ETA
EFFICIENT TECHNOLOGY ACCELERATOR

LLLC Market Insights Report: Lighting Designers

ACKNOWLEDGEMENTS

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The Luminaire Level Lighting Control (LLLC) Initiative and this report are funded through Minnesota's Efficient Technology Accelerator, a partnership funded by the state's investor-owned utilities (IOUs), administered by the Minnesota Department of Commerce, Division of Energy Resources (DER), and implemented by Center for Energy and Environment (CEE).

We would like to extend our appreciation to all the designers who participated in this research. We would also like to thank the following CEE staff in assisting with data collection, analysis, and reporting including:

- Heath Heiberg
- Ed McGlynn
- Ashley Robertson
- Allison Rodriguez
- Claire Rung

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Executive Summary

Background

The LLLC Initiative is an effort under Minnesota's Efficient Technology Accelerator that promotes luminaire-level lighting controls (LLLCs), a commercial lighting strategy with individual fixture level control components. Lighting designers are often the first to suggest the lighting design for a project and can play a key role in promoting LLLCs, primarily for new construction and major building renovations. To better understand market perceptions and track market indicators, CEE interviewed 11 lighting designers that offer services throughout the state of Minnesota. Key findings are presented throughout this report.

Key findings

Interviewees were asked specific questions about specifying processes and preferences, LLLC familiarity and insights, and resources and training needs.

Specifying processes and preferences

- **Wired communication systems are preferred over wireless systems.** 7 of 11 interviewees preferred starting with wired systems, noting reliability, security, familiarity, and cost as benefits. However, many did talk about the benefits of wireless for retrofit scenarios.
- **A code minimum approach is more common.** 6 of 11 said they start with code-minimum approaches, as they generate energy savings and functionality while minimizing costs. However, **more advanced controls are specified based on customer need.**
- **Providing a preferred list of brands or manufacturers is common when submitting plans, though bid processes can dictate if a brand can be listed.** For example, a public bid may require it to be open, whereas private entities or those with specific systems in place could be sole sourced.
- **Value engineering (VE) happens, but controls may be more insulated than other features.** Responses were mixed with about half saying VE happens on every job, and half saying VE seldom happens for controls, indicating fixtures may be more targeted. However, since LLLCs are fixture-level controls, they could be more affected.
- **Designers sometimes create sequences of operation (SOOs).** 8 mentioned they do at least some SOOs for lighting controls.

LLLC familiarity and insights

- **Designers are familiar with the concept of LLLCs and use them but are not always familiar with the term**. 6 were familiar with the term, 3 with the concept but not the term, and one was not aware of the concept or the term.
- **Standalone options are being used**. LLLCs are often described as a form of networked lighting control, but we did not specify this in our definition. Based on responses, it is clear that several interviewees are using standalone control systems rather than networked LLLC systems, citing particular applications where this is more useful (e.g., corridors).

- **Costs and lack of familiarity are the biggest barriers.** 10 of 11 interviewees mentioned costs as a barrier, but they are often not using rebates to help alleviate costs, citing awareness and process challenges. 6 interviewees mentioned lack of familiarity as a barrier, noting facilities managers and customers were not aware, or didn't understand the technology well, dovetailing with challenges around system complexity and staff changes.
- **Ease of installation (n=8), cost savings (n=7), and flexibility (n=6) are acknowledged advantages** of LLLC systems, largely due to the system being wireless. Interviewees were also asked about more robust feature advantages like HVAC integration. While interviewees acknowledged HVAC integration has the capability for big energy savings, it can be practically challenging to get mechanical and lighting systems to properly interface.

Resources and training needs

- **Customers and electrical engineers/designers would benefit from additional information around LLLCs.** Customers are a big driver for product installation and customer education was highlighted as a need. Electrical engineers and designers may also benefit from additional training and education to bridge familiarity gaps and advocate for LLLCs.
- **Case studies and information about costs would be helpful.** Case studies can help showcase areas of success and common pitfalls, as well as demonstrate to potential interested parties that this is being done elsewhere. Costs are such a large driver that highlighting cost savings and paybacks can more effectively illuminate true costs associated with lighting controls strategies.

Recommendations

Based on the key findings, the LLLC Initiative should consider the following recommendations.

1. **Consider how standalone options and wired communication applications should apply to the Initiative's definition of LLLCs,** which typically promotes networked and wireless products. Due to preferences and utilization of standalone and wired applications it will be important to effectively define and navigate these product types, while recognizing limitations of any definition shifts.
2. **Determine effective ways to mitigate costs and structure rebates.** Upfront cost is a major concern and rebate programs are being underutilized. Working with utilities and designers to figure out the most effective structures could help mitigate costs.
3. **Continue increasing familiarity with LLLCs on both the electrical engineer/designer and customer sides**, through case studies and by discussing cost-saving opportunities.
4. **Highlight flexibility, ease of installation, and cost-saving options, as well as pathways to code compliance**. Leaning into these advantages can help highlight a common message, and with code-minimum approaches driving choices, recognizing LLLCs as a flexible, easy, cost-effective strategy to meet code could be beneficial.
5. **Explore HVAC integration** and how proprietary systems can be more effectively integrated. While interviewees noted possibilities with HVAC and lighting control system integration, barriers would need to be addressed before widescale adoption.

BACKGROUND

LLLC Initiative

While lighting efficiency has long been a key opportunity for electric energy savings, widespread market adoption of efficient solid-state lighting is shifting opportunities for savings from loads to controls[1]. Building energy code requires implementing advanced lighting control strategies in newly constructed commercial buildings and is trending towards controls more broadly. Despite this, the most recent concrete study on the subject in 2019 estimated only 2% of all luminaires in U.S. commercial and industrial spaces were connected.[2, 3]

Luminaire-level lighting controls, or LLLCs, are a commercial and industrial lighting strategy with individual fixture level control components. LLLCs present a cost-effective lighting solution that streamline implementation of controls and can deliver substantial energy savings and mitigate peak demand. LLLCs can simplify compliance with energy codes and offer labor savings over traditional lighting controls, making them an advantageous choice for both new and existing buildings. Additionally, LLLCs can provide the foundation for smart, connected buildings of the future, providing spatial data acquisition, integration with other building automation systems like occupancy-based control of HVAC, and value beyond energy savings.

In efforts to move Minnesota toward the adoption of more LLLC systems, the LLLC Initiative was launched as a program under Minnesota's Efficient Technology Accelerator (ETA). ETA is a partnership funded by the state's investor-owned utilities, administered by the Minnesota Department of Commerce, Division of Energy Resources, and implemented by Center for Energy and Environment (CEE). Ultimately, the initiative strives to make LLLCs the standard approach for incorporating lighting controls in commercial and industrial buildings.

LLLC technology

LLLCs are individually programmable luminaires that contain embedded sensors and compact control components. In additional to manual switches and scheduling, primary control strategies typically include occupancy sensing, daylight harvesting, high-end trim, task and comfort lighting, and demand response and load-shedding capabilities. LLLCs are traditionally a form of networked lighting controls (NLCs).

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[1] An estimated of 72% penetration of LEDs among installed lighting stock nationally by 2025 in the commercial sector. Yamada, M., et al. 2019. "Energy Savings Forecast of Solid-State Lighting in General Illumination Applications." Washington, D.C. Navigant Consulting – U.S. Department of Energy Office of Energy Efficiency & Renewable Energy. https://www.energy.gov/sites/default/files/2020/02/f72/2019_ssl-energy-savings-forecast.pdf.

[2] Connected lighting is an umbrella term used to describe lighting systems with distributed intelligence and are also referred to as networked or internet-of-things lighting systems. Multiple technologies fall under this category, including smart lamps, power over ethernet systems, ancillary accessories like sensors, circuit-level power and energy metering, LLLCs, and more

[3] Yamada, M., et al. 2019. "Energy Savings Forecast of Solid-State Lighting in General Illumination Applications." Washington, D.C. Navigant Consulting – U.S. Department of Energy Office of Energy Efficiency & Renewable Energy. Pp 32. https://www.energy.gov/sites/default/files/2020/02/f72/2019_ssl-energy-savings-forecast.pdf.

Many LLLC systems use wireless communication, with mesh networks as a common type of wireless architecture. Systems can be controlled with remote controls, smartphone/tablet apps, or computer applications. Some systems connect to the internet for remote access, while others are controlled locally through a wired or wireless LAN.

LLLC market

LLLC systems have existed for nearly a decade, are widely applicable across building types, and can save on average 63% of the energy consumed by a traditional lighting system.[4] However, they still make up a very small proportion of lighting installations. The technology does have some form factor limitations and higher energy savings for certain applications like in high bay and troffer scenarios.

While lighting installation processes can follow a few different pathways, for new construction and major renovation scenarios, LLLCs need to be included in some form of an initial electrical design to be installed. Thus, lighting designers are critical market actors in increasing the adoption of LLLCs. While there is still a chance that specified LLLC systems get removed before installation through the process of value engineering, starting with this upstream set of market actors can help us better determine how and when LLLCs are included in projects and why they may or may not make it to full installation.

This research effort largely focuses on the new construction and major renovation market, where lighting designers play a key role. While this is a smaller subset of the overall market, it is still important to understand the processes and experiences within this market.

Research goals and scope

This report is intended to provide a snapshot of lighting specifier insights in the LLLC market.

The key research goals included:

- Understanding current specifier experiences and perceptions
- Tracking and baselining market progress indicators
- Ultimately providing strategic insights for the initiative

Methodology

CEE compiled a list of 60 firms to participate in interviews. The list included design and design-adjacent firms that were:

- Known to operate in Minnesota
- Known or suspected to provide services related to mechanical, electrical, and plumbing (MEP)
- Could plausibly have an interest in or exposure to LLLC technologies.

[4] Wen, Y., et al. 2020. *Energy Savings from Networked Lighting Control (NLC) Systems with and without LLLC.* Oakland. Energy Solutions – Northwest Energy Efficiency Alliance and the DesignLights Consortium. Pp 39. https://designlights.org/resources/reports/report-energy-savings-from-networked-lighting-control-nlc-systems-with-and-without-lllc/.

Firms included a range of specialties (e.g., architecture, engineering, contracting) but all included design components, and the majority were true design firms. The list was compiled using CEE staff's extensive market knowledge and included a mix of firms who had previously engaged with CEE and those who had not. While we recognize this may include some bias in respondents, this list allowed for a more targeted and high-quality outreach approach, and efforts were taken to balance perspectives. Firms were deprioritized if they had extensive recent communication with CEE or were known or suspected not to feature electrical design.

Ultimately, 11 firms accepted the invitation and participated in an hour-long phone interview for an 18% response rate. Interviewees were offered a $100 gift card to thank them for their time.

KEY FINDINGS

Business areas

Most interviewees worked in multiple commercial sectors and with a variety of clients. Sectors mentioned by at least two people included:

- Healthcare
- Retail
- Multifamily
- Education
- Government
- Hospitality
- Offices
- Specialty spaces (e.g., fitness centers, ice arenas, parking ramps)

Interviewees mentioned they work with a multitude of client types (e.g., end user, developer, general contractors) often depending on the process and what they are called to do.

Interviewees generally mentioned their firms worked on both retrofit and new construction buildings, with only one explicitly noting they worked in retrofit and two citing mostly new construction. Splits between retrofit and new construction ranged anywhere from 20% retrofit and 80% new construction to 90% retrofit and 10% new construction. It should be noted that while we asked about retrofit applications specifically, designers are usually involved in more major renovations that would trigger code rather than traditional associations with retrofit applications. Thus, it may be more accurate to note that there was a mix of work on existing buildings and new construction.

Specifying processes and preferences

We asked interviewees to walk us through their processes for designing or specifying lighting controls. Again, processes varied for where lighting controls came into play including predesign, energy modeling, plan/spec, design/build, and others. Most involved the customer at the beginning and end of the project to set expectations and hear about client needs to make sure they are met. However, there were some distinct preferences in what level and type of systems are specified.

Wired are preferred over wireless communication systems

We talked with interviewees about their preferences for wired versus wireless communication systems. Overall, there was a strong preference for wired over wireless systems with 7 of 11 mentioning they preferred to start with wired systems or that they mainly used wired systems, and only one saying they preferred wireless and 3 noting that they do both or don't have a preference. Even if wireless was not preferred, half of respondents noted that wireless systems were particularly good for retrofits.

> *"Retrofits are where you will dabble into doing the wireless, and that's where you can save money because you can just tear out the stuff — you already have your electrical circuit there, wiring there, and can't get into walls and run Cat5 cabling. Now wireless is way better in this situation." – Int. 6*

For those who mentioned wired systems, they noted a few key benefits including reliability, security, familiarity, and cost. Four respondents said that they either had challenges with the reliability of wireless systems or otherwise felt wired systems were more reliable, noting that wireless sensors may not always work the way that they should and that people generally trust wired systems more. Similarly, three mentioned the security wired systems provide, and that in some applications, like in healthcare or on federal government projects, wired applications are mandated. Two people mentioned that wired systems are familiar to them, and two others mentioned that it costs less to do wired systems.

> *"I think [wireless controls are] great and it's potentially the future, but we did have one early on project where for some reason the batteries on these wireless controls were not lasting...it was just a really bad situation — a lot of people at our company are overall burned and don't want to touch it because of one project…I typically start with wired — it's familiar to me. I definitely will [put in wireless] — not shying away from them, so if there's a situation where we are remodeling a conference room and we need to add lighting controls and don't want to cut up the wall, I am going to jump right to wireless controls for sure. I do wireless, but on a big project, I haven't jumped there yet — the bigger projects are new buildings and you're not cutting open walls to pull the cabling." – Int. 1*

Code-minimum approach is more common, but more advanced controls specified based on customer need

LLLCs are code compliant and can be used as a way to achieve code requirements while also providing advanced features. Because of this, we wanted to learn more about how design interfaces with code. Six of 11 interviewees described that they start with a code-minimum approach. Several interviewees noted that code minimum gives you a lot of functionality for most spaces, and that in certain circumstances like churches or conferences rooms, or for sustainability-oriented programs, something more advanced may be warranted. Cost is a factor in this as well, as one interviewee noted the cost-conscious condition of the market as driving their code minimum

approach and another noted that in a design build project, they are "going with code minimum because we want to get the job." One also mentioned that energy modeling results can trigger additional review if they go above code, so they often don't take advantage of that to avoid the extra review.

Two interviewees noted that they start with an above-code approach, and the rest indicated that they go either way, focusing on what the customer and budget will allow.

> *"We base it on their wants and needs, where it would work or other situations where it may not apply."- Int. 9*

Additionally, when discussing advantages of LLLCs, two interviewees mentioned energy code compliance as one pro for LLLCs, though they are not the only system available to meet code.

Providing a preferred list of brands or manufacturers is common

To gain a sense of how products were selected, we inquired whether interviewees indicated specific manufacturers or products within their specifications or if they preferred open bids. Responses were relatively split. Again, interviewees indicated that they would do what a customer wanted. If a customer was already using a particular brand or had strong preferences, they would try to incorporate that. Providing a list of preferred brands or product equivalents was common, with six mentioning they used that approach if the situation allowed. Four interviewees mentioned they will do sole source or spec one brand, whereas four also indicated they kept their bid process open. Some noted that their process depended on the type of job and where their company fit in the procurement process.

> *"Depends on how the project is happening. If they want to use us for the fixture procurement, then we will specify our own stuff — if they are just hiring us as a design subcontractor, then it needs to be agnostic for bid." – Int. 5*
>
> *"Public jobs, we have to keep it open without showing favoritism or preference. For private jobs there are a few options, or we can do [sole source]." – Int. 4*

Interviewees also mentioned working some with manufacturers reps, but their influence may be limited due to other constraints as one interviewee commented.

"We get a lot of that when talking to reps — you guys should try this and that — and it's fancy and we'd love to, but for us to pitch that to a client is fewer and farther between. It's like you guys need to go and convince contractors that it's cost-effective or convince the building owner that it's worth the premium. Engineers don't want to be the person pushing the pocketbook…Often by the time we've been brought on, the direction is pretty sorted out, and occasionally they'll ask us for some guidance and then we can sometimes push the envelope but not as often as we'd like." – Int. 11

Value engineering happens, but controls may be more insulated than other features

We know that value engineering or VE, the process of evaluating designed features and alternative options and subsequently adjusting design elements to balance cost and functionality, is a common practice that can affect which features and products eventually are installed. This typically happens after the designer has completed their work. As such, we were interested in better understanding whether lighting controls were often affected by value engineering. About half the interviewees indicated VE happened almost all the time, while the other half indicated it seldom affected lighting controls. Several interviewees who indicated VE was prevalent mentioned this was something their firms actively pursued. Others noted that some of this happens even before traditional VE occurs, where it's in the design or predesign phase and the owner wants something, but then expectations are adjusted based on budget.

"I kind of feel like it's a part of every project. It's 100% gonna happen. At the beginning of the project, clients ask for the sky because they've got nothing to lose and they don't know what systems are capable of. And then put a number in front of them and get a reaction and work it back." – Int. 5

On the flip side, several of those who said VE was rarer for lighting controls acknowledged that VE does happen, but fixtures or other things were targeted more often with VE than controls, as controls are necessary to meet code.

"90% of projects we do what is specified, 10% is value engineer where you can get by with certain things. They will just stick to what code is required. [We use] code minimum and we're not going to design beyond that for a lot of people. I feel like fixtures are targeted more than controls. It's usually the lighting product that gets value engineered… Code minimum lighting controls are pretty good — there's not a lot you're going to strip out of it." – Int. 4

However, one noted that VE can even happen with code-minimum controls with code exemptions and loopholes.

"Oh yeah 100% — sometimes it's not even going above code — it's simply just complying with the code. We get corridors in multifamily apartments — we fight it all the time from contractors — corridor lighting controls on multifamily aren't required by code because you can use the health safety exemption out of the code, even though the code does specifically call for corridor lighting controls." – Int. 3

Designers sometimes create sequences of operations

Sequences of operations, or SOOs, provide a detailed roadmap of the desired lighting operation to communicate with programmers and owners about how the system should function. They are important to make sure that lights are installed and programmed to match their design and occur early in the design process. However, these are not always included on projects. Two interviewees mentioned they do not do SOOs, but eight mentioned they at least make SOOs some of the time.

LLLC familiarity and insights

Designers are familiar with the concept of LLLCs and use them, but are not always familiar with the term

We know different definitions of LLLCs exist, and that LLLC is a newer term. When asked if they were familiar with the term LLLC, six said they were familiar with the term, another three were familiar with the concept but not necessarily the term, and one said they were not aware. Some interviewees were asked to describe what the term meant to them, with the most common responses being individual light fixture control and general advanced controls. We then defined LLLC for the interviewees as "individually programmable luminaires that contain embedded sensors and compact control components." When asked what other terms might be used to describe those types of systems interviewees mentioned:

- Point of use
- Individual fixture controllability or fixture controls
- Wireless system
- Embedded sensors
- Smart fixtures
- Just controls in general

While some interviewees mentioned networked capabilities, we did not explicitly mention network capabilities in our definition to interviewees, though it is commonly defined as such in the industry. The Design Lights Consortium defines LLLC as, "The capability to have a networked occupancy sensor and ambient light sensor installed for each luminaire or kit, and directly integrated or embedded into the form factor during the luminaire or kit manufacturing process."[5] However, it was clear that several interviewees are using luminaire-level control technology as standalone controls

[5] Dilouie, Craig. June 2022. "Introduction to luminaire-level lighting controls." Lighting Controls Association. https://lightingcontrolsassociation.org/2022/06/15/introduction-to-luminaire-level-lighting-controls/.

rather than networked systems, citing particular applications where this is more useful. The use of standalone controls should be considered in following insights regarding LLLCs.

> *"Biggest candidate for us is the lighting corridor — we are leveraging the fact that each one of these fixtures has its own occupancy sensor, and its own program for how long it stays on. Some will have programs for light temperature for what the lighting looks like. It's pretty awesome the way we're able to individually tailor our lighting strategies….Generally speaking, they are all pretty standalone for our applications — I honestly can't say if they're networked together in any other way than maybe being on the same circuit." – Int. 11*

Interviewees noted varying experiences with LLLCs, with two mentioning they, or their company, have done 50-60 projects with LLLCs in the past year, and one mentioning they do not use them at all. Most had only a handful of projects in which LLLCs were used. It should be noted these numbers may not reflect Minnesota projects specifically. Several interviewees mentioned LLLC popularity is growing. When asked where LLLCs may be most appropriate, interviewees mentioned several different spaces. At least two people mentioned the following:

- Schools (4)
- Offices (3)
- Exterior lighting or parking garages (3)
- Corridors or stairwells (3)
- Warehouses (2)
- Retail (2)
- Healthcare (2)
- Anywhere you need controls (2)

Costs and lack of familiarity are the biggest barriers

When asked explicitly about barriers, or through the course of the interview, 10 of 11 interviewees mentioned cost as a concern. Upfront costs were higher for the project, and while some noted that costs are coming down to be more in line with other systems, it's still a driver. One interviewee noted that while there might be labor savings associated with LLLCs, risk pricing means the owner doesn't see those savings.

> *"Money would be the biggest [driver] — it's just more expensive." – Int. 8*
>
> *"[Cost is a] huge barrier, huge constraint right now — cost defines what the project looks like. Budgets are typically set before we get hired…For the specifier [LLLCs are] going to be an added cost to us — adding more devices. In terms of the contractors' side — he's saving more on his end without the wiring and conduits — I don't know how much owners are seeing that credit…We are hoping to offset with lower labor and wire costs, but they aren't giving a real labor discount because they are having to learn the stuff – their risk costs money…there's risk with something less familiar to them." – Int. 4*

To combat high upfront costs for emerging technology, rebates are often used, and several MN utilities offer LLLC-specific rebates. While a couple interviewees mentioned the benefits of rebates to the customer, interviewees were not especially familiar with the LLLC-specific rebates. Two mentioned they use rebate processes through the Energy Design Assistance Program (EDA), which includes whole building modeling and does not deal with LLLCs specifically but does incentivize controls. Several mentioned they do not really use rebates, or that rebates are handled by the contractor, so they come into play later or run into challenges with the process and don't play a big role in design considerations.

"We use them all the time — most common utility program we are a part of would be the Energy Design Assistance program through Willdan — just incentivizes control, it doesn't specify LLLC controls. You could meet it with LLLCs, but you don't have to implement that level of control if for whatever reasons it was cost prohibitive. That is by far the most common utility program in the new construction industry." – Int. 3

"[Rebates] that are specific to LLLCs, I can't say I have specifically seen those… that's often the subcontractor or general contractor helping owners when it comes to rebates." – Int. 11

"If the customer asks — I've tried to work [with the ETA team] a couple times to get on the front end, but it's very difficult — I have to get that approved — our bidding window is less than 2 weeks, typically a week, in order for me to get LLLCs approved on the front end and get [the ETA team] together, if anything, it's an after the fact situation — it doesn't help us — unless the customer that we feel an inkling that it might benefit — typically once the shovel hits the ground we go." – Int. 7

Awareness and familiarity with LLLCs were also described as challenges by six interviewees. While interviewees noted that many people in the industry were aware of LLLCs, some were not as familiar, and facilities managers and customers were generally not aware of LLLCs or did not understand the technology well. Lack of familiarity also often dovetailed with system complexity, with interviewees noting that for customers the learning curve, staff training, and turnover can be a challenge. This in turn led to callbacks or perceptions of harder maintenance, in addition to the fact that LLLCs have individual control components and therefore more pieces that could fail.

"Owners are worried because if they don't understand the tech, they think it's harder to maintain and they worry it's going to fall onto them after the installation — it's the scariness of unknown… [there's a] lack of familiarity." – Int. 4

"You walk away and you've trained one person on the programming and what it does — how you control this fixture vs. that fixture, but it's like a game of telephone — it gets lost at some point and someone comes in and does something they weren't supposed to do and then they can't get it to go back and

we get a phone call — especially in public spaces or conference rooms that multiple people use." – Int. 7

"If you have a 1,000 lights, then you have a control in every single one of them…you have 1,000 control components. There is more likely a chance for a failure or a product malfunctioning vs. one Power Pack or switch. Failure rate may be the same – maybe it's a 10% failure rate but 10% of 1000 is way different than 10% of 100." – Int. 8

In addition to costs and familiarity, the challenges noted with wireless systems, namely security and reliability concerns, also apply to wireless LLLC systems. While other challenges were not mentioned by multiple interviewees, several had good points worth considering. One indicated that coordination and timing is a challenge for specifiers, another indicated that systems were often proprietary, and another noted that sensor heights and spacing can pose problems.

"Specifier side — it's always the thing that never gets coordinated right — the other thing is our budget. To do the coordination, we need to have enough time. Where do we put our time? Luminaire-level controls require coordination —I have to talk to the vendor, make sure the manufacturers are doing it right – is it factory install, other install, so many elements. Do we go this route or just do the typical controls where everybody knows everything?" – Int. 4

"Also have to have other tech — like a specific laptop to work it. A lot of it is proprietary — you better like [the brand] because you are not changing." – Int. 8

"For example, a sensor itself, there are height limits that those little devices can do — you have to have more of them, typically they are closer together. If you have higher ceilings they don't tend to work — atriums same thing — those are the big issues. Height restriction and spacing." – Int. 10

Ease of installation, cost savings, and flexibility are advantages

On the opposite side, seven interviewees noted cost savings associated with LLLCs both in the form of energy savings and in labor cost savings associated with wireless installations, though again, the labor cost savings is not always passed through to the customer but could be an incentive for contractors.

"I think it's really cheap and energy savings could be huge — especially if you're already doing the lighting control — it should be really cheap to add a relay and you could have massive energy savings." Int.3

"No wires — that part of the job is simpler and could potentially make more money — we bid it the same… technically you shouldn't be bidding it the same, but

everyone does — that's where your cost savings come in but the people who are installing and bidding don't necessarily look at it that way." – Int. 7

Eight interviewees mentioned ease of installation as a major advantage. Interviewees mentioned that wireless is easier to install, phone apps make programming simple, and isolated fixture components make it easier to manage a problem or replace a component.

"Biggest advantage for peers is how quickly things go in — usually it's a time crunch where the faster we can get it done, the better." – Int. 2

Six interviewees also mentioned the flexibility or customizability of the system as being advantageous. This came through in how individual lights could adjust to individual user preferences, how different spaces could be adjusted for different purposes or looks, and for adaptability down the road if you want to reconfigure lighting.

"It's all interfaced with BMS, you can reconfigure your lighting to have it where you want. If it's in an open office area, and you want to add 2 rooms, you can easily reconfigure it without having to bring in an electrical contractor to rewire things." – Int. 4

"You can come back and reprogram things — can change set points for photo cells and time delays, that kind of thing… being able to reprogram things and make changes in the field without having an electrician come do it is certainly handy…Somewhat frequently, we have an owner that would like to change something that's already been installed." – Int. 1

"It gives them the flexibility of having areas, things lit up to the level they want or dimmed down to the level they want… It gives them flexibility on how they want their building to look or be used…You're [also] giving more individual control — for example, if you have a big open office space and you have people that are more sensitive to light levels, you can give them that ability to just have their light fixtures over the area dimmed — or the light level at a different level —you can separately have the setting for each fixture — I think that's the biggest pro for those." – Int. 10

While complexity may be a challenge, several interviewees also mentioned additional features that LLLCs offer as benefits including things like asset identification, space and occupancy tracking, and tunability for emotional reactions and physical health. They also mentioned overall system integration by tying into a building management system or building automation system, and HVAC integration.

HVAC integration was of particular interest for the ETA team and interviewees were asked more about their thoughts with HVAC integration. In general, interviewees mentioned this happens on occasion and could be appropriate, but it has not been a big focus. One mentioned the large amount of energy savings that could come with this approach.

> *"Yeah, definitely seems like it would be natural to have those talk to each other or just have one system that accomplishes both... Definitely up and coming. BMS control panel and lighting control panel have a lot of the same parts." – Int. 1*

> *"We'll tie a VAV box into the lighting control panel — we throw a relay on it to control ventilation… we've found that to be more cost-effective and more energy savings than demand control ventilation… I've seen in the energy model where integrating the ventilation system in with the lighting control will save more energy through occupancy control than demand control that can be required by code." – Int. 3*

However, interviewees also mentioned areas of caution and struggle with HVAC integration including:

- Systems can be proprietary, and HVAC and lighting people do not have access to each other's systems, and the systems do not necessarily work well together
- Caution against allowing temperatures to drift too far based on occupancy triggers
- Potential need for upgrading HVAC equipment to get systems to work together

> *"What we find is the lighting controls do not play well with the mechanical controls… Whoever is making the system is making it for mechanical system or for lighting systems. They're note technically making it for both." – Int. 2*

Resources and training needs

Customers and electrical engineers would benefit from information

In general, interviewees identified that customers are big drivers of product installation and customer education was a need. Interviewees noted that they can provide options, but the customer ultimately makes the decision.

> *"Most customers don't really know stuff until we tell them. Then they are really interested in it and they want it, and then we give them the prices, and then they're not interested." – Int. 9*

Because of this, customers, including facilities managers and owners, were noted as a key focus for training. Interviewees remarked on the fact that training is more available to them as industry professionals whereas it may be less available for customers, and there is a learning curve and knowledge gap for customers.

Electrical engineers or lighting designers like the interviewees could also benefit from training. While again noting that training is more available to them through lighting reps, they are a key

audience for designing systems with LLLCs, getting the customers on board, and ultimately getting systems installed. As mentioned, there is also a gap around system familiarity so training could help familiarize designers with the products and see them as solutions.

> *"The reps are great about talking about what the given fixtures are capable of doing. That's often what will initiate that initial use — we've been having this challenge, and suddenly there's now a product on the market that addresses that challenge. Then you go, well ok how much does that cost? I think education is a big thing whether it's reps or lighting manufacturers, maybe it's right in their literature – pros and cons. I think that's the biggest thing is really awareness. With a lot of technology, it's like 'oh there's a piece of equipment for that,' but sometimes you just get so stuck doing something the same way because it's been reliable. You keep 'fixing' the problem with the same solution even when there's a better solution." – Int. 11*

Case studies and information about costs would be helpful

When asked what types of resources may be helpful, about half agreed that case studies or examples would be valuable and about half mentioned information specifically around costs would be helpful. Case studies can help illustrate real-world examples and show designers and customers that they are not the first ones to use this technology, or be successful with it, which can help alleviate concerns. Costs also drive a lot of decision-making and having resources that show possible return on investment or paybacks over time could better illustrate the true costs and savings associated with LLLC technology.

> *"Case studies are always great because it proves the technology is out in the field and you know we're not the first ones to be leveraging it. That's a big part of it. And, with the world being cost based, you see a lot of those charts that are like, 'here's our product compared to all these other products that you know that it either replaces or why ours is better or cost effective.' Knowing the flexibility of the features is a big selling point. Case studies are great…There are a couple mechanical technologies we've been super skeptical of and our reps are like, 'no we literally did this at our office, and it's been great.'" – Int. 11*

> *"Basically, just showing them how it would benefit them and how fast it would pay off. If you can show them it's going to pay off within 5 years, they'd be like Ok. If you're showing 20 years, it's gonna be no, I'd rather pay less now. Showing the payback you can get." – Int. 6*

While not a theme across multiple individuals, one person suggested they mostly needed information about how systems work and how to appropriately navigate spec'ing with bid requirements, which is worth consideration.

"For me I wouldn't need case studies as much as knowing how it works, what it can do, what it can't do and is it a standalone system. Are there any other manufacturers that can do what this system does? Is it a proprietary system where you have to use only Lutron, or Crestron? Especially if it requires a 3 named spec — you have to know that going into the owner, that's a one-named spec — are you ok with that, can you do that — if it's a state project, you have to have 3 names on there. It's good to know are there other equals to that system — not all specifiers will say that." – Int. 10

RECOMMENDATIONS

Based on the key findings, the LLLC Initiative should consider the following recommendations.

1. **Consider how standalone options and wired communication applications should apply in the initiative's definition of LLLCs** as more classic definitions often include wireless and networked capabilities. With clear preferences for wired systems among lighting designers and understanding that
2. controls are being used in certain situations, it is worth considering whether our definition should be inclusive of these options and break from others in this space. However, it will be important to recognize what limitations may exist for expanded definitions, especially around national collaboration and data availability.
3. **Determine effective ways to mitigate costs and structure rebates.** Cost is a major concern for multiple market actors and even with incremental costs diminishing, there are still upfront cost barriers. It also appears that current rebate programs are being underutilized, and structures may be preventative for larger uptake to influence design. Working with utilities and designers to figure out the most effective structures for market actors could help accommodate cost offsets and make LLLCs more appealing for designers to include.
4. **Continue increasing familiarity with LLLCs on both the electrical engineer/designer and customer side**, creating case studies and discussing cost-saving opportunities. Interviewees identified electrical engineers/designers as well as facilities managers and owners as key leverage points in decision-making and as entities that could benefit from additional information and training. Case studies and cost information can help these market actors better understand what they can expect with LLLCs and increase familiarity and ultimately installation.
5. **Highlight flexibility, ease of installation, and cost-saving options**, as well as pathways to code compliance. Flexibility, ease of installation, and cost savings were the key benefits designers identified for LLLC systems. Leaning into these advantages and clearly articulating them can help highlight a common message across the industry that resonates with market actors. In addition, interviewees discussed that they often begin with a code-minimum approach but would design for what the customer needed. Highlighting that LLLCs are an easy, flexible way to meet code, while also providing additional benefits for customers could make the system more attractive for designers and customers alike.

6. **Explore HVAC integration** and how proprietary systems can be more effectively integrated. While interviewees noted possibilities with HVAC and lighting control system integration, there were several barriers leading to minimal applications of this integration. Further investigating these barriers and the energy savings this type of technology could provide can help determine if this is something the initiative should take on more squarely, potentially working with manufacturers and others to advocate for system integration.