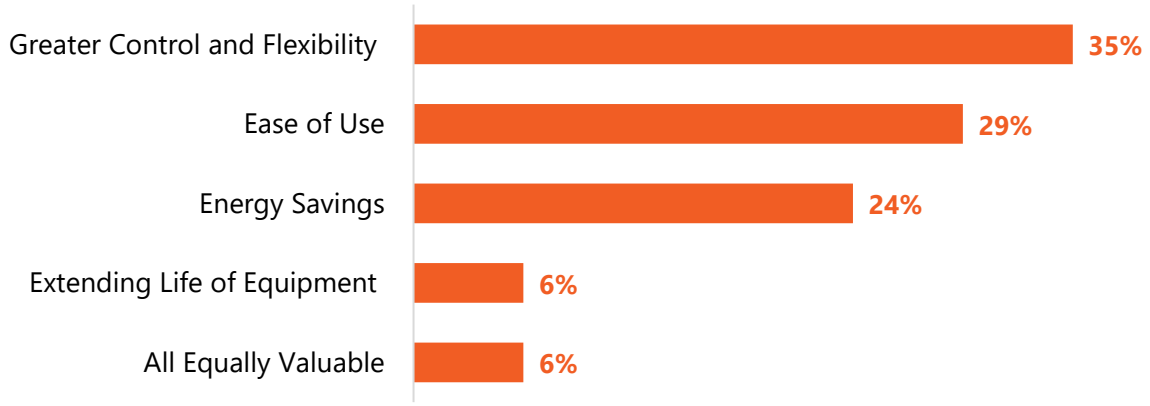
Offering more flexibility to customize lighting characteristics scored similarly, with 7 of the 17 (41%) saying valuable, 5 saying somewhat valuable, and another 5 saying not at all valuable. Those who did not think this feature was particularly valuable suggested it was because building occupants and end users just were not interested in customizing the lights. One of the participants who answered somewhat valuable explained by saying, *"We've offered that before at other schools and no one has really been interested in that. Just sort of not used besides dimming.*" Another of the participants who said not valuable said that *"I see how it's important, but in the buildings I manage, they're more Class B, or B-, and it's just not a big selling point."*

Only 7 of the 17 participants (41%) thought that being enabled for remote control or monitoring via an app was valuable.

The interviewer next asked participants which of the listed features they had just rated would be the most valuable. And while many answered with features that were included in the list above, this question was

open-ended and some answers were not included in the previous question. Their answers are shown in Figure 15.

Figure 15: Most Valuable Feature of Networked Lighting Controls, (n=17)



Four of the 17 participants said they thought that the energy savings were the most valuable benefit. Ease of use is considered the most valuable by 5 of the 17 participants. Extending the life of the equipment is only considered the most important by one participant.

Despite only seven participants saying that greater control and flexibility was valuable previously, the highest number of participants considered it the most valuable. Six of the 17 participants (35%) thought that greater control over the amount of light and flexibility was the most valuable. So, while not everyone thought this was a valuable feature, those who reported it was considered it the most valuable.

One participant thought that listed control features were all equally valuable.

Only one participant highlighted cost savings as most important but listed it together with energy savings. These two features may be linked for participants.

Ideal Locations for LLLCs

Participants' answers about spaces that would make a particularly good fit for LLLCs varied greatly. Three participants thought that common spaces, like hallways, stairwells, and parking garages, would be great candidates for LLLCs. Another two participants thought that office spaces would be a good fit while two others thought that hospitals or doctor's offices would benefit. Two participants who worked in school systems thought that LLLCs would be a good fit for classrooms. And another participant who worked as property manager for a county thought that 24-hr facilities and jails would be good applications for LLLCs, especially because they would allow for easy changes to light settings and would be minimally disruptive.

Section 6 Conclusions and Recommendations

6.1 Conclusions

The team's research revealed an emerging LLLC market in Minnesota. While LLLC technology faces some critical market barriers, the Minnesota market also has some existing strengths that present opportunities for market transformation.

6.1.1 Market Conditions

This research identified the following key LLLC market conditions:

LLLC systems are widely applicable. Supply chain and specifier interviews identified offices (including corporate campuses and open office spaces in particular), schools, and higher-education campuses as the ideal applications for LLLCs. End users also suggested common spaces like hallways and stairwells, and parking garages as potentially beneficial applications for LLLC. Specifiers and contractors also mentioned warehouses and industrial settings as good applications, but supply chain interviewees noted that some of these facilities may have concerns about safety.

Advanced controls remain rare. The research team assessed the frequency of installation of LLLCs as compared to other control strategies through the contractor survey. The survey results indicate that standalone (non-networked, not fixture-embedded) occupancy sensors and photocells are the most commonly installed control equipment in Minnesota today. Among the projects reported by contractor respondents, 77% had no lighting controls and an additional 17% had standalone controls (including occupancy sensors, photocells, and timeclocks). The remaining share of projects had a mix of LLLCs (1%), NLCs (.5%), and non-networked light fixtures with embedded sensors (4%). These results indicate that LLLCs are rarely installed in Minnesota, while standalone controls are typical for projects that include controls.[19] Our data did not reveal notable differences in LLLC market share between new construction and retrofit. If it is important to understand adoption in new construction and retrofit markets separately, future research could investigate each segment.

Competing solutions are available. Given their similarity in features, LLLCs likely compete most often with NLCs and with non-networked light fixtures with embedded sensors. Supply chain and specifier interviewees described achieving advanced control capabilities by installing NLC systems with individually addressable fixtures without embedded sensors.[20] Non-networked fixtures with embedded sensors may provide an alternative to LLLCs. Interviewees described LLLC systems' scalability—i.e., the ability to upgrade system software to enable more features—as one of the technology's advantages.

Inconsistent terminology hampers understanding. Across all market actor data collection, the team observed that the term LLLC is not widely or consistently used, and there is a lack of consistency in the terms market actors use to describe various types of NLCs and other control strategies. Resolving this disparity is essential to facilitating effective communication between lighting professionals, contractors, and end users.

[19] See Section 3.2.3 Market Share of LLLCs for detail on how the team analyzed market share.
[20] Addressable fixtures have communication components that allow each fixture to be controlled individually. This is an NLC configuration that is distinct from LLLC, which additionally includes sensors in each fixture.

6.1.2 Market Actor Roles and Influences

A complex ecosystem of influence informs lighting control decisions. The team identified three key roles that exert influence on project decisions in various project types: specifiers, manufacturers' reps, and contractors.

Specification is a critical decision-making step in any project and the prime opportunity to influence lighting and controls decision making. The specification role includes selecting and specifying the products and their configuration and can be performed by different market actors depending on project type. Electrical engineers typically specify controls on new construction and major renovation projects. On retrofit projects, the electrical or lighting contractor is most likely to specify controls. In both segments, manufacturers' reps often provide input on specification.

Manufacturers' reps are a key source of information and influence in project decisions, given their influence on specification and broad interaction with all other market actors. Reps tend to be up-to-date and very knowledgeable about their specific product lines and their capabilities. Manufacturer reps are also a frequent source of project support for contractors, indicating that reps may be an effective resource for improving contractor education and comfort with LLLC.

Building decision makers consistently reported relying on their contractors to recommend lighting and controls solutions. They also described multiple factors affecting their decision-making process. For example, new and efficient technology being available on the market, and rebates to help them cover the cost of installation. Others commented that while one or the other factor may lead them to consider their options, they still tried to maintain older equipment for as long as possible.

Most contractors are not currently promoting LLLC. Findings from the market actor interviews indicate that customers are unlikely to request LLLC and instead rely on a contractor to guide their lighting decisions. However, contractors report that they generally only recommend advanced controls, including LLLCs, if customers request these solutions. Additionally, specifiers mentioned that even among contractors who are comfortable with LLLCs, most will not include them in bids unless they are explicitly mentioned in the specification. Contractor education is needed, particularly on the configuration and programming aspects of LLLCs and on how to promote LLLCs to customers by articulating the value proposition, including life cycle cost savings.

6.1.3 LLLC Awareness

End users and contractors lack awareness of LLLC. The team's findings indicate that awareness of LLLC technology is strongest at the top of the supply chain, with all supply chain actors and specifiers having at least some familiarity with LLLC technology. The lowest levels of awareness were observed among end users, 29% of whom were familiar with LLLC. Next lowest awareness was among contractors, at 62%. Strengthening understanding of LLLC benefits and how LLLC can meet specific end user needs will be most impactful in the customer-facing end of the supply chain.

6.1.4 Contractor Preparedness

Contractors have insufficient expertise in LLLCs, including technical installation and programming skills as well as sales skills. Less than 20% of contractors feel fully prepared to sell, install, and program an LLLC system. Additionally, only 20% of contractors had received any training on LLLC systems, and even fewer had received hands-on training, which is their preferred method of learning. Interviews also indicated that

smaller contractors are likely to need the most support, while larger contractors are more likely to pursue training on new technologies.

6.1.5 LLLC Value Propositions

Market actors and end users alike recognize an array of benefits that LLLC can offer. However, building decision makers value some benefits more highly than others, and may not be interested in all the benefits manufacturers tout.

Energy savings, extending equipment life, and ease of changing settings were the benefits end users valued most highly. Conversely, flexibility, remote monitoring, and collecting building data were viewed as less valuable. However, for end users who valued flexibility, they considered flexibility as the most valuable benefit, indicating it is very important for a smaller number of end users. None of the end users interviewed had installed LLLCs in their buildings, demonstrating that thus far they have not perceived the value of LLLCs as compelling enough to overcome the barriers they face. Market actors should highlight value propositions that clearly demonstrate how LLLC offers advantages in areas of greatest importance to end users over other competing options. For example, education and marketing materials should clarify that additional energy savings, beyond those produced by standalone controls or other NLC configurations, are possible with LLLC. To highlight ease of changing settings, materials could feature examples of using LLLC systems to set distinct schedules for emergency lighting, a desired use case one respondent mentioned.

Contractors value the labor cost and time savings they can achieve when using LLLC systems. Contractors reported that the most valuable benefits of LLLC systems for them are lower installation costs and faster installation. Some contractors also value the ability to program LLLCs themselves, as opposed to requiring a third-party programmer, as well as easy reconfiguration and fewer components to manage or install.

Supply chain actors and specifiers view flexibility as an attractive feature of LLLC, but this value does not resonate strongly with most end users. LLLC systems provide flexibility in multiple ways: systems can be reconfigured to accommodate changes in space layout, systems can be upgraded to enable additional features, and systems can be modified during the construction process without rewiring. Supply chain interviewees, contractors, and specifiers all recognized the value of these flexibility features. But most building decision maker interviewees did not find these features as compelling.

6.1.6 Awareness and Role of Rebates

The research indicates that contractors lack awareness of utility rebates for LLLCs, but all market actor groups agreed that rebates are an important sales tool.

Contractors lack awareness of utility incentives for LLLC. Thirty-nine percent of the contractors surveyed are aware of utility rebates for LLLC in the area they work in. This likely means that utility incentives are an underutilized tool for promoting the adoption of LLLC and offsetting market concerns about high upfront cost.

Utility incentives are a widely recognized tool for promoting LLLC. All market actors view utility incentives as a valuable tool for encouraging LLLC adoption. Despite their low awareness of incentives for LLLC, most contractors surveyed (65%) believe rebates are important in encouraging selection of LLLC

systems. Some end users indicated that rebates directly influence their decision making about lighting projects.

6.1.7 Market Barriers and Opportunities by Market Actor Group

Interviews across the supply chain identified a number of challenges specific to each group we interviewed. These barriers and opportunities consider how the different supply chain actors interact with each other and how they do their jobs. It is a more people-focused view of the barriers and opportunities for advanced lighting controls. This will help CEE understand the point of view of market actors for future conversations and factors into the best opportunities for programmatic intervention.

Supply Chain Market Actors

(Manufacturers, Manufacturers' Representatives, Distributors)

Barriers	Opportunities
⊘ The high initial costs of LLLC systems often deter would-be adopters, making consistency of value proposition messaging important. ⊘ The flexibility and customizability of LLLC systems can require complex programming steps. This complexity, combined with the need for specifiers and contractors to learn the details of multiple systems, contributes to slow uptake. Frustrating experiences with programming can discourage specifiers and contractors from embracing LLLC.	✓ Contractor awareness building and education, including offering or collaborating on hands-on skill building to help contractors gain fluency with programming LLLC systems. ✓ Informing specifiers of value proposition of LLLCs. ✓ Promotion of the opportunity to offset costs through rebates. ✓ Code education for both contractors and specifiers.

Contractors

Barriers	Opportunities
⊘ Contractors face challenges with programming control systems, especially those with more complex programming processes. Few contractors have received training on LLLC.	✓ Contractors are interested in receiving LLLC training and need hands-on education on programming LLLC systems as well as education on how to communicate the value of LLLC.

- ⊘ Contractors are not prepared to sell LLLC or communicate the value of LLLC to their customers. This means that they are not prepared to justify higher material costs that may be associated with LLLCs as compared to other lighting and controls solutions.
- ⊘ Many contractors are unaware of available utility rebates that could be applicable to LLLC projects.
- ✓ Contractors can save installation time and costs by utilizing LLLC.
- ✓ Contractors have an opportunity to leverage utility rebates for LLLC but need to be informed of rebate opportunities and may need support in following rebate requirements.

Specifiers

Barriers	Opportunities
⊘ Ability to communicate value proposition of LLLCs to customers. ⊘ Although specifiers design to meet energy code requirements, they report that code is not always adequately enforced, therefore controls seldom are implemented in retrofits. ⊘ Cost is almost always a top consideration for projects and higher up-front costs (as compared to other solutions) can steer customers away from implementing LLLCs. ⊘ Specifiers are faced with learning about many new technologies and products.	✓ Ability to communicate value proposition of LLLCs to customers. ✓ Specifiers may also be interested in on-demand education on new technologies and products to ease the burden of learning. ✓ Ensuring specifiers are aware of utility rebates that can apply to LLLC will allow them to leverage rebates to offset costs. ✓ Improving code enforcement would help ensure that controls are included in retrofits and in new construction, specifications are correctly implemented in buildings.

Building Decision Makers

Barriers	Opportunities
⊘ Building decision makers find navigating available lighting and controls solutions to be challenging and sometimes overwhelming. Many interviewees reported	✓ Building skills among contractors will help building representatives improve their lighting decision making.

having limited staff bandwidth for handling lighting or control needs.
- ⊘ Lack of contractor availability or lack of strong contractor relationships can make it challenging for decision makers to have their lighting and control needs understood.
- ⊘ With the proliferation of new lighting and controls technologies, some manufacturers have discontinued and stopped supporting systems over time, leaving end users without help managing their controls.
- ⊘ Funding constraints and limited budgets can prevent building decision makers from investing in new lighting equipment.
- ⊘ Advanced control systems, including LLLC, are not viewed as a priority except in high-end spaces like Class-A commercial buildings.

- ✓ Some building owners would be motivated to upgrade their control system to achieve inter-building connectivity.
- ✓ Ensuring utility rebates are widely available and supported will help diminish (but not eliminate) cost concerns.

6.2 Recommendations

Based on our research findings, the Cadeo team offers the following recommendations for CEE to consider in designing its LLLC market interventions. Market transformation efforts need multiple tools for intervening in the market, and these recommendations present a variety of options for market intervention approaches. CEE may determine that certain interventions need a near-term focus while others can be delayed, resulting in a staged approach to introducing multiple intervention strategies.

CEE should strengthen partnerships with leading firms in Minnesota that sell, design, specify, install, and program lighting control systems. Supply chain actors, specifiers, and contractors all influence end user decisions around lighting controls. For CEE's market intervention to succeed, it will need to partner with these professionals to influence market practices and support continuous learning and adaptation to market conditions over time. To influence the retrofit market, CEE should prioritize building relationships with leading electrical contracting firms, lighting retrofit firms, and lighting consulting firms as well as exploring partnerships with manufacturer rep agencies that represent LLLC systems. To influence new construction and major renovation activity, CEE should prioritize building relationships with manufacturer rep agencies that represent LLLC systems, and leading architecture, engineering, and lighting design firms. Building these partnerships should be a near-term priority for CEE, because partnerships will strengthen and enhance all subsequent market interventions.

CEE should invest in educating contractors on (1) technical skills for installing and programming LLLCs and (2) understanding and communicating the LLLC value proposition in retrofit projects. Contractors indicated interest in receiving more training on LLLC. Professional organizations and supply chain market actors, particularly manufacturers' reps, may be effective partners in education. Hands-on training is of particular importance for contractors to learn technical skills, and the greatest need for technical training is in programming LLLC systems. One distributor interviewee noted that medium- to larger-sized contractors are more interested in training than smaller firms. Supply chain interviewees

believe that once contractors gain familiarity and comfort with LLLC technical skills they will be strong champions of the technology. Therefore, it is also critical for contractors to understand how to communicate the value of LLLC to their retrofit customers. All market actor and end user groups studied in this effort highlighted the need for contractor education, indicating that this need affects multiple aspects of the LLLC market, and CEE should consider it a priority area for intervention.

CEE should consider direct and indirect strategies for educating end users and building owners on the value of LLLC. Lack of awareness and a poor understanding of the benefits of LLLC among building decision makers can be a barrier to wider LLLC adoption. In particular, cost is a critical decision driver, and the cost savings associated with LLLC technology (via labor savings at installation and via energy savings upon occupying the space) may be compelling enough to influence purchasing decisions. Efforts to drive improved awareness and increased promotion through the supply chain will indirectly bridge this knowledge gap by improving specifier and contractor knowledge and understanding of LLLCs and its benefits. However, CEE should also consider direct strategies for building awareness among end users to increase the market acceptance of LLLC, particularly among high-leverage building decision makers such as commercial property managers who influence a portfolio of buildings.

CEE should develop and disseminate clear, targeted, and compelling value proposition messaging to assist market actors in communicating the value of LLLC. For example, CEE could develop case studies that illustrate the cost savings that can be achieved through LLLC systems, featuring different building types that would allow diverse building decision makers to relate their own facilities to the value proposition. As another example, interviews with supply chain actors revealed some hesitancy and misunderstanding around LLLC technology in warehouse and manufacturing settings, with interviewees mentioning that such facilities cannot risk malfunctioning lighting controls causing unsafe conditions. However, another interviewee indicated that properly implemented LLLCs can *reduce* safety hazards. CEE can build greater market acceptance of LLLC by finding ways to ensure systems are programmed correctly and operation is verified thoroughly. CEE's efforts to build understanding of LLLC's value propositions will also add credibility to manufacturer messaging.

CEE should support standard terminology around LLLC definitions across programs and key stakeholders. Interviewees revealed inconsistent understanding of the term Luminaire Level Lighting Control (LLLC). Once interviewers explained the characteristics of LLLC technology, all respondents were at least somewhat familiar with the concept. This indicates a lack of consistent terminology for LLLC, which can create confusion that prevents adoption. Currently, market actors tend to speak about all forms of embedded controls as a category, lumping LLLC together with other approaches. Market actors may miss opportunities to highlight LLLC as the most beneficial approach, when relevant, if they don't distinguish between LLLC and other control strategies. CEE can encourage consistency by using consistent terminology in all marketing and educational materials. This will help market actors differentiate between LLLCs, with their rich set of energy and non-energy benefits, and other approaches to wireless or embedded controls that may provide less value.

CEE should support Minnesota utilities in offering simple-to-use, financially compelling rebates for LLLC. LLLC systems are eligible for lighting controls rebates in some areas of Minnesota, but awareness of LLLC rebates is low, particularly among contractors: 60% of surveyed contractors were unaware of rebates for LLLCs. Competitive stand-alone rebates for LLLCs may improve awareness and adoption of the technology. While respondents agreed that simplicity is paramount for rebates to be most effective,

various rebate designs for LLLCs can be effective, including stand-alone rebates for LLLCs or LLLC rebates as part of a broader lighting controls rebate offering.

CEE should consider (1) promoting (through educational or media channels) LLLC as a tool for meeting energy code requirements and (2) seeking opportunities to improve energy code enforcement. Recent changes in Minnesota's energy code are already driving specifiers to consider LLLC more frequently, but improved awareness of LLLC as a tool for meeting code requirements would strengthen the impact of this shift in professional practice. Furthermore, specifiers indicated that lack of energy code enforcement means Minnesota is not maximizing the impact of the transformative effects of the code. The issue of non-compliance with energy code is particularly common on retrofit projects that may not involve an engineer in design and specification.[21] A new construction or major renovation project is more likely to be designed to meet code, but even in these projects, interviewees said there may be either no inspection for energy code compliance or a cursory inspection that does not confirm controls are programmed correctly.

6.3 Research Opportunities

The team identified several areas where CEE may benefit from additional learning to support the development and launch of its program.

Assess user experience through interviews with LLLC users. Interviews with market actors and decision makers gave us insight into barriers and opportunities for LLLC adoption, but they did not give us insight into the user experience after installing LLLC systems. Engaging with LLLC end users can offer a firsthand perspective on usability, challenges, and overall satisfaction. These interviews could help inform CEE's portrayal of the LLLC value proposition and ground communication in real-world experiences of LLLC benefits. Identifying these users may be challenging, but Cadeo would recommend reviewing utility incentive records and tapping into relationships with manufacturer reps as two potential channels for finding instances of LLLC systems installed in Minnesota.

Collect building audit data and survey building contacts. The interviews with building contacts revealed that many key decision makers might not be fully informed about what lighting controls they currently have installed across their portfolios. Enhancing our understanding of the current presence and characteristics of lighting controls in different buildings necessitates more comprehensive data collection. Carrying out building audits and surveying additional individuals responsible for building management could provide more detailed insights into currently installed control systems and practices, as well as opportunities for improvement.

Gain insights from additional industry professionals by interviewing architects, design-build firms, and large electrical contracting firms. The perspectives of key contacts within architecture firms, design build firms, and large electrical contracting firms may help CEE identify opportunities for intervention, particularly targeting the new construction segment of the market. Conducting these interviews can give additional insights into the integration, perception, and utilization of LLLC within their respective spheres, beyond what we gathered for this report.

Investigate risks and benefits of the application of LLLC in warehouse and manufacturing settings. The interview results revealed mixed opinions on whether LLLC may be beneficial or harmful in businesses

[21] Minnesota Energy Code is applicable in some lighting retrofit scenarios. This study did not include a review of code applicability, but future research could investigate the opportunity to improve code compliance in applicable retrofit settings.

that involve heavy equipment and potential for safety risk. CEE may want to clarify this issue by investigating to what extent safety concerns around LLLC in these environments stem from genuine issues with products or implementation or a market misunderstanding.

Explore the potential of LLLC in confined spaces. Another research avenue involves investigating the extent to which LLLC's benefits diminish in small spaces. Some interviewees shared a perception that smaller spaces do not benefit from LLLC. Understanding whether LLLC's advantages remain consistent across different scales will help CEE make better recommendations, or combat market misconceptions about LLLC suitability.

Catalogue Minnesota Energy Code requirements and applicability as it pertains to LLLC. In order to provide accurate and valuable education and awareness building, CEE should develop a detailed understanding of how LLLC can be used to meet energy code requirements, in what scenarios these requirements apply (e.g., in retrofit projects), and how LLLC compares favorably or otherwise with alternative methods for code compliance.

Appendix A Project Approach

Cadeo conducted primary data collection in the form of in-depth interviews and focus groups with the LLLC supply chain market actors and key decision makers for commercial buildings, as well as an online survey with contractors. The Cadeo team took detailed notes during interviews and focus groups, and calls were recorded to facilitate thorough analysis. The research team utilized qualitative analysis techniques to identify patterns, themes, and key findings from the collected data.

A.1 Supply Chain Market Actors In-Depth Interviews

The Cadeo team contacted 94 individuals representing 59 firms, ultimately interviewing 19 contacts. Interviewers used a population frame including contact information provided by CEE for a range of market actors as well as contacts identified through Cadeo research. Interviewers also recruited participants through snowball sampling in which respondents provided referrals for additional contacts. Supply chain market actors who completed an interview received a $100 gift card for their participation.

The disposition of the market actor in-depth interviews is included in Table 15.

Table 15: Supply Chain Market Actor In-Depth Interviews Disposition

Final Disposition Summary	Count
Complete	19
Refusal or "soft" refusal (includes those who responded to a recruitment email but did not complete an interview)	5
No response after a minimum of two attempts to contact via email and one via phone, if phone number available	63
List Errors	
Business or contact no longer available	2
Bad or wrong number	2
Total	**91**

A.2 Contractor Survey

We recruited respondents using a CEE-provided list of 650 contacts known to be involved in lighting projects in Minnesota, most of whom had done at least one project with CEE in the past. Contacts received emails containing a link to a Qualtrics programmed survey. Researchers sent two follow-up emails to unresponsive contacts over the course of one week. Forty-four contacts began the survey, but three did not meet the screening criteria and one did not complete the survey. Thirty-nine contacts completed the survey, yielding a response rate of 8% (39/481, removing bounced emails from the list). Contractors who completed the survey received a $100 gift card to recognize their participation. Table 16 summarizes the disposition of the contractor survey.

Table 16: Contractor Survey Disposition

Final Disposition Summary	Count
Complete	**39**
Started survey but did not complete	1
No response after two follow-up attempts	438
Disqualified at question one	3
List Errors	
Email bounced	169
Total	**650**

A.3 Specifier Focus Groups and Interviews

The research team developed a list of 240 potential participants using contacts procured via Data Axle, supplemented with online research and referrals from CEE. The team sent an email containing a link to an initial screening survey to 238 contacts, and 2 additional contacts were provided via referrals from participants. The team sought lighting professionals who design lighting control systems or specify lighting controls for commercial buildings, including but not limited to lighting designers, electrical engineers, and lighting architects. Four attended the focus group and we added detail through in-depth interviews with qualified specifiers who could not make the focus group.

Table 17 includes the final disposition summary of the specifier focus groups and interviews. All specifiers received a $150 gift card.

Table17: Specifier Interviews Disposition

Final Disposition Summary	Count
Complete	**6**
Attended focus group	4
Participated in in-depth interview	2
Attempted	**215**
Completed screening	4
No response	210
Did not qualify	1
List Error/Bounced Email	**19**

Total	**240**

A.4 Building Decision Maker Interviews

Outreach and recruitment with building decision makers began on June 9, 2023, and data collection ended July 7, 2023. The research team used email recruitment to contact a total of 317 building contacts using lists provided by CEE that primarily consisted of property managers and public entities who had worked with CEE previously. While these lists had over 300 contacts, they were not representative of the entire state and were limited to Xcel's service territory. These CEE-provided lists were supplemented with 11 additional contacts suggested by other participants or identified through online sources by the research team staff. The roles of contacts recruited for interviews varied and included building owners, third-party property managers, facility managers, maintenance managers, superintendents, and city sustainability coordinators.

We completed interviews with 17 building contacts. These contacts were also used for a simultaneous interview effort related to HVAC. Two scheduled interviews did not take place because the participants did not attend. Of the 328 contacts, 46 emails came back as undeliverable and 4 responded that they were not interested in participating in the study. The research team sent a minimum of 2 emails to the remaining 259 contacts.

The disposition of the building decision-maker in-depth interviews is summarized in Table 18.

Table18: Key Decision Maker In-Depth Interviews Disposition

Final Disposition Summary	Count
Complete	17
No-Show	2
Refused	4
No response	259
List Error	46
Total	**328**

Appendix B Market Actor Roles and Relationships

This appendix includes descriptions of market actor roles in the lighting and controls market, including both the new construction and retrofit segments. Within new construction and major renovation projects, processes include design/bid/build and design/build. Design/bid/build design teams are typically led by architects, whereas in design/build project teams, design and construction are completed by the same firm, often a general contractor with in-house design capabilities. Retrofit projects, in contrast, are most often led by electrical/lighting contractors, general contractors when lighting retrofits are performed as part of a broader building retrofit, or ESCOs.

Architect

- Relevant Project Types: New construction, major renovation, design/bid/build, design/build (as part of contractor team).
- Role: Clarify owner's needs, spatial and aesthetic requirements for space.
- Who they Influence: Owners, lighting designers, electrical engineers.

Lighting Designer

- Relevant Project Types: New construction, major renovation, design/bid/build, design/build.
- Role: Define intent of lighting for space, select fixtures, design layout.
- Who they Influence: Architects, electrical engineers, contractors, owners (sometimes).

Electrical Engineer

- Relevant Project Types: New construction, major renovation, design/bid/build, design/build.
- Role: Specify lighting (following fixture selection and layout created by architect or lighting designer) and controls, design control system (rarely).
- Who they Influence: Lighting designers (rarely), contractors.

General Contractor

- Relevant Project Types: All—New construction, major renovation, retrofit, design/bid/build, design/build.
- Role: Lead construction phase of project, sometimes lead design phase (for D/B projects).
- Who they Influence: Owners, engineers, and lighting designers (for D/B projects).

Manufacturer Representative (Specification Sales and Distributor and Contractor Sales)

- Relevant Project Types: All—New construction, major renovation, retrofit, design/bid/build, design/build.
- Role: Contracted by the manufacturer, educate market actors about products, assist in design and specification, develop detailed specifications, assist in order fulfillment.
- Who they Influence (may depend on contract):
    - Specification Sales Reps: Electrical engineers, lighting designers, architects, owners.
    - Distributor and Contractor Sales Reps: Distributors, contractors.

Distributor (Order Fulfillment and Project Team/Energy Team)

- Relevant Project Types: All—New construction, major renovation, retrofit, design/bid/build, design/build.
- Role: Assist contractors in selecting products, provide pricing, place orders, design and specify distributor-led retrofit projects.
- Who they Influence: Contractors, owners.

Electrical/Lighting Contractor

- Relevant Project Types: All—New construction, major renovation, retrofit, design/bid/build, design/build.
- Role: Bid on projects, may select and order products, design and specify contractor-led retrofit projects, install lighting and control products/systems, program systems (in some cases).
- Who they Influence: Owners, particularly for retrofit projects.

As described here, market actor interactions vary depending on project type, and even within project type there can be variation. Figure 16 and Figure 17 show generalized market actor relationships and influences for new construction (including major renovation) and retrofit projects. The key difference between these two project types is that contractors have much greater influence over project decisions in retrofit projects, while a design team, often led by an architecture firm, is a strong influencer in a new construction project.

Figure 16. Generalized New Construction Project Roles

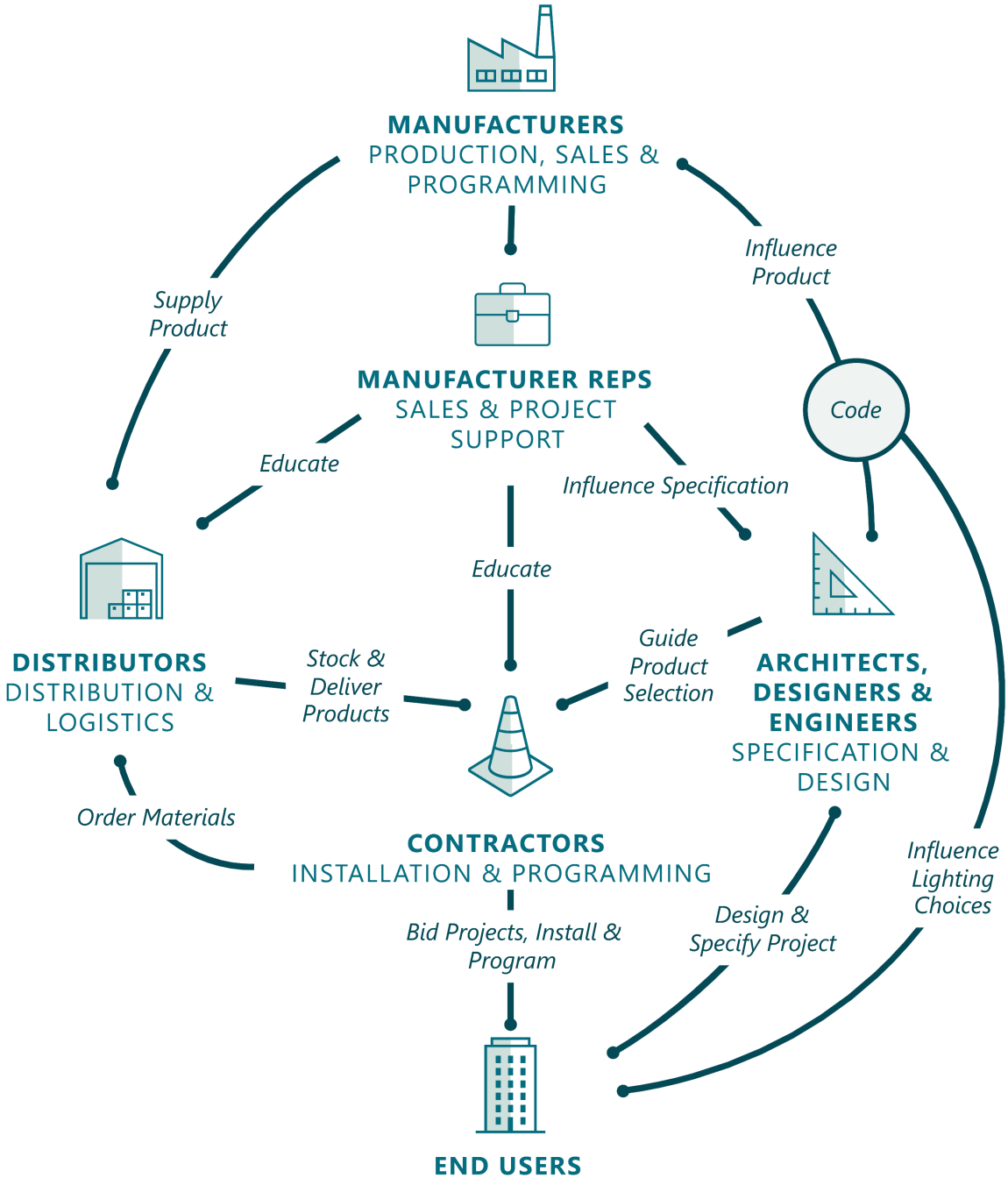
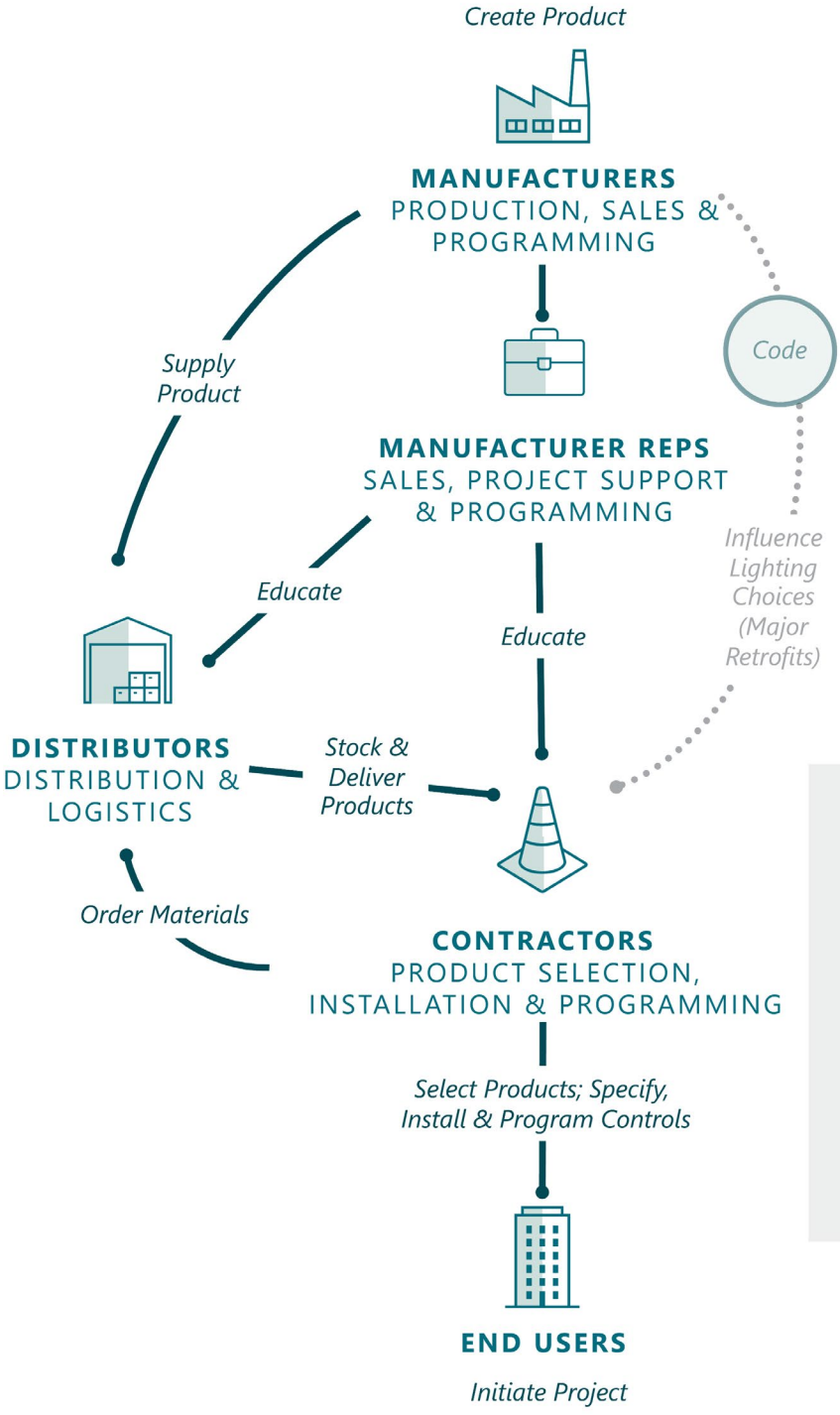


Figure 17. Generalized Retrofit Project Roles



Architects, designers, and engineers can be involved in retrofit projects, though this is less common and would generally only be the case for large or high-end projects.

Appendix C Data Collection Instruments

This appendix includes the following data collection instruments:

- Supply Chain Actor Interview Guide
- Contractor Survey
- Specifier Focus Group Guide
- Building Contact Interview Guide

Supply Chain Research: Market Actor Interviews

Table 1: Overview of Data Collection Activity

Descriptor	This Instrument
Instrument Type	In-Depth Interview
Estimated Time to Complete	30 minutes
Population Description	Lighting controls manufacturers, manufacturers' reps, and distributors in Minnesota
Sampling Strata Definitions	Market actors must have experience producing, selling, buying, or facilitating transactions relating to lighting controls
Call List Size	
Completion Goal(s)	24 interview completes (8 Manufacturers, 8 Manufacturer Reps, 8 Distributors)
Call List Source and Date	
Type of Sampling	Purposive
Contact Sought	Lighting controls manufacturers, manufacturers' reps, and distributors in Minnesota
Fielding Firm	Cadeo
Incentive Plan	$100 incentive delivered through Tango

Table 2: Research Objectives and Associated Questions

Research Objective	Associated Questions
Understand/confirm supply chain dynamics and the customer's "path to purchase"	Q5, Q6, Q7, Q8
Understand barriers, opportunities, and leverage point for market intervention	Q9, Q10 Q11 Q12, Q13, Q14
Understand current marketing and training efforts around LLLCs.	
Establish the readiness level of contractors in Minnesota to bid out and install LLLCs.	Q15, Q16, Q17, Q18 Q19, Q20
Identify market leaders in LLLC sales and what they are doing differently from others.	Q21, Q22
Test LLLC value propositions—which non-energy benefits are the most relevant and important—and determine value proposition differences between submarkets when possible.	Q23
Understand awareness and importance of existing utility rebates.	Q24, Q25, Q26, Q27

Understand market share of LLLCs vs. other lighting control or non-control strategies.	Q8

Background

This interview guide targets lighting controls manufacturers, manufacturers' reps, and distributors with sales in Minnesota. The Cadeo team is seeking insight into lighting controls supply chain dynamics, including understanding any barriers, opportunities, and leverage points for market intervention.

Instrument

Outreach

Phone

Hi, my name is _____ and I'm calling from Cadeo, an Energy Efficiency research firm. We are calling on behalf of Center for Energy and Environment in Minnesota to collect information on the current state of the lighting market with a focus on lighting controls. I'd like to ask you some questions about this industry. My questions should take about 30 minutes and we are offering a $100 gift card to say thank you for your time. We are happy to send you a copy of our findings when the study is complete.

Is this a good time, or should we schedule a follow up call?

[If referred to a different contact, collect their name/email/number and release contact.]

Thank you for your time today—do you have any questions for me before we get started?

Email

Hi [Contact name],

I am reaching out on behalf of the Center for Energy and Environment (CEE) in Minnesota to learn more about the current state of the lighting market with a focus on lighting controls. You've been identified as someone with great insight, and I'd like to talk with you about your experience with this industry. Would you be willing to set up a 30-minute interview with me? To say thank you for your time, we are offering a $100 e-gift card.

The results of our discussion will help CEE reduce energy consumption in Minnesota by targeting strategic areas to increase lighting controls programs and education. We will use data gathered from discussions like this one to better understand experiences with lighting controls as a baseline for building our programs. We are happy to send you a copy of our findings when the study is complete at the end of the year.

Please email me back at ljudson@cadeogroup.com or call me at 503-905-6473 at your earliest convenience to schedule a time to discuss this topic.

If you know someone else who would be a good person for us to talk to about this industry, we'd love to be connected with them as well.

Thank you for your time, and hope to hear from you soon!

Introduction

Thank you for taking the time to speak with us about lighting controls. Our questions today should last about 30 minutes, and we'll cover topics about supply chain, general market trends, and your experience with controls. As a reminder, all information you provide is voluntary and confidential and will not be shared beyond the team working on this research. Do you have any questions for me before we get started?

We also like to record these calls so the research team can review any notes we may miss during the discussion today. Is it okay with you if we record this call?

Screening Questions [ASK ALL]

First, I'd like to confirm your role:

Q1. I understand that your company is a lighting controls [manufacturer, rep agency, distributor], is that right?

Q2. To start off, please tell me about your role with lighting controls.

Great – we are hoping to speak to someone about the market barriers and opportunities, supply chain dynamics, and how lighting controls, particularly Luminaire Level Lighting Controls, go to market. Are you able to speak to these topics and is there someone else in your organization we should reach out to?

Awareness [ASK ALL]

Q3. Have you heard of LLLCs or Luminaire Level Lighting Controls?

[**SINGLE RESPONSE**]

1. Yes
2. No
3. Unsure

Background Questions [ASK ALL]

Q4. Does your company (make, sell, stock, design, install) luminaire level lighting controls? Luminaire Level Lighting Controls or LLLCs as we will refer to them are connected systems comprised of light fixtures with embedded controls and a dedicated sensor per luminaire, providing granular control over the lighting in a space. LLLCs are typically used in commercial buildings and include occupancy sensors, daylight sensors, and/or wireless communication capabilities.

Supply Chain Dynamics

Q5. [Manufacturers] What percent of your lighting controls sales over the past year would you estimate go through distributors vs. other channels [If information is sensitive, probe: Could you tell me what type of sales are most common?]

Q6. [Manufacturers] What are those other channels and what proportion of your overall sales go through each?

1. Probe: [Manufacturers] Do building owners buy directly from your company? What percent of sales over the past year occur this way?

Q7. [Distributors] What portion of your branch's sales of lighting and lighting controls go to contractors vs. direct to institutions?

Q8. [ALL] Do LLLCs move through the lighting supply chain any differently than other lighting controls? How so?

Barriers, Opportunities, and Market Intervention [ASK ALL]

Q9. How will the lighting market change in the next 5 years?

Q10. What are some of the challenges that innovative lighting controls approaches have faced in the past?

Specifically regarding LLLCs for the next several questions:

Q11. What barriers prevent you from selling more LLLCs?

Q12. What would encourage more installations of LLLCs?

Q13. What applications would you recommend LLLC technology for? What types of customers would you recommend them to?

Q14. Are there times you would not recommend LLLC technology? (Applications, customers, etc.)

Marketing and Training [MANUFACTURER REPS, DISTRIBUTORS]

Q15. What kind of training do you receive on LLLC equipment and sales?

Q16. Does it adequately prepare you to sell LLLCs?

Q17. Who provides your LLLC trainings?

Q18. What type of training would be useful for increasing LLLC sales?

Contractor Readiness

Q19. What skills do you think contractors need to develop to successfully deliver projects that include LLLCs? [If needed, probe: considering the issues that contractors have come to you with]

Q20. [Manufacturer, if yes direct sales] How are direct sales customers supported after installation of LLLCs?

Market Leaders [ASK ALL]

Q21. Which types of customers are asking for LLLCs?

We are trying to understand who in Minnesota is most commonly involved in LLLC specification or installation.

Q22. Are there specific firms or professionals you see frequently promoting this technology?

1. [If no]: What about other lighting controls technologies?

Value Propositions [ASK ALL]

Q23. What is the largest benefit to end users of this technology?

1. What is the largest benefit to specifiers?
2. How about for contractors?

Rebate Awareness & Importance [ASK ALL]

Q24. What do you know about rebates for LLLC projects?

Q25. For new construction projects, how relevant are utility rebates for lighting controls?

Q26. LLLC retrofit projects qualify for lighting controls rebates. Do you think that is enough to support LLLC sales, or would you prefer a separate rebate for LLLCs such as a dollars per fixture or per watt add-on?

Conclusion [ASK ALL]

Q27. Thank you so much for answering our questions! Can we use the email we have on file to send you the $100 e-gift card?

Q28. [Mfr Reps]: We are also hoping to interview manufacturers for this research effort. Would you be willing to connect us to a contact at a manufacturer that offers LLLC products? They will also receive $100 for their time.

Q29. For this research effort we are also hoping to interview specifiers, including lighting designers, architects, and electrical engineers. Do you know anyone that we can contact that may be willing to speak with us about lighting controls? They will also receive $100 for their time.

CEE Minnesota LLLC Supply Chain Research: Contractor Survey

Table 1: Overview of Data Collection Activity

Descriptor	This Instrument
Instrument Type	Web Survey
Estimated Time to Complete	10-15 minutes
Population Description	Lighting controls contractors in Minnesota
Sampling Strata Definitions	Xcel Energy contractors will be contacted first, followed by the contractor list provided by CEE
Population Size	Unknown
Call List Size	TBD (pending receipt of Xcel Energy list)
Completion Goal(s)	20-50 survey completes
Call List Source and Date	List provided by OneStop team
Type of Sampling	Stratified Random
Contact Sought	Contractor population must have experience installing lighting controls in non-residential buildings
Fielding Firm	Cadeo
Incentive Plan	$100 incentive delivered through Tango

Table 2: Research Objectives and Associated Questions

Research Objective	Associated Questions
Understand/confirm supply chain dynamics and the customer's "path to purchase"	Q8, Q9, Q15, Q16
Understand barriers, opportunities, and leverage point for market intervention	Q10, Q11, Q12, Q13, Q14, Q17, Q18, Q19, Q20
Understand current marketing and training efforts around LLLCs.	
Establish the readiness level of contractors in Minnesota to bid out and install LLLCs.	Q21, Q22, Q23, Q24
Identify market leaders in LLLC sales and what they are doing differently from others.	Q25, Q26, Q27, Q28, Q29, Q30, Q31
Test LLLC value propositions—which non-energy benefits are the most relevant and important—and determine value proposition differences between submarkets when possible.	Q32 Q33
Understand awareness and importance of existing utility rebates.	Q34, Q35

Understand market share of LLLCs vs. other lighting control or non-control strategies.	Q5, Q6

Background

This survey targets contractors that install lighting controls in Minnesota. The Cadeo team is seeking insight into lighting controls supply chain dynamics, including understanding any barriers, opportunities, and leverage points for market intervention. The contractor survey will be deployed following manufacturer, manufacturer rep, and distributor interviews and will gather market intelligence on how contactors specifically interact with lighting controls, especially luminaire level lighting controls, or LLLCs.

Initial Outreach Email

Hi [Name],

We are working with Center for Energy and Environment (CEE) to better understand contractor experiences with lighting controls in Minnesota. We would greatly appreciate your participation in a survey to help shape programs to reduce energy consumption and improve occupant experiences in buildings in Minnesota.

This survey is voluntary and confidential and should take about 10-15 minutes to complete. To say thank you for your time, **we are offering a $100 e-gift card.**

Please click this link to access our survey. [insert link]

Please reach out to lhossain@cadeogroup.com with any questions. Thank you for participating in this research effort!

Follow-up Outreach Email

Hi [Name],

We contacted you earlier this week and would like to remind you to please take 10-15 minutes to complete a quick survey on contractor experience with lighting controls in Minnesota. We only need 20 more responses – will you help us reach our goal? As a reminder, we will send you a $100 gift card within 2 days of completing the survey as a thank you.

[Survey link]

Please reach out to lhossain@cadeogroup.com with any questions. Thank you for participating in this research effort!

Instrument

Introduction

Thank you for participating in the Center for Energy and Environment (CEE) Minnesota Contractor Lighting Controls survey. The survey will ask questions about your experience with lighting controls, project processes, and training needs. Once you complete the survey, we will send you a $100 e-gift card via Tango, which allows you to select your choice of dozens of popular e-gift cards, such as Target, Amazon, and Kroger. Your responses will be kept confidential, and your name will not be tied to results.

Screening [ASK ALL]

[**IF Q1=2, SEND TO DISQUALIFICATION PAGE]**

Q1. Do you work on commercial projects with lighting controls?

[**SINGLE RESPONSE**]

1. Yes
2. No

Specifier Screening Questions [ASK ALL]

Q2. Do you offer lighting design services, such as helping with lighting layout, appearance, and function of a space?

[**SINGLE RESPONSE**]

1. Yes
2. No
3. Other, please specify: [**OPEN-ENDED RESPONSE]**

Awareness [ASK ALL]

Q3. Have you heard of "LLLCs", which stands for Luminaire Level Lighting Controls?

[**SINGLE RESPONSE**]

1. Yes
2. No
3. Unsure

Experience with installation

Q4. What percentage of lighting installation projects you have worked on in the last 3 years were:

[**MULTIPLE NUMERIC RESPONSE**]

1. New Construction/Major Renovation
2. Retrofit _____

Adds up to 100%

Q5. Please select each lighting controls strategy you have installed in the last 3 years:

[**MULTIPLE RESPONSE**]

1. **Standalone occupancy sensors**
2. **Standalone photocells**
3. **Standalone timeclocks**
4. **Networked lighting controls (NLCs)** – A connected combination of sensors, network interfaces (gateways/hubs/timeclocks), user interfaces (keypads/touchscreens)) and controllers (relays/dimmers/panels)
5. **Light fixtures with embedded sensors -** Not part of a networked lighting control system
6. **Luminaire level lighting controls (LLLCs)** – Networked systems of light fixtures with embedded controls and a dedicated sensor per luminaire. Sensors are typically occupancy and/or daylight sensors, and often use wireless communication. Since controls are housed within, additional relays/dimmers/control panels are not required like in other NLCs.
7. None of the above

Q6. [FOR EACH SELECTED] How many projects have you installed in the last 3 years that were associated with the following types of controls? Your best guess is fine.

[**MULTIPLE NUMERIC RESPONSE**]

1. No controls/manual switch only _____
2. Standalone controls (non-networked sensors/photocells/timeclocks) _____
3. Networked Lighting Control Systems (NLCs) _____
4. Light fixtures with embedded sensors _____
5. Luminaire Level Lighting Controls (LLLCs) _____

[**IF Q4 DOES NOT INCLUDE 4 OR 6, SKIP THIS SECTION**]

Q7. When installing networked lighting control systems, who has installed/terminated network cabling? Select all that apply:

[**MULTIPLE RESPONSE**]

1. Our company's staff
2. Sub-contracted low-voltage network cabling installer

-96. Other, please specify: [**OPEN-ENDED RESPONSE]**
-97. Don't know

Supply Chain Dynamics [ASK ALL]

Q8. What types of project processes do you participate in? Please select all that apply:

[**MULTIPLE RESPONSE**]

1. Spec – Bid – Buy
2. Government bidding processes
3. RFPs (non-government)

4. We are subcontracted by another contractor
5. We are contracted directly by building owners/managers

-96. Other, please specify: [**OPEN-ENDED RESPONSE]**

Q9. Who estimates the labor for lighting and lighting controls installation when quoting work?

[**MULTIPLE RESPONSE**]

1. Distributor
2. Estimator (in house)
3. Consultant
4. Another role in house
5. Another outsourced role
6. If you selected 4 or 5, please describe: [**OPEN-ENDED RESPONSE]**

-96. Don't know

Barriers, Opportunities, and Market Intervention [ASK ALL]

Q10. How often do you run into problems with lighting control installations?

[**SINGLE RESPONSE**]

1. Every time
2. Usually
3. Occasionally/sometimes
4. Rarely
5. Never

Q11. What are the biggest challenges with installations involving lighting controls in general? Please consider all types of lighting controls and select all that apply:

[**MULTIPLE RESPONSE**]

1. Installation time is unpredictable
2. Low voltage wiring
3. Programming/configuration
4. Product quality
5. Technical support
6. Inconsistency between manufacturers
7. Vague or incomplete specifications
8. Change requests
9. Callbacks or punch lists
10. Other, please specify: [**OPEN-ENDED RESPONSE]**

Q12. Who do you typically ask for help when troubleshooting problems in lighting control installation and programming? Please select all that apply:

[**MULTIPLE RESPONSE**]

1. Project Foreman/Other Installers

2. Project Manager
3. Distributor Contact
4. Manufacturer's Local Representative
5. Manufacturer's Technical Support
6. Someone else (Please specify_____) [**OPEN-ENDED RESPONSE**]
-98. I have not asked for help

Marketing and Training [ASK ALL]

The next set of questions ask about your experience with LLLCs specifically –again our definition is that **Luminaire Level Lighting Controls are networked systems of light fixtures with embedded controls and a dedicated sensor per luminaire.** Sensors are typically occupancy and/or daylight sensors, and often use wireless communication. Since controls are housed within, additional relays/dimmers/control panels are not required like in other networked lighting control systems.

Q13. Have you received any training on LLLC equipment?

[**SINGLE RESPONSE**]

1. Yes
2. No
3. I don't know

Q14. [If Q13=Yes] Where did you participate in the training? Please select all that apply.

[**MULTIPLE RESPONSE**]

1. Someone came into our company to provide training
2. Went to a trade show
3. Went to a training at a distributor or other supply chain entity
4. Participated in an online training
5. Another place (please specify) [**OPEN-ENDED RESPONSE**]

Q15. If offered, would you be interested in training or resources to improve your confidence in installing and configuring LLLCs?

[**SINGLE RESPONSE**]

1. Yes
2. No
3. Unsure/Would need more information to make a decision

[**IF Q15=NO, SKIP THIS QUESTION]**

Q16. What kinds of training or resources would improve your confidence installing and configuring LLLCs? Please select all that apply:

[**MULTIPLE RESPONSE**]

1. Hands-on demonstration/mockup installation

2. Classroom instruction
3. Dedicated project-specific pre-wire session
4. On-site/project support (programming/re-programming, troubleshooting, user training)
5. Another type of training or resource (please specify) [**OPEN-ENDED RESPONSE**]
-98. Don't know

Contractor Readiness [ASK ALL]

[DISPLAY Q17 TO Q20 ON THE SAME PAGE IN A GRID]

Q17. The next set of questions asks you to select how prepared you feel for various steps in an LLLC project. Please select one option for each activity. How prepared do you feel to **install** LLLC systems?

[**SINGLE RESPONSE**]

1. Extremely prepared
2. Very prepared
3. Somewhat prepared
4. Slightly prepared
5. Not at all prepared

Q18. How prepared do you feel to **program** LLLC systems?

[**SINGLE RESPONSE**]

1. Extremely prepared
2. Very prepared
3. Somewhat prepared
4. Slightly prepared
5. Not at all prepared

Q19. How prepared do you feel to **explain the benefits** of an LLLC system to a customer?

[**SINGLE RESPONSE**]

1. Extremely prepared
2. Very prepared
3. Somewhat prepared
4. Slightly prepared
5. Not at all prepared

Q20. How prepared do you feel to **explain the system operation** of an LLLC system to a customer?

[**SINGLE RESPONSE**]

1. Extremely prepared
2. Very prepared
3. Somewhat prepared
4. Slightly prepared
5. Not at all prepared

For the next few questions, please indicate your level of agreement with the following statements:

Q21. I prefer installing wireless systems over wired ones

[**SINGLE RESPONSE**]

1. Strongly agree
2. Somewhat agree
3. Neutral
4. Somewhat disagree
5. Strongly disagree
-98. Don't know

Q22. I prefer installing light fixtures with an embedded sensor over installing separate sensors

[**SINGLE RESPONSE**]

1. Strongly agree
2. Somewhat agree
3. Neutral
4. Somewhat disagree
5. Strongly disagree
-98. Don't know

Q23. I prefer lighting control systems that I can program over ones where a factory technician is required

[**SINGLE RESPONSE**]

1. Strongly agree
2. Somewhat agree
3. Neutral
4. Somewhat disagree
5. Strongly disagree
-98. Don't know

LLLC-specific Questions

The next set of questions ask about your experience with LLLCs specifically –again our definition is that **Luminaire Level Lighting Controls are** networked systems of light fixtures with embedded controls and a dedicated sensor per luminaire. Sensors are typically occupancy and/or daylight sensors, and often use wireless communication. Since controls are housed within, additional relays/dimmers/control panels are not required like in other networked lighting control systems.

Q24. What are the reasons that LLLCs are not used on more projects today? Please select all that apply:

[**MULTIPLE RESPONSE**]

1. Cost is too high
2. Products are not available

3. Customers are not aware of the equipment or its benefits
4. My team is not adequately trained on LLLCs
5. LLLC products are not a good option for the spaces I work on
6. They are not specified

-96. Other, please specify: [**OPEN-ENDED RESPONSE]**

-97. Don't know

[**IF Q4 DOES NOT INCLUDE 6, SKIP THIS QUESTION]**

Q25. Into what types of buildings have you installed LLLC products? Please select all that apply.

[**MULTIPLE RESPONSE**]

1. Schools
2. Hospitals
3. Warehouses
4. Office spaces
5. Government buildings
6. Industrial/Manufacturing

-96. Other, please specify: [**OPEN-ENDED RESPONSE]**

[**IF Q4 DOES NOT INCLUDE 6, SKIP THIS QUESTION]**

Q26. Where have the LLLCs been purchased for the projects you have worked on? Please select all that apply. (Reminder: LLLCs are networked systems with sensors embedded in or mounted on every fixture)

[**MULTIPLE RESPONSE**]

1. Electrical distributor
2. Other distributor
3. Direct from manufacturer
4. Another contractor

-96. Other, please specify: [**OPEN-ENDED RESPONSE]**

-97. Don't know

[**IF Q4 DOES NOT INCLUDE 6, SKIP THIS QUESTION]**

Q27. Where do you most often purchase LLLC equipment? Please provide the business name.

1. [**OPEN-ENDED RESPONSE**]

[**IF Q4 DOES NOT INCLUDE 6, SKIP THIS QUESTION]**

Q28. What challenges have you faced with sourcing LLLC equipment? Please select all that apply.

[**MULTIPLE RESPONSE**]

1. Product is not available where I source my equipment
2. High cost
3. Shipping/supply chain issues
4. None of the above

-96. Other, please specify: [**OPEN-ENDED RESPONSE]**

[**IF Q4 DOES NOT INCLUDE 6, SKIP THIS QUESTION**]

Q29. In what ways have your LLLC projects been successful?

[**MULTIPLE RESPONSE**]

1. They have provided high energy savings for customers
2. They have reduced labor costs
3. The installation has been easier than for other controls projects
4. There has been more flexibility with configuration
5. LLLCs are more affordable to purchase
6. Retrofit didn't require running new cable for communication
7. Factory start-up/programming wasn't required
8. They have not been successful

-96. Other, please specify: [**OPEN-ENDED RESPONSE**]

-97. Don't know

[**IF Q4 DOES NOT INCLUDE 6, SKIP THIS QUESTION**]

Q30. Do you like working with LLLC equipment?

[**SINGLE RESPONSE**]

1. Yes
2. Somewhat
3. No

-98. Don't know

[**IF Q4 DOES NOT INCLUDE 6, SKIP THIS QUESTION**]

[**DISPLAY THIS QUESTION ON THE SAME PAGE AS Q30**]

Q31. Please describe why you chose your answer.

1. [**OPEN-ENDED RESPONSE**]

Market Leaders [ASK ALL]

Q32. Which companies are successful with LLLCs in Minnesota? Please list the name of the company and type of company (e.g. manufacturer, distributor, contractor, etc.)

1. [**OPEN-ENDED RESPONSE**]

-98. Don't know

-99. Prefer not to answer

Value Propositions [ASK ALL]

Q33. As a contractor, what benefits of LLLC products are, or would be, the most valuable to you? Select up to three options:

[**MULTIPLE RESPONSE**]

1. Faster installation

2. Fewer components to manage or install
3. Lower installation costs
4. Granular, fixture level control
5. Adaptable; easily reconfigured
6. I can program them myself
7. Data cabling may not be required
8. Fewer callbacks

-96. Other, please specify: [**OPEN-ENDED RESPONSE]**

9. None of the above

Rebate Awareness [ASK ALL]

Q34. Are you aware of any utility rebates for LLLCs in the area you work in?

[**SINGLE RESPONSE**]

1. Yes
2. No

-98. Don't know

Q35. How important are rebates in getting selected for projects?

[**SINGLE RESPONSE**]

1. Extremely important
2. Very important
3. Somewhat important
4. Not too important
5. Not at all important

-98. Don't know

Conclusion [ASK ALL]

Thank you so much for your responses! That is the last survey question.

Q36. Please enter your name and email address if you would like us to send you a $100 e-gift card as a thank you for completing our survey. If you cannot accept this gift card, please leave this information blank. Again, your name will not be tied with any of your answers; all responses are kept strictly confidential.

1. [**MAKE THIS A FORM WITH REQUIRED FORMATTED RESPONSE**]

Q37. For this research effort we are also hoping to interview specifiers, including lighting designers, architects, and electrical engineers. Do you know anyone that we can contact that may be willing to speak with us about lighting controls? Please enter their name, company name, email address, and phone number below. They will also receive $100 for their time.

1. [**MAKE THIS A FORM**]

Thank you for your responses! If you entered your name and email address, you will soon receive a $100 e-gift card via Tango, which allows you to select your choice of dozens of popular e-gift cards, such as Target, Amazon, and Kroger to the email you provided.

Disqualification Page [ASK ONLY IF Q1=2]

Thank you for your willingness to participate in our survey. At this time we are only hoping to hear from contractors with experience installing commercial interior lighting and lighting controls products. We appreciate your time.

Specifier Research: Focus Groups

Table 1: Overview of Data Collection Activity

Descriptor	This Instrument
Instrument Type	Focus Group Discussion Guide
Estimated Time to Complete	90 minutes
Population Description	Lighting designers, electrical engineers, lighting architects
Completion Goal(s)	2 focus groups with 6 participants each (a target of 12 total focus group participants)
Contact Sought	Market actors must have experience designing or otherwise specifying lighting controls.
Fielding Firm	Cadeo
Incentive Plan	$150 incentive delivered through Tango

Table 2: Research Objectives

Research Objective
Understand specifier awareness of and impressions of LLLC solutions.
Explore how code requirements affect lighting control specification and inclusion of LLLCs specifically.
Understand the barriers and opportunities to including LLLCs in projects and investigate the overall considerations behind lighting control specifications for new construction and major remodeling. How do these considerations support or hinder inclusion of LLLCs?
How control specifications are affected by the needs of specific sub-markets, and how these affect the attractiveness of LLLC specifications.
How value engineering affects lighting control specification generally and LLLCs specifically.

Background

These focus groups are expected to engage a range of professionals involved in specifying lighting controls in Minnesota. This could include electrical engineers, architects, lighting designers, and design-build contractors. The Cadeo team is seeking insight into the specifying process, including the barriers and opportunities for specifying LLLC in more projects and the relationship between code and LLLC specification. We are planning two virtual focus groups, with a target of 10-12 total participating specifiers.

Instrument

Welcome

Thank you all for joining today's focus group discussion! My name is Dulane, and this is my colleague Paige; we conduct market research on energy efficiency technologies. We host discussions like this one to learn more about the lighting controls market in Minnesota, including the design and specification process. Before we get started, I want to set a few expectations so you all feel comfortable with how this discussion will work:

1. This discussion will be recorded, and we expect the conversation will last about 90 minutes.
2. This is meant to be an informal discussion with me more as a facilitator than an interviewer, so please interact and respond to each other as you naturally would.
3. It's okay to disagree with each other, so please feel free to do so, but be respectful of each other's opinions and experiences.

I also want to reiterate that this call is voluntary and confidential - it will not be shared beyond the CEE team. Do you have any questions for me before we get started?

Introductions (15 minutes)

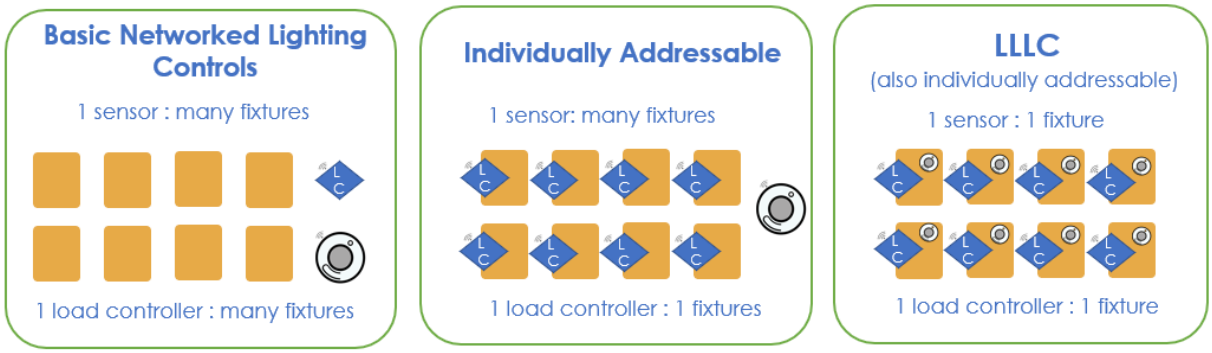
Q1. Let's start by going around the room. Could each of you introduce yourself by telling us your name and your role in lighting design and lighting control specification. [Probe: Do you typically specify products or systems or are you more likely to specify performance requirements?]

Q2. What are your clients looking for when you talk to them about lighting controls? [Probes: Who else is involved? (Architects? Owners? Someone else?) Are there different considerations for new construction versus renovations?]

Awareness and Impressions of LLLC Solutions (15 minutes)

Q3. Okay, let's turn to a specific type of networked lighting control system, Luminaire Level Lighting Control (LLLCs). By show of hands, how many of you have heard the term Luminaire Level Lighting Control or LLLC before today?

To share our definition: Luminaire Level Lighting Controls are networked systems of light fixtures with embedded controls and a dedicated sensor per luminaire. Sensors are typically occupancy and/or daylight sensors, and often use wireless communication. Since controls are housed within, additional relays/dimmers/control panels are not required like in other networked lighting control systems.



Q4. Does anyone have different terminology you would typically use to describe this type of technology? [Probe: Are there any parts of this definition that are surprising or confusing?]

Q5. By show of hands, how many of you have used LLLCs in any of your projects?

Q6. [Follow-up questions for those who have used LLLCs] What led to the inclusion of LLLC in your project(s)? Were these projects successful?

Barriers and opportunities for LLLCs (20 minutes)

Q7. [Back-up question if many unfamiliar with LLLCs] What challenges do you face specifying lighting controls?

Q8. How likely are you to specify a control system that includes LLLCs?

Q9. [Follow-up questions for those who say "not likely"] What stops you from specifying LLLCs?

Q10. What would be an ideal project for LLLCs? [If unfamiliar with LLLCs: what about networked lighting controls, or lighting controls in general?] [Probes: Are there certain types of customers, or building types? Certain kinds of control needs? Certain types of renovations?]

Value Engineering (10 minutes)

Q11. I want to hear a little bit about value engineering. How does value engineering affect your lighting controls projects? [Probes: What alternatives are approved during this process? What things are considered to inform that decision? How does it result in changes to control strategies?]

Q12. Is it more likely for LLLCs to be removed from a project or added to a project through value engineering? Why?

Code and LLLCs (10 minutes)

Q13. How do current energy code requirements affect your approach to lighting controls?

Q14. How do you think code will affect specifications of LLLCs over the next few years? [Probe: How do you think the changes in code coming this fall might change the use of LLLCs?][1]

Q15. How might a system with luminaire-level controls help you design to meet code?

Wrap up (10 minutes)

Q16. I want to leave a little time to hear your final thoughts on the lighting controls market. Is there anything you think we should know that we haven't already talked about?

Bonus Questions, if time allows:

Ask first: In general, what do you think the trajectory of LLLCs will look like over the next few years? (probe – will the uptake increase, do they think it will just be a fad, etc.)

Does the "sequence of operations" or "controls narrative" vary depending on the sector or application? In what ways?

What kind of support do you receive from vendors or manufacturers in the industry? For example, do manufacturers provide product information or training support?

What would help get LLLCs onto more projects? [Probe: contractor/customer education, product accessibility, incentive programs]

[1] Code is being updated to ASHRAE 90.1 – 2019. This will replace 2016 with IECC 2018.

LLLC High-Opportunity Building Contact Research: Market Actor Interviews

Table 1: Overview of Data Collection Activity

Descriptor	This Instrument
Instrument Type	In-Depth Interview
Estimated Time to Complete	30 minutes
Population Description	Key contacts – representatives of commercial buildings
Sampling Strata Definitions	Representatives of four building types: offices, warehouse, schools, and hospitals
Call List Size	
Completion Goal(s)	20 total completes, with at least 2 in each of the four building types listed above
Call List Source and Date	
Type of Sampling	Purposive
Contact Sought	Contacts with experience procuring or maintaining building systems.
Fielding Firm	Cadeo
Incentive Plan	$100 incentive delivered through Tango

Table 2: Research Objectives and Associated Questions

Research Objective	Associated Questions
Awareness, attitudes, and behaviors toward lighting controls in general.	Q1, Q2, Q3, Q4, Q5, Q9, Q18
Barriers and opportunities associated with lighting controls.	Q7, Q8, Q9, Q16, Q17, Q19, Q20, Q21
Experience with controls in general and LLLCs specifically (when applicable)	Q4, Q15
The process for identifying and specifying controls in general and LLLCs specifically (when applicable)	Q6, Q10, Q11, Q12, Q13, Q14

Background

This interview guide targets building owners, third-party property managers, facility managers, and/or building engineers involved in selecting, operating, or maintaining lighting and lighting controls in Minnesota. The Cadeo team is seeking insight into the current experience of these building contacts to identify opportunities for LLLC adoption. The interview guide includes questions about LLLC value propositions in addition to the four key research objectives.

Outreach

Hi, my name is _____ and we are conducting research on behalf of Center for Energy and Environment in the Twin Cities to understand the needs of building representatives when it comes to lighting. I'd like to ask you some questions about your experience selecting or maintaining lighting equipment in commercial buildings. My questions should take about 30 minutes. We are offering a $100 e-gift card to say thank you for your time.

Is this a good time, or should we schedule a follow up call?

[If referred to a different contact, collect their name/email/number and release contact.]

Thank you for your time today—do you have any questions for me before we get started?

Instrument

Introduction

Thank you again for taking the time to speak with us about your experience. I have a few questions about how professionals like you approach lighting equipment upgrades, your experience with lighting controls, and your interest in this. If there are questions that do not apply to your experience, just let me know and we can go ahead and skip those.

Before we get started, I wanted to let you know that this call is voluntary and confidential - it will not be shared beyond the CEE team. Do you have any questions for me?

Great – we also like to record these calls so the research team can use them to augment note taking. Is it okay with you if we record?

Screening Questions

First, I'd like to confirm your role:

Q1. Are you involved in picking out lighting or lighting control systems for upgrades or replacements?

Q2. Are you involved in operating, maintaining, or interacting with lighting and lighting control systems?

[**IF Q1 & Q2 = NO, THANK AND TERMINATE, ASK FOR ANOTHER CONTACT**]

Awareness, Attitudes, and Behaviors

Q3. Do you have advanced lighting controls in your building(s) now? Common equipment includes occupancy sensors, daylight sensors, scheduling, high-end trim (limits the wattage associated with a lighting system), or a combination of these.

[**IF YES, SKIP TO Q5**]

Q4. Have you considered installing lighting controls in your building(s)? Why or why not?

[**IF Q3 = NO OR JUST DIMMER/SWITCH, SKIP TO Q9**]

Q5. What types of lighting controls functions do you have in your building(s)? [If needed, probe for: occupancy sensors, daylight sensors, timeclock/scheduling, high-end trim (limits the wattage associated with a lighting system), or a combination].

Q6. Do you actively interact with your controls system(s) like adjusting light levels, remotely controlling lights, monitoring energy usage of lighting systems, or creating/adjusting light schedules?

Q7. What benefits have you seen from lighting controls? [Probe: any maintenance benefits? Energy/cost savings?]

Q8. Are there any drawbacks? [Probe: any maintenance challenges?].

Q9. In a perfect world, what would your lighting control system be able to do?

Identifying Options

Q10. When does lighting equipment get upgraded or replaced in your building(s)?

Q11. How do you decide what type of lighting equipment you need during a lighting replacement/upgrade? [Probe: Who do you contact? What type of information do you look for?]

Q12. Are there other people or other sources of information you tend to consult when making these decisions?

Q13. Do you review plans or bids for projects involving lighting? (If so): What challenges do you face when reviewing bids and selecting lighting systems and controls?

[IF Q3 = YES, CONTINUE. IF Q3 = NO, SKIP TO Q18]

Q14. Thinking about your lighting controls, do you have any that get programmed? Is there someone who does this? If so, who?

Q15. What are your main concerns about how they are programmed? Are you involved in these decisions? [If needed, explain: In new control system installations programming gets lumped with commissioning, program all the settings for the controls. Can be done by contractor, factory representative or a manufacturer rep, could be reviewed or interfaced with commissioning agent.]

Barriers and Opportunities

[ASK IF Q3 = NO]

Q16. (If no controls currently in building) Do you see an opportunity to add lighting controls to your building? Why or why not?

[ASK IF Q3 = YES]

Q17. (If building currently has controls) Do you see an opportunity to improve the lighting controls in your building? If yes, how? If no, why not?

[ASK ALL]

Q18. Are you familiar with luminaire level lighting controls, also referred to as LLLCs?

Interviewer note: Read definition

Luminaire Level Lighting Controls are connected systems of light fixtures with embedded controls and a dedicated sensor per luminaire which provide granular control over the lighting in a space. Sensors typically include motion and daylight which allow for increased energy savings. The lights typically communicate with one another wirelessly which allows for flexibility design and reconfiguration of spaces.

Q19. LLLCs provide a variety of benefits. I'm going to list several, please tell me if each one seems valuable, somewhat valuable, or not at all valuable. Networked lighting controls like LLLCs:

1. Extend the life of lighting equipment.
2. Provide control over energy use.
3. Provide building data for other applications, like informing HVAC systems of occupancy status, informing on building traffic patterns, providing indoor navigation, etc
4. Offer more flexibility to customize lighting characteristics (sensor timeout, brightness, presets or scenes).
5. Facilitate easy changes in lighting settings or configuration, for example if a tenant moves or a space use changes.
6. Are enabled for remote control or monitoring via an app.

Q20. Thinking about these potential benefits, which do you think would be most valuable for you or your occupants?

Q21. Are there specific types of spaces you think LLLCs would be a good fit for?

Conclusion

Q22. Thank you so much for answering our questions! Can we use the email we have on file to send you the $100 e-gift card?

Q23. For this research effort we are also hoping to interview specifiers, including lighting designers, architects, and electrical engineers. Do you know anyone that we can contact that may be willing to speak with us about lighting controls? They will also receive $100 for their time.