

Qualitative Evaluation of Barriers, Awareness, and Adoption of LLLC Technologies

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ABSTRACT

Luminaire Level Lighting Controls (LLLC) represent a significant source of energy savings. Furthermore, the ubiquitous nature of increasingly networked lighting is crucial for the practical application of connected buildings and IoT. The Northwest Energy Efficiency Alliance's LLLC program seeks to: (1) accelerate the adoption of LLLCs by addressing barriers such as cost, product readiness, value propositions, and (2) to increase awareness of LLLCs as a cost-effective option for commercial new construction, renovation, and retrofits. In support of these efforts, NEEA works with industry partners and invests in activities including, education, resource development, and market research. Previous market reports have validated product and feature availability as well as increased energy savings delivered by LLLCs. Despite these advantages, LLLC market share has yet to gain broad market adoption. This paper contributes to existing research by identifying (1) barriers to LLLC adoption, (2) the most valued features of the technology, (3) hurdles surrounding value engineering, and (4) identifying popularly held beliefs about what drives the market, from leading specifiers. The researchers conducted 15 interviews with product specifiers, lighting designers, and design-build contractors. Twelve surveys, documenting 67 projects were also gathered. The outcomes of this research inform the refinement of industry-focused marketing strategies for the LLLC market.

Introduction and Background

The lighting market is well on its way in the transition to LED lighting with advances across most markets, yet adoption of networked lighting control systems lag far behind. Though they have been around for 20+ years, lighting control systems with basic occupancy sensors, timers, and daylighting controls have not been widely adopted due to a variety of factors including higher costs, lack of awareness, technical challenges, and lack of expertise to install, commission, and operate (Taylor 2022).

In many cases, these systems are not installed or set up properly, sometimes resulting in occupants covering sensors, and/or installers refusing to even propose them to customers. In addition, once LEDs are installed, it makes it more difficult and costly for these controls to be installed later, presenting a lost opportunity to deliver additional savings in the lighting market. According to the Northwest Energy Efficiency Alliance (NEEA), LLLCs are a type of networked lighting control (NLC) system in which each individual light fixture has its own built-in sensor and controllers. Luminaires are individually addressable, can communicate wirelessly and transmit data, and be flexibly programmed and re-programmed in any grouping needed.

Prior to ~2010, the lighting industry controls paradigm was dominated by non-networked, stand-alone controls. Standalone controls are commonly designated by their specific and limited capabilities (e.g., a mechanical time clock or occupancy sensor). Because stand-alone

controls are designed for a single purpose, layering multiple stand-alone controls to achieve more sophisticated capabilities often causes complexity and confusion. Furthermore, while stand-alone controls may come pre-programmed, configuring common settings, such as sensor sensitivity or timeouts, may require an electrician or is often beyond the means of the average facility operator.

By 2010, a majority of leading lighting controls manufacturers began offering networked lighting control (NLC) systems. When compared to standalone controls, NLC systems offer the following additional capabilities: a) high-end trim, b) scheduling, c) building wide control, d) remote access, and e) the ability to integrate with other building systems. As their name implies, NLC systems are networked, with the smallest network being limited to individual rooms and room-based devices. With additional hardware and mesh topologies, modern NLC systems are capable of being networked throughout entire buildings, and even remotely.

Furthermore, NLC systems are designed to incorporate multiple control methods and commonly offer much more user-friendly interfaces for initial system programming and reconfiguration. The current NLC paradigm (extending from ~2010 through today) can be best be described by the three categories shown in Figure 1 (Wilson 2021).

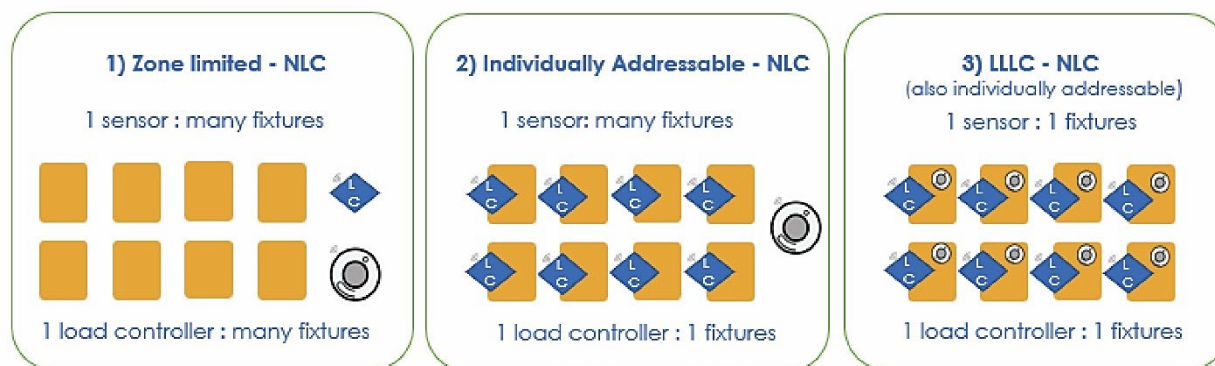


Figure 1. Types of networked lighting configurations. *Source:* Fernhill Shopworks

Zone limited NLC (Figure 1, box 1) represents the most basic form of NLC systems. In this configuration, multiple luminaires are controlled from a single load controller and sensor. Individually Addressable NLC (Figure 1, box 2) represents the middle tier of NLC systems. In this configuration, a single sensor may control multiple fixtures, but individual luminaires each have their own addressable load controller. Luminaire Level Lighting Control NLC (Figure 1, box 3) represents the most integrated and advanced form of NLC. In this configuration, every luminaire includes its own addressable load control and sensor, itself, capable of both presence detection and daylight harvesting.

In the context of NLC systems, wireless most commonly refers to the availability of battery powered wall stations and sensors, which can communicate wirelessly with the load controller. Wireless may also refer to a system's ability to create a network between devices or the method by which it is configured. All three configurations of NLC systems (Figure 1, boxes 1-3) include examples of both wired and wireless approaches.

Some of the benefits of LLLC include occupant comfort, code compliance, and energy savings. Overall, LLLC integration allows for greater granularity and capabilities, meaning greater energy savings, more precise data, greater space flexibility, and ease of reconfiguration. In addition, it enables Internet of Things (IOT Capabilities) and connected buildings. LLLC

systems have been proven to reliably provide more energy savings than basic NLC systems. Informed by multiple research studies, the PNW's Regional Technical Forum offers guidance for utility programs, which suggests that LLLC systems can save 30-50% more energy than their basic NLC cousins (RTF 2021). Paradoxically, many of the features that make LLLC products more flexible and capable, are the same issues causing barriers in the market (Research Into Action, Energy, and Northwest Energy Efficiency Alliance 2016). For example, increased sensor coverage provides greater granularity and increased unit cost.

While savings from lighting systems alone are significant, the future of energy efficiency programs (and grid management at large) has already pivoted away from legacy sector specific technology approaches. Instead, market forces are emphasizing whole-system building efficiencies, as well as the technologies that enable those features, such as energy monitoring, integration with HVAC, and demand response. Actualizing these more sophisticated approaches requires a robust network of devices capable of collecting, processing, and sharing information, as well as the network capability of covering an entire site, with a degree of efficacy.

In this context, LLLC systems, which are increasingly integrated, sophisticated, and capable can be understood as a critical enabler for connected buildings and the future of building management (BetterBricks and LDL 2022). However, for LLLCs to gain widespread market adoption, the following three barriers need to be addressed.

1. First, the cost of LLLC systems is often more expensive than less capable versions of NLC (as seen in the leftmost box of Figure 1). This could be due to limited fixture options, lag in product manufacturers viewing it as an in-demand product, or the initial costs associated with sensors in each fixture.
2. Next is the issue of perceived complexity, i.e., that LLLC systems end up requiring extra sets for either specification, initial setup, or both. While not necessarily true in all cases, there is confusion on how specifiers and contractors can install a successful system without prior understanding and resources.
3. Lastly, a lack of customer demand is observed based on poor experiences with legacy standalone controls or early NLC systems. These barriers have been recognized as key issues to investigate.

Our team conducted a research study to further investigate some of these barriers, to ultimately offer insights into how these barriers can be overcome.

Research Focus

The specific purpose of this research was to engage and interview influential lighting controls product specifiers who are in a unique position to provide unbiased feedback and real-world experiences; common themes and insights from these interviews can inform NEEA's program strategy. The goal of this project was to gain a thorough understanding of the motivators for lighting control product specifications, as well as challenges and barriers they encounter in their projects. To ensure a comprehensive understanding, the project did not solely focus on LLLC, and the survey and interview tools focused broadly on lighting controls.

With an understanding that professional opinions may vary when describing a specific project vs. the market at large, this project aimed to collect both project specific information, as well as opinions about the state of the market at large. A comprehensive approach included: a) project specific journal entries b) participants surveys, and c) an in-depth follow up interviews. These findings informed key takeaways and program recommendations. The study consisted of 15 interviews with product specifiers, lighting designers, and design-build contractors. Twelve

participants completed the survey and submitted a total of 67 unique documented projects. Additional details on the methodological approach are outlined in the section below.

Methodology

The sponsoring agency, NEEA, contracted with the Integrated Design and Construction Laboratory (ID+CL) and Fernhill Shopworks to conduct research surround LLLC technologies and market barriers, titled the “LLLC Journal Project.” The method employed by this research study was qualitative in nature, seeking participant perceptions of the lighting industry and markets.

Research Questions and Approach

The following research questions guided the development of the surveys and the semi-structured interview questionnaire:

Market actors

1. What is the background and practice of the participants?
2. What are the participant’s pre-existing beliefs and preferences surrounding NLC and LLLC?
3. How do specifiers receive and interpret end-user demands?

Market landscape

4. Where are non-LLLC NLCs best suited and being installed?
5. Where are LLLC best suited and being installed?
6. What systems seem to gravitate to what kinds of applications?

Market drivers, transformation, and barriers

7. Where are NLC and LLLC not going in at all, and why?
8. Which value proposition messaging for LLLC resonates with these market actors?
9. What factors are driving lighting specifications?
10. Who is driving the adoption of LLLCs? Why are LLLCs not yet widely adopted?
11. How useful are existing resources for specifiers, contractors, and installers?

This study, which lasted over four months, employed several research tactics including interviews and survey journals to better understand how people who are currently specifying LLLC systems are using them, in addition to challenges they may be facing. The results of this study can be used to develop targeted market and educational materials for industry professionals and key market players.

Research Sample

This project employed a purposive sampling technique to target key lighting experts and specifiers in Oregon and Washington. This technique of purposive sampling is frequently used in qualitative research when the research calls for specific information or participants rather than selecting the sample randomly (Newman et al. 2003), and in addition, purposive samples are usually selected by the judgment of the researcher (Teddlie and Tashakkori 2009). Considering

the in-depth nature of this project and the estimated participant time commitment, the decision was made to seek out a smaller group of influential and experienced lighting controls specifiers as opposed to a larger participant pool. A deliberate effort was made to ensure representation from both the design-bid-build, and design-bid construction markets (see Figure 2 for recruitment flyer). It should be noted that this purposive selection method limits the generalizability of the results, but this is typical of smaller qualitative studies such as this project. Additional details of the data collection methods are outlined below.

Data Collection

Data collection took place of a period of four months (from July – October 2021). Ultimately, there were 15 interviews, 12 surveys, and 67 unique project journal entries completed. To encourage participation, and as a token of appreciation, participants who completed the project received \$500 compensation in the form of a VISA gift card. All participants were over the age of 18, were lighting designers, engineers, or contractor representatives, and had a prior understanding of lighting systems and controls (including LLCs) prior to being selected as a participant. Participants either completed all surveys at once or updated them periodically through the study period, depending on their work capacity, time, and applicable projects.

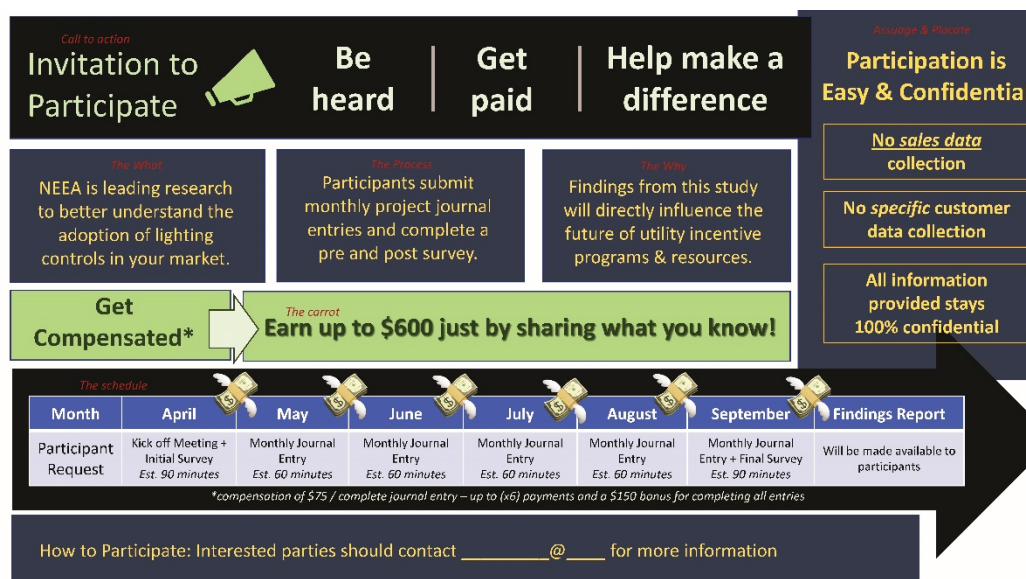


Figure 2. Invitation flyer sent to prospective participants during project recruitment. *Source:* Fernhill Shopworks, 2021.

Research Study Design and Process

For this study, the original plan was to implement only one survey, but after some testing and logistical conversations, the single survey was split into two surveys. The first is referred to as the “initial survey,” which was built to collect demographic, professional experience, and participant beliefs of lighting controls and products. To inform the general specification landscape and key dynamics, participants completed this in-depth survey, which included 23 prompts and consisted of both Likert scale quantitative measures and open ended short-response

style questions. It gauged industry interest, benefits, and barriers to LLLC adoption from the perspective of product specifiers. Additionally, this survey collected participants' specification preferences and training/education experiences. The purpose of the survey was to directly measure how LLLC systems are perceived and to compare those perceptions with other types of NLC and standalone control systems. The survey also served as a platform to ask very pointed questions about topics like cyber security, value engineering, and preferences for training.

Next, to understand the nuances of specific projects, participants completed journal entries (i.e., the secondary survey), which documented and identified the key factors influencing specification. Project-specific journal entries for projects that were either actively in the construction phase or had been completed within the past two years. The project-specific journal entries offered a standardized format for participants to provide information relevant to what was specified, instances of value engineering, and other mitigating factors. This journal-entry survey was also designed to reveal where along the project timeline changes are made to specifications, as well as any complications that arose with changing from one technology to another. The data collected from this survey gauged industry interest, benefits, and barriers to adopting LLLC systems in their projects, which can be used to inform the overall marketing and messaging directions for lighting and controls.

Lastly, to ensure true understanding of the data, survey and project entry responses were reviewed and analyzed before participants were engaged for a 60-minute interview to provide greater insight into their responses. For instance, whereas the survey asked the question, *what type of projects do you prefer LLLC – or NLC*, the interview looked at the responses and asked *why*. It is with this three-tier data collection strategy that a holistic understanding of the participant's responses could be formulated.

Data Analysis

Data were collected via Qualtrics (an online survey platform) and via phone interviews. After the data were cleaned, a codebook was developed, and different data types were analyzed accordingly. Qualitative data from the survey and interview notes were compiled and coded to reveal emerging themes. Open-ended responses and interview notes were then summarized, organized by topic and subject matter, and holistically analyzed to determine participant perceptions in regard the research questions. Quantitative Likert responses in the surveys were analyzed by descriptive statistics.

Limitations

Due to COVID-19 concerns, all research activities were conducted remotely via Zoom or phone. While open-ended responses were collected in the surveys, word for word transcripts of phone conversations were not recorded, and therefore, interview results are in the form of interviewer notes. In addition, as previously mentioned, the small sample size and qualitative methods employed mean that these results may not be generalizable.

Results

The research questions listed above guided the development of survey and interview data collection tools. The results presented in this paper are organized by key themes that emerged through the data collection and analysis process.

Participants

In total, 12 participants completed the initial survey. In the second, project specific survey, 67 projects were entered into the survey platform, which outlined specific characteristics about local projects that used either legacy control, NLC, and LLLC (or a mix of these). After participants completed the surveys, follow up interviews were conducted to further explain key findings and statements from the surveys with 15 individuals. Over half of the participants (58%) identified themselves as lighting designers and engineers, influencing their respective projects through design-bid contracts, and a quarter (25%) identified as electrical engineers who operated through design build contracts. The remaining participants were members from representative agencies (17%).

Overall Understanding of LLLC

Overall, all participants understood LLLC and the intent behind LLLC. If there were no cost limitations, it was cited as a great and an easy choice. Previously, people complained about the amount of devices/load controllers, but flexibility as a feature and capability outweighed those challenges. Overall, those interviewed could not deny the benefits of flexibility of LLLC.

Benefits

A majority of participants expressed that they understand LLLC and they would use LLLC in certain areas, but overall, there was mostly tepid enthusiasm. Participants said, they were excited about the "nice to have's" LLLC can offer and recognized it as very capable. Within the context of all possible lighting control types, several participants described LLLC as a special tool — the perfect tool – in certain instances.

Participants widely agreed that the primary value of LLLC is the flexibility it provides to spaces that predict the need to reconfigure in the future. This was cited multiple times as way more important than having a sensor in every fixture. Again, participants widely agreed that if LLLC is a “slam dunk” for codes, then NLC is an easy solution for meeting codes (they were saying... “yes, LLLC checks all the code requirements... you know what else checks all the requirements and is usually simpler and cheaper? NLC”). With regard to code, while LLLC checks all the boxes, it is not necessarily viewed as either the cheapest or easiest choice.

LLLC is highly configurable in aspects such as lighting warmth and time to commission with customization that can be controlled by an application. Many LLLC systems are unboxed as “plug and play,” meaning they are ready to commission once connected to the network and power. One of the benefits of LLLC systems is the ease and practicality of installation, use, and flexibility of commissioning long term. Available products allow remote commissioning and controls through an app, tablet, or building control system. Retrofit kits offered by some manufacturers make upgrades easy for buildings with existing fluorescent fixtures. A majority of participants said they believe LLLC takes either the same amount of time or is a little faster than NLC systems. Respondents were supplying their best guess based on design and installation and system setup.

After considering the requirements of code and value, the top three benefits cited (or reasons for using LLLC) in the survey were:

1. Flexibility and addressability of the systems and fixtures

2. Ease of use and maintenance
3. Client requested LLLCs (very specifically for these and other capabilities).

Challenges & Opportunities

The top three challenges with LLLC, as cited in the survey data (and confirmed in the interviews) include the following:

1. *Cost and value added.* For many people who simply want to specify a typical lighting system, LLLC is not the cheapest option, and seemingly overshoots the minimum qualifications (perceived complexity).
2. *Supply chain challenges.* There are several layers that contribute to this, as currently LLLC is the most susceptible to supply chain shortages.
3. *Definition of LLLC.* Regarding definitions, confusion hinges on two different axes where reasonable minds can differ: How integrated? How networked?

Summarizing the first two challenges: most participants cited cost and value as the primary driver for specification. While LLLC is not always the cheapest option, it provides more than the minimum solution; however, concerns emerged around meeting client expectations, perceived complexity, and perceived and potential confusion. In addition, confusion (and frustration) around the definition of LLLC specific to integration emerged, as well as limitations surrounding prefabrication of building components.

Several participants described (to their understanding) that LLLC fixtures are room based only. They interpreted that LLLC is not associated with a gateway and does not communicate with a central system, seeing it as far less scalable than NLC. Their perceptions of LLLC systems include it being a granular approach to room-based systems. This confusion that LLLC systems are network capable, but are not networked, resemble something much more aligned with standalone controls. Several participants cited confusion and frustrations about the definition of what LLLC is (and isn't), specific to system integration. Overall, participant sentiments in this regard include statements such as "why would I pay for and install an LLLC system if I am just going to configure it to operate like an NLC system?" More detail on the topic of networked and non-networked LLLCs and their definition challenges is noted in the "Cyber Security & Wired vs. Wireless" section below.

LLLC Specification

Very few projects had a single control type. Specification is not a simple science and is project, client, project type, and technology specific. Participants mentioned that specification systems often get locked in by contractors or installers. In other words, based on the type of specification that is written, a competitive advantage has been eroded because of certain features that might be available in one product vs another. We asked participants where they would and where they would never specify NLC and LLLC. The results of these questions were inconsistent and often conflicted with one another in terms of where to put these controls in specific building types. Aside from costs and building type responses, the only "would not specify" LLLC response was "when the fixture I want isn't available in LLLC" — this shows that they may have wanted to use LLLC but could not find a compatible fixture. In general, it

was found that people were more interested in specifying LLLC (or not) based on explicit feature benefits. Benefits are the leading motivator, not necessarily a type of space.

In the survey, participants were asked to list the top three factors that determined lighting control specifications. The top five factors that influenced specification are highlighted in Figure 3 (i.e., costs/value, code, flexibility, client request, and ease of use/maintenance).

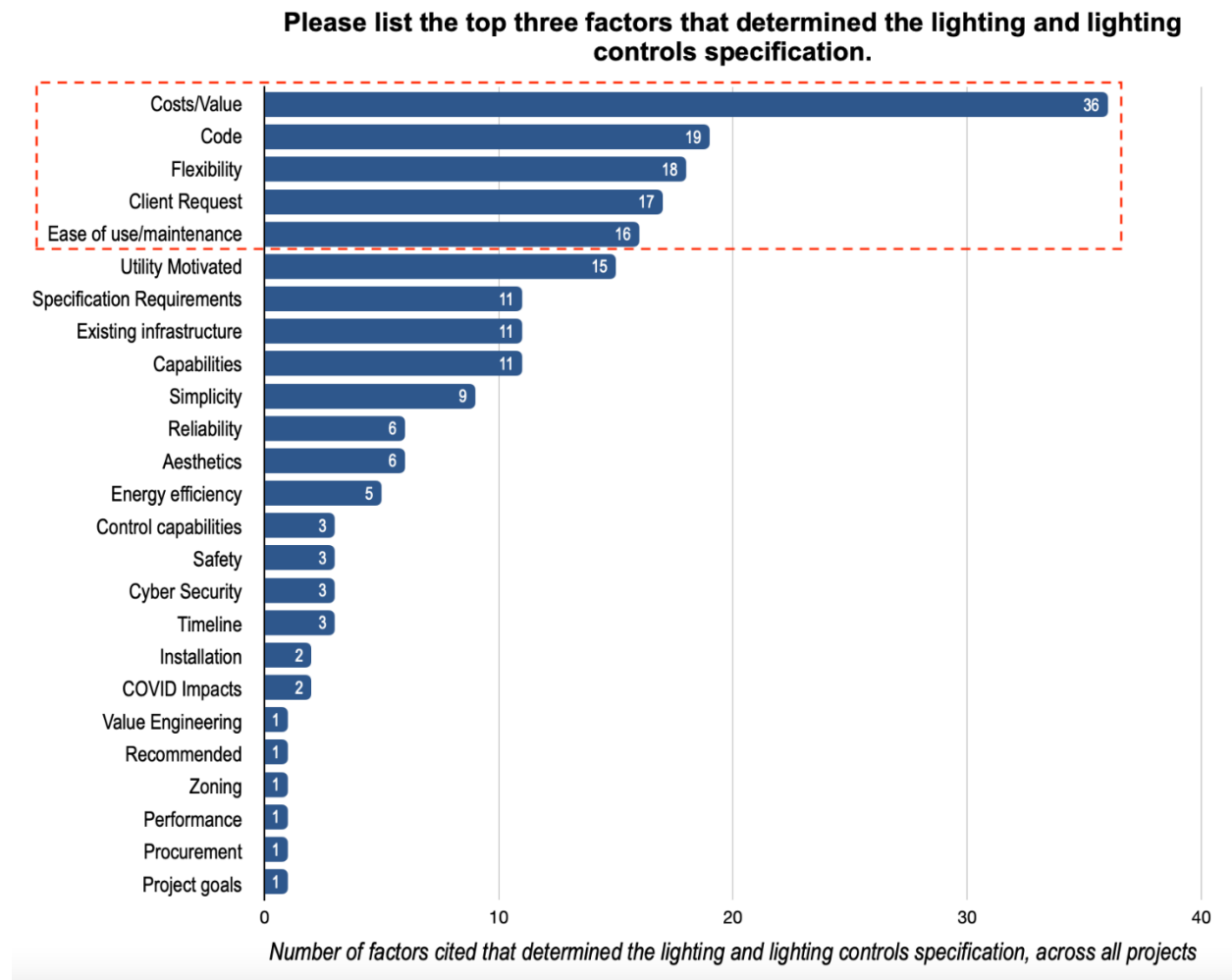


Figure 3. Top factors that determined controls specification, across all project data collected.

Source: Integrated Design + Construction Lab, 2021.

In terms of the types of people who were most influential in making decisions surrounding lighting control specifications, lighting designers and controls engineers were the most influential, who fell into the “other” category in Figure 4. Owners, clients, developers, and tenants (when it is a tenant owned building) were also major decision makers in this context.

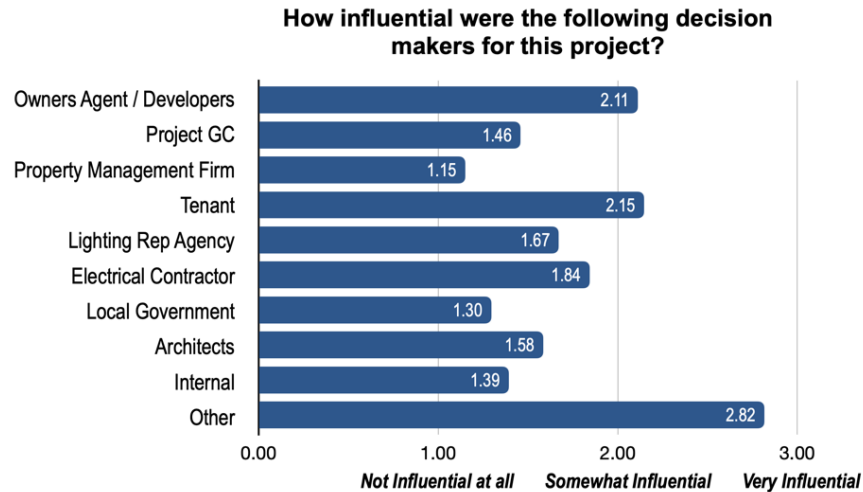


Figure 4. Results from the question asking, "How influential were the following decision makers for this project?"
Source: Integrated Design + Construction Lab, 2021.

The surveys and interview responses also offered insights into how and why LLLCs were value engineered out of projects.

Value Engineering

Specific to value engineering issues, sentiments included that the electrical contractor is the primary driver of value engineering when it comes to lighting specifications.

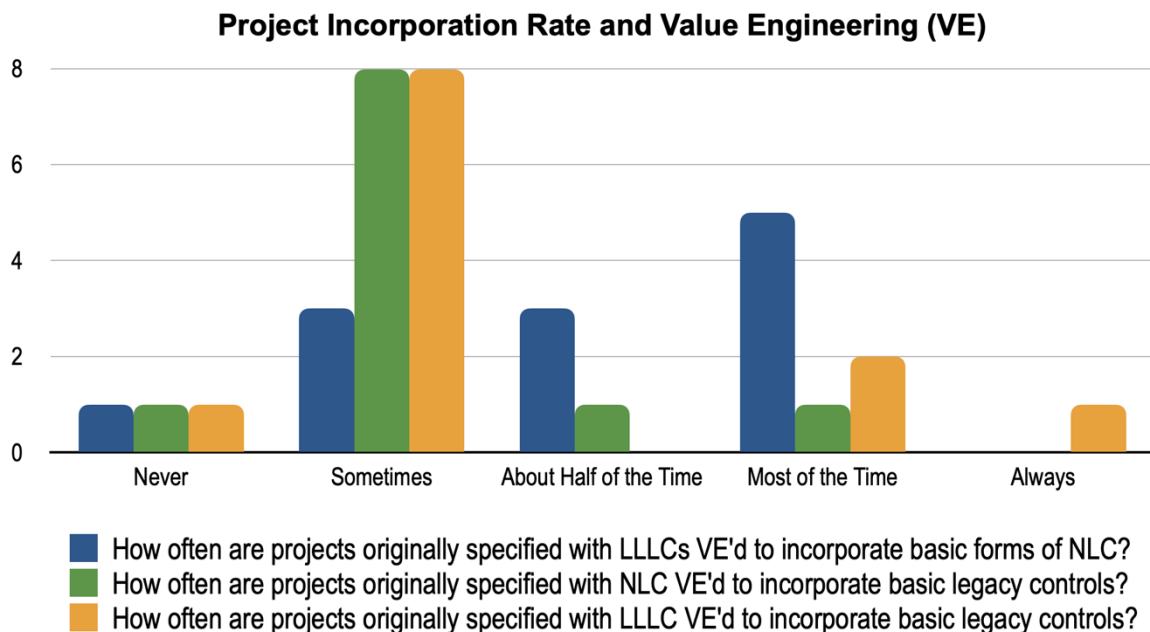


Figure 5. Project incorporation rates and value engineering of LLLC by contractors. *Source:* Integrated Design + Construction Laboratory, 2021.

Unless LLLC was requested directly from the client or project owner, there was a limited chance of it being implemented in the project by completion. Electrical Contractors play a key role in project life cycle. Most participants cited electrical sub-contractors as the primary source when pushing for value engineering lighting packages. A few participants highlighted how the developers enable the electrical subcontractors to act this way. Additionally, when the specifications are written to simply “meet code,” designers and contractors are more likely than not to find cheaper and simpler configurations than LLLC for their projects. Overall, a very consistent picture is painted where lighting is the easiest specification to save money on and is easily value engineered out unless the owner explicitly requests a specific control strategy.

Once an owner's representative realizes they can save considerable amounts of a project budget by switching to a more familiar lighting and controls package, putting sensors in every fixture becomes far less appealing. Several participants highlighted the dynamic where the owner's representative is on the job site everyday with the electrical subcontractor – so they have many opportunities to influence the project, and lighting is a perennial favorite item to go VE. As seen in Figure 5, it is common for LLLCs to be replaced by NLCs through the process of construction and value engineering.

Cyber Security & Wired vs. Wireless

One of the biggest concerns surrounding LLLCs on the owner/client side was the wireless/cyber security issue. From the qualitative (open-ended) survey data, the primary themes that emerged regarding cyber security were (1) project requirements that made wireless systems not acceptable or not allowed by customer refusal, and (2) overall system security concerns including access points, firewall management, hackers, and security/control between departments. In total, 87% of project responses cited some type of cyber security concern or requirement (Figure 6). However, in the interviews, the majority of the respondents clarified that "cyber security concerns" were almost entirely limited to the specific issue of wired vs. wireless systems.

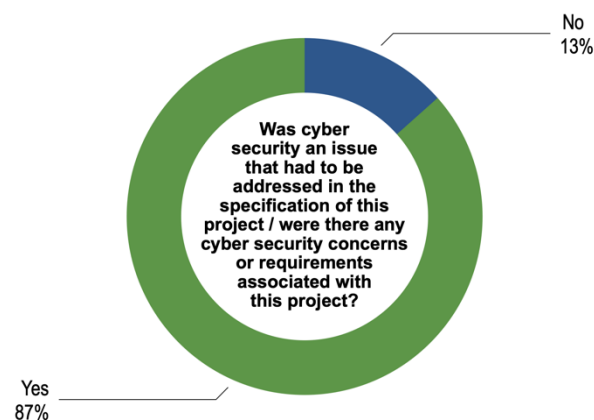


Figure 6. Was cyber security an issue that had to be addressed in the specification of this project? *Source:* Integrated Design + Construction Laboratory, 2021.

Ironically, both old-school facilities managers and high-tech engineers tended to prefer wired control systems, but for quite different reasons. Those who considered themselves on the high-tech end of the spectrum saw wireless controls as a security concern, and as creating additional access points unintentionally exposes the system to malicious activity. For seasoned,

but less technology driven facility managers, wired systems provided familiar control environments, that were more predictable long term.

A majority of participants said that the number one cyber-security issue that comes up in the process of specification is wired and wireless systems. However, many respondents stated that it does not become an issue long term because wireless is specified out in early phases of the conversation. This issue is nearly always resolved by redacting the wireless configuration entirely, specifying something more in line with a wired, non-networked system.

Client Demands & Awareness

Customer demand for LLLC is currently less than NLC. There is an opportunity to further educate owners/clients about the value of LLLCs. Participants routinely stated, “you have to meet the customer where they are at (e.g., code and costs).” Figures 7 and 8 illustrate the key survey findings related to client awareness and opportunities for client education.

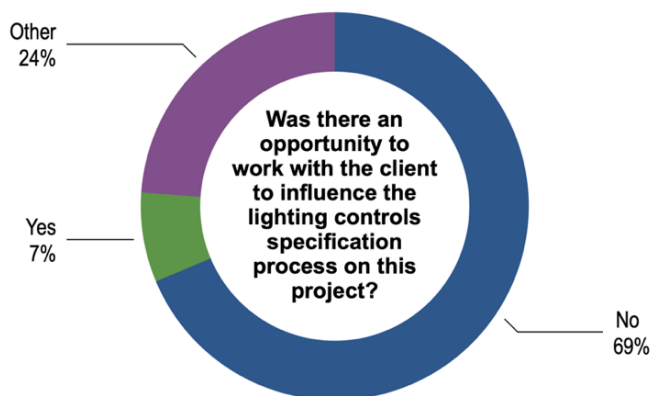


Figure 7. Was there an opportunity to work with the client to influence lighting controls specification? *Source:* Integrated Design + Construction Laboratory, 2021.

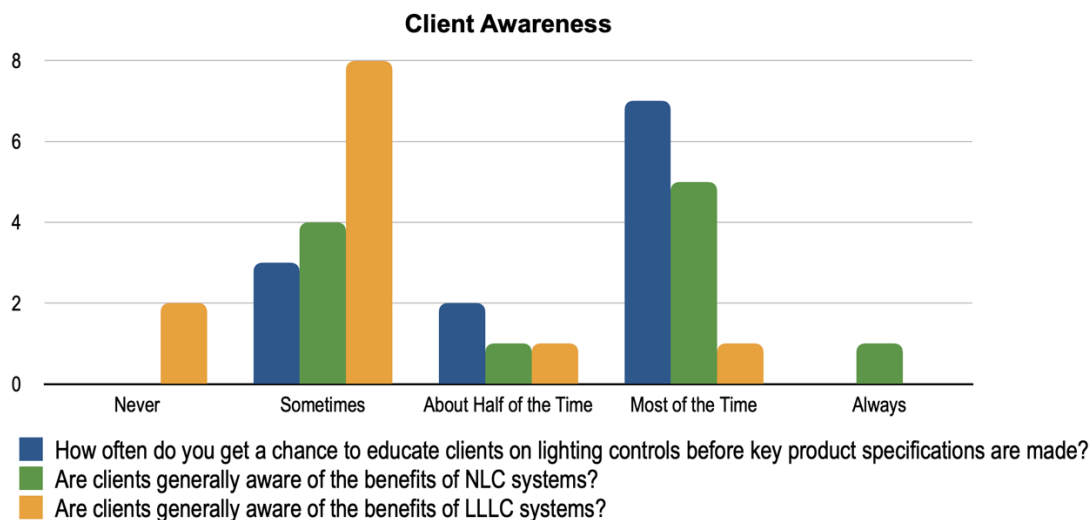


Figure 8. Results from questions asking, “How often do you get to educate clients on lighting controls before decisions are made?” and “Are clients aware of the benefits of NLC/LLLC systems?” *Source:* Integrated Design + Construction Laboratory, 2021.

Education & Training

The survey asked participants what kind of trainings they currently used, and they were to rank those from least to most helpful. It also asked participants what kinds of materials and resources they felt that were still needed that were not being currently met by available educational resources. For the latter, training needs were cited in the areas of LLLC and Building Automation System (BAS) compatibility, the installation and commissioning process, end user interactions with the controls, product and manufacturer specific trainings (including limitations and what to expect for the user interfaces), and how to do the documentation for LLLC systems (regarding building certifications, code requirements, and utility incentives). A majority of respondents said they wanted most training content directly from the manufacturer. Respondents said that trainings are best when they are product specific, go in detail on the pros/cons of a system, and include expert subject matter advice from the factory or representative agency.

Discussion and Conclusions

Market Actors and Landscape

This study used qualitative research methods to gather perceptions of the drivers of lighting specification. A small sample was used to target a very specific group of project specification influencers, and therefore is not representative of the lighting market in general. The participants of this study were primarily lighting designers and engineers.

It was clear from this study, that electrical engineers and their contractors play a critical role in the project life cycle of lighting specification and can be the influence that causes LLLC to be value engineered out of a project design. The reasons for this are numerous, as some contractors may choose a far more familiar system to keep things simple, while others are looking at the bottom line in upfront costs. Luminaire Level Lighting Controls may not be as broadly available as other lighting systems, and initial costs are higher than a traditional legacy system due to the extra functionality of having sensors in every fixture. Targeting electrical engineers with LLLC education that has an emphasis on the aspects of value engineering may help resolve this problem in market adoption.

Of the projects reported, very few had only one single control strategy applied. It is for this reason that a correlation between project type and control strategy was not clear. However, it was noted that the limited fixture types and compatibility between systems was a primary reason that LLLC would never be used in a specific project. It is suggested that marketing efforts focus on the benefits of LLLC rather than applicability to a type of space or environment, as blanket recommendations for schools or offices, for instance, may not apply to every project.

Market Drivers, Transformation, and Barriers

For a system to be truly flexible, every luminaire needs to be individually addressable. In practical terms the benefits of flexibility reported in this study are the ability to wirelessly rezone and reconfigure spaces with only an app. This concept of flexibility via addressability was a consistent desire regarding the specification of lighting products. Beyond the requirements of code, individual addressability (as flexibility in the system), ease of use, and client requests are what is driving investment in the LLLC market, and these may need to be highlighted more in market outreach and engagement measures. Owners, clients, developers, and tenants (when it is a

tenant owned building) were major decision makers or influencers in this context. During the interviews, this quote was repeatedly cited: “When the clients ask for LLLC, it never gets value engineered out.” This shows a significant gap in client facing LLLC education. The importance of owner/client facing and user facing educational content for LLLCs may be a mechanism to increase the demand for LLLC systems moving forward. Participants of this study noted that in many, if not most cases, there is an opportunity to engage with their clients on lighting controls before specifications are made, highlighting the importance of education and training materials for those without a deep prior knowledge on these complex systems. Additionally, when project owners/clients specifically requested LLLCs, it was much more likely that they would not be value engineered out, further emphasizing the need for client-facing education to increase LLLC adoption. Focusing on the flexibility of LLLC, instead of capabilities that are available through other networked controls (such as meeting code requirements or energy savings), seems to be a strategy that can be implemented in all educational and market outreach materials to increase market adoption.

Lastly, a significant finding and barrier to LLLC adoption is that many participants of the study saw LLLC through their own lens of understanding, very few of them aligning with established definitions of what LLLC is or should be. NEEA’s definition of LLLC accounts for wireless capabilities only, which brought up concerns from different demographics in the study. Both veterans and newcomers from the field favored wired LLLCs, but for different reasons. For newcomers, security and creating unintentional access points seemed to be a concern. For more seasoned individuals, they were more comfortable with wired systems as it was similar to the central system and the wired wall stations that they are familiar with. Recent efforts by the industry to establish cyber security standard for LLLC may help alleviate these concerns. Continuing to educate and help walk specifiers, contractors and installers through the legitimate IT solutions and best practices of LLLC, may help to further diminish these fears. Further, strengthening the market understanding, messaging, and project specific solutions available through LLLC can help to improve market adoption.

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