EFFICIENT TECHNOLOGY ACCELERATOR

Luminaire Level Lighting Controls Market Transformation Plan

Center for Energy and Environment

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CONTENTS

INTRODUCTION

Minnesota Efficient Technology Accelerator

The Minnesota Efficient Technology Accelerator (ETA) is a statewide market transformation program that accelerates deployment and reduces the cost of emerging and innovative efficient technologies, bringing lower energy bills and environmental benefits to Minnesotans. The ETA is 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).[1]

The ETA program has set four overarching goals:

- Create a strategic process to accelerate market deployment of key technologies.
- Employ effective strategies to leverage market forces.
- Become a hub for collaboration among stakeholders.
- Achieve cost-effective energy savings and other benefits for utilities and Minnesotans.

The ETA program develops individual market transformation initiatives for a handful of targeted technologies and approaches, often starting at an early stage of development. The ETA approach involves working closely with market partners and other key stakeholders. Initiatives move through four stages of a life cycle that includes: 1) concept development; 2) program development; 3) market development; and 4) long-term monitoring and tracking. The majority of effort and resources are spent during the market development stage, which is the "implementation" stage that involves intensive market engagement. Before moving from one stage to the next, an initiative must be vetted and approved by a coordinating committee consisting of the DER and the utilities funding the ETA.

Purpose of this plan

The Market Transformation Plan is the culmination of the program development stage, where extensive research and planning is done to prepare the initiative for market launch. The purpose of this plan is to summarize key contextual information, lay out the basic program logic and desired end state that informs our market strategy, and the present the fundamental market support activities necessary for success. This plan will then be the guide in developing specific activities each year during the market development phase. By being transparent in our objectives and strategies as much as possible, we hope to better facilitate stakeholder engagement, and alignment on strategy with key stakeholders, so we can together be coordinated and successful in achieving common goals. Supporting and informing this plan are

[1] Minnesota Statutes § 216B.241 subd. 14 created the framework for the ETA program, which is funded by Xcel Energy, CenterPoint Energy, Minnesota Energy Resources, Minnesota Power, and Otter Tail Power.

the Market Characterization Report and the Energy Savings and Evaluation Plan (Appendices A and B).

Summary of our approach

This section contains a brief summary of our approach, including our theory of how we expect to transform the market for luminaire-level lighting controls (LLLCs).

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.[2] Building energy code requires implementing advanced lighting control strategies in newly constructed commercial buildings. Despite this, less than 1% of all luminaires in the United States are connected, largely due to the complexity of implementation and associated cost.[3,4]

LLLCs are a cost-effective lighting solution that streamline implementation of controls and can deliver substantial energy savings and mitigate peak demand. LLLCs simplify compliance with energy codes and offer labor savings over traditional lighting controls, making them an advantageous choice for new buildings and major renovations. 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.

Lack of awareness and the technical skills required to successfully implement LLLCs are still limited among market actors, contributing to high mark-ups that impact upfront costs. By leveraging industry relationships and providing support, training, and hands-on experience to empower and instill confidence in market actors, our market transformation initiative will accelerate the decline of those upfront costs. As a result, access to lighting controls will increase and be incorporated in more retrofit installations, where they are not often considered.

Our goal is to transform the market, with LLLCs leading the way in the standard practice of implementing lighting controls in commercial and industrial buildings in Minnesota.

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[2] An estimated of 72% penetration of LEDs among installed lighting stock nationally by 2025 in the commercial sector.
Yamada, Penning, Schober, Lee, and Elliot, "Energy Savings Forecast of Solid-State Lighting in General Illumination Applications" (Washington, D.C.: Navigant Consulting, 2019). Available here.

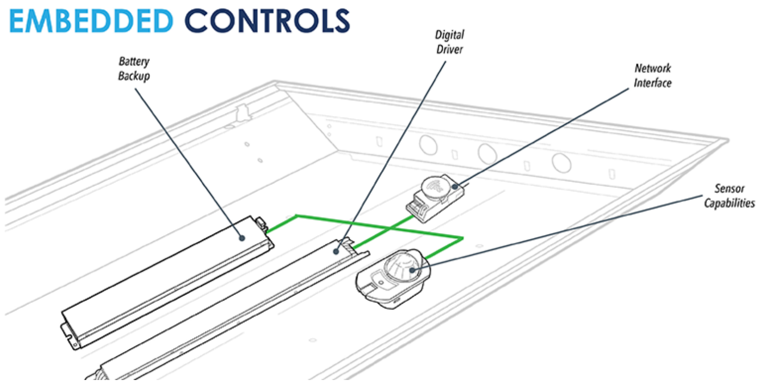
[3] Connected lighting is an umbrella term used to describe lighting systems with distributed intelligence and are also referred to as networked or internet-of-things lighting systems. Multiple technologies fall under this category, including smart lamps, power over ethernet systems, ancillary accessories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

[4] Yamada, Penning, Schober, Lee, and Elliot, "Energy Savings Forecast of Solid-State Lighting in General Illumination Applications" (Washington, D.C.: Navigant Consulting, 2019). Available here.

Product description

LLLCs bridge the gap between the lighting and lighting controls markets. They are connected systems of luminaires that contain control and sensor components.

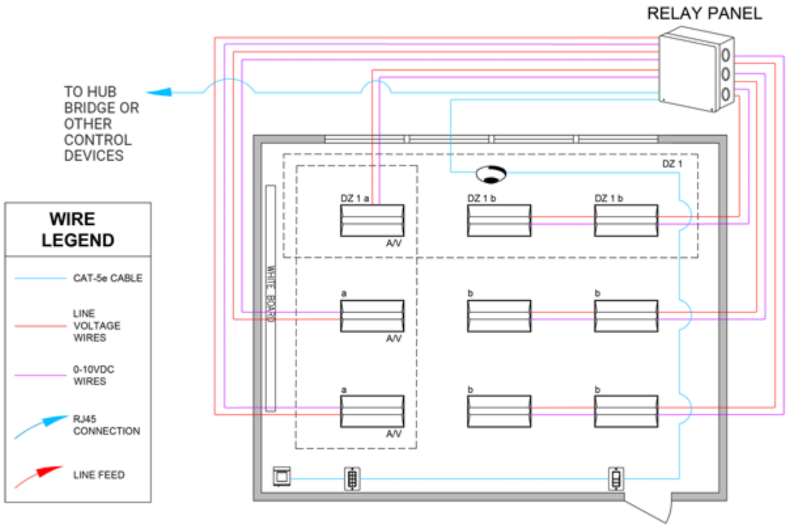
Figure 1: Diagram of components contained within an LLLC[5]



The term Luminaire Level Lighting Controls (LLLCs) was coined by our partners at the Northwest Energy Efficiency Alliance (NEEA) as part of their market transformation initiative. This type of networked lighting control (NLC) system typically relies on few, if any, devices that aren't housed within the luminaires themselves (see Figure 1). Other lighting control systems have supplemental control components that require separate installation and wiring (see example in Figure 2).

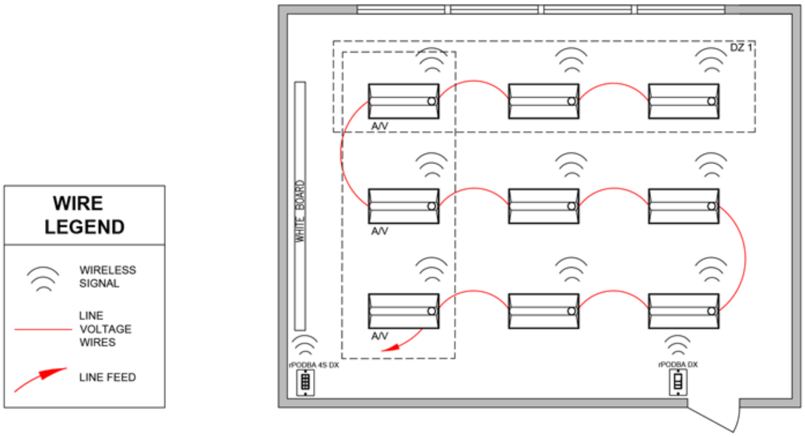
[5] AcuityBrands, "The Value of Embedded Controls" (2023, 8 18). Available here.

Figure 2: Current baseline code compliant, room-based, networked lighting control system for a typical classroom with dimming, motion control, daylight harvesting, and keypads for manual control[6]



Because LLLCs are individually controllable, reconfiguration of control zones does not necessitate rewiring. LLLCs simplify design, installation, and maintenance compared to other types of networked lighting controls.

Figure 3: Code compliant LLLC system for a typical classroom with wirelessly connected luminaires, embedded sensors and controls and wireless keypads for manual control[7]



[6] Ibid

[7] Ibid

Embedded sensors typically include a passive infrared (PIR) motion sensor and a photocell (also referred to as a light sensor). Sometimes other sensor types are utilized for integrated system applications, such as humidity and temperature.

LLLCs can communicate with one another, sharing occupancy status to operate synchronously in zones (groups of light fixtures identified with dotted lines in Figure 2 and Figure 3). This communication typically is done wirelessly with LLLCs, although wired systems also exist. Of systems with wireless communications, most use Bluetooth or a Zigbee mesh networks.[8] Some systems can be programmed and controlled using remote controls, apps for smartphones/tablets, or computer applications. Some systems can connect to the internet and be accessed remotely via a web browser, while other systems can only be controlled locally via a local area network (LAN) which can be wired or wireless.

The difference between LLLC systems and standalone LEDs with embedded sensors is that they are programed, typically after installation, to function as a system instead of as individual luminaires.

Lighting control systems can contain both LLLC luminaires and non-LLLC luminaires, depending on the system. Not all manufacturers' systems can integrate both LLLCs and non-LLLC luminaires on the same system.

Key features and benefits:

- Enhanced Control and Energy Savings: LLLCs enable precise control over lighting by incorporating motion sensors, photocells, and often wireless communication capabilities. This allows for efficient energy management, zoning, continuous dimming, daylight harvesting, load shedding, high-end trim, scheduling, personal controls, and integration with external systems including building management and HVAC systems.
- Flexibility and Customization: Each individual luminaire can be controlled separately, offering greater flexibility in lighting design. Customized lighting scenes can be easily adjusted to suit specific needs and preferences, creating optimal lighting conditions for improved comfort and productivity.
- Extended Lifespan: By reducing the operating hours of lighting systems, LLLCs extend the lifespan of the LED boards and drivers. This not only reduces maintenance costs but also minimizes waste, making it a more sustainable lighting solution.
- Non-Energy Benefits (NEBs): LLLCs provide opportunities for integration and data leveraging in smart building applications. By using embedded sensors, LLLCs enable asset tracking, occupancy tracking, environmental monitoring, and navigation systems. These features can enhance operational productivity, profitability, security, and occupant health and comfort.

[8] There are other system architectures that leverage other wireless protocols. An example is Clear Connect, a proprietary protocol used by Lutron Vive and Athena products, which operates at a lower frequency than other interior wireless lighting control systems that operate like key fobs for automobiles.

- Cost-Effective and Simple Installation: Compared to other NLCs, LLLCs offer simplified installation and maintenance processes. They eliminate the need for extensive design, additional equipment, and in the case of wireless LLLCs, communication wiring, all of which result in reduced installation time and costs.
- Energy Code Compliance: LLLCs enable compliance with energy code requirements for lighting control strategies in commercial buildings, including motion control and daylight harvesting. Their built-in sensors eliminate the need for additional equipment, streamlining compliance and facilitating faster project execution.

Application types and focus

LLLCs are primarily used in commercial and industrial buildings, with linear troffer and low/high bay fixtures being the most common. These fixtures are found in various building types, including offices, warehouses, and MUSH (municipalities, universities, schools, hospitals) market buildings, where significant energy savings are possible.

LLLCs offer a compelling value proposition for retrofits, simplifying energy code compliance without the need for extensive rewiring. Compared to other NLCs, they particularly benefit small businesses and budget-constrained organizations.

Specific applications within buildings have especially excellent value propositions.

- Granular zoning in open office areas is valuable for motion control, especially post-COVID-19, when occupancy rates have decreased in commercial office buildings, since individuals may now work from home more often.
- Stairwells and corridors benefit the most from motion control, reducing energy use outside their short occupancy periods while also satisfying egress lighting requirements.
- LLLCs also automate testing and reporting procedures required by the NFPA National Life Safety Code 101, saving on maintenance labor costs, and potentially earning insurance discounts.

Product specification

LLLCs combine LEDs, controllers, and sensors within each individual luminaire, and enable individual, fixture level control and a networked system.

Default operation

In the future, it is the goal of this initiative to define minimum out of the box configurations to ensure LLLCs save energy independent of custom configuration. Such defaults may resemble the following:

LLLCs must individually:

- Turn off after a period of 20 minutes of no motion[9]
- Regulate light levels based on photocell input to a setpoint no greater than 400 lux (or 40 footcandles)[10]

Qualified products

The DesignLights Consortium (DLC) currently maintains a qualified product list (QPL) of NLCs with the ability to filter by *Integral Controls*. This filter can locate lighting control systems including LLLCs. This QPL includes some details about luminaires and retrofit kits available within the systems.[11]

State of the market

LLLCs have reached a level of maturity that well suits them for market adoption. The technology is already utilized in the commercial and industrial sectors, with a growing number of installations in various building types.

Additional information can be found in the market characterization report in the Appendix. While the market is not yet saturated, competition is increasing and leading to greater product availability and cost competitiveness. Currently, several big players in the lighting industry, as well as specialized control system manufacturers, offer LLLC solutions. This diversity of suppliers produces a healthy market ecosystem, fostering innovation and product improvement.

We anticipate that future advancements may include more seamless integration with other building systems, expanded smart building applications, and increased interoperability between different manufacturers' products.

"Controls ready" or "scalable" solutions

In the past few years, a trend has emerged in the market where incremental solutions are being offered. For example, controls can be added or enabled in the future for luminaires which are LLLC or sensor "ready."

Software, system limitations, and feature parity

While LLLCs offer substantial lighting control and energy-saving advantages, they face system limitations, particularly concerning project scale, system integration (including HVAC), and nested zoning features. Nested zoning allows precise lighting control in applications with higher functional density. This presents challenges in matching NLC expectations. To overcome these limitations, manufacturers and integrators must either clearly document and communicate

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[9] Exceptions made for units ordered as nightlights or set to a nightlight mode using an onboard switch. Such units may dim to low-end instead of turning off.

[10] Exceptions made for units ordered for use in high-illumination applications (e.g., hospitals) or with onboard switches for setpoint configuration.

[11] Retrofit kits contain the control components that differentiate a luminaire from an LLLC and can be used to convert an uncontrolled luminaire to a connected one.

capabilities or develop advanced programming algorithms and user-friendly interfaces to improve LLLCs' capacity to handle such applications. System architecture must also be robust and scalable to manage complex setups.

Wireless layouts and troubleshooting

Designing layouts for wireless systems poses unique challenges due to diverse coexisting wireless technologies in the built environment. Wi-Fi, Bluetooth, and Zigbee contribute to a congested RF spectrum, causing signal issues like degradation and packet loss. Efficient layouts require careful consideration of the environment and coexisting technologies. Troubleshooting these issues demands specialized RF engineering skills, which many lighting professionals currently lack.

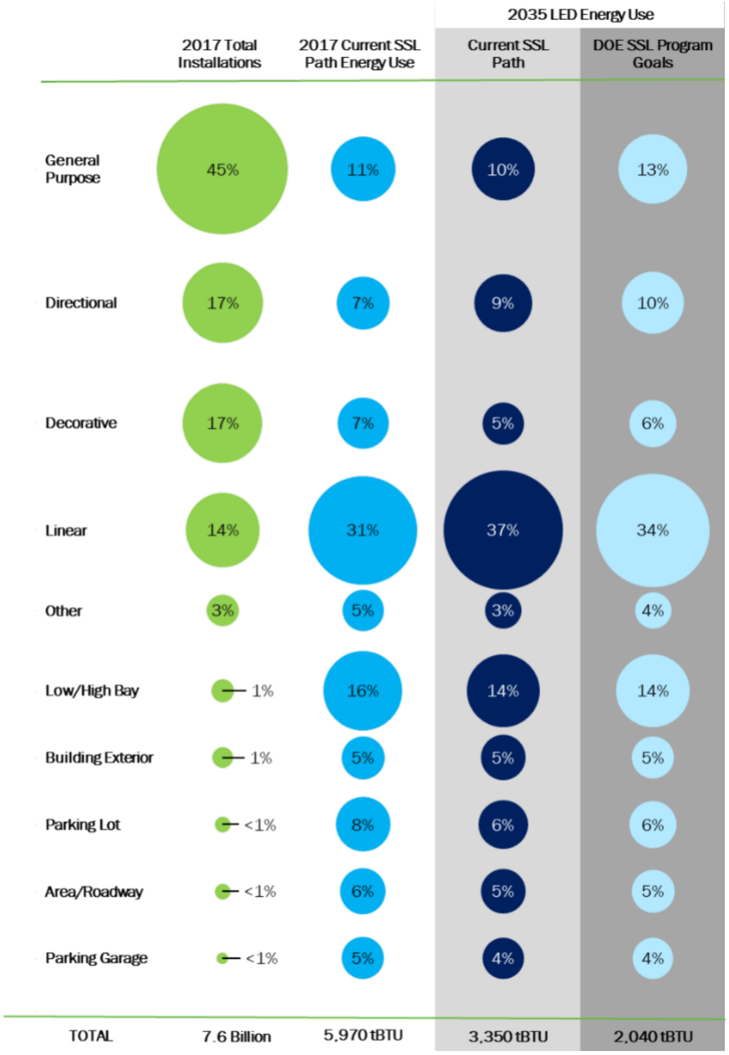
Form factors

Not all commercial and industrial luminaires can be LLLCs. Decorative fixtures like chandeliers, wall sconces, cove lights, and wall washers are not often available as LLLCs. These fixture types are often selected for aesthetic reasons and may be installed out of line of sight, which may restrict or render ineffective the embedded sensors. While they may be able to be included and individually controlled on systems with LLLCs, luminaires aren't considered LLLCs without these attributes. Downlights, common for general illumination, also are not typically available as LLLCs due to their compact form.

By 2035, the current solid-state lighting path forecasts that linear and low and high bay form factors will represent 37% and 14% of all LED energy use, respectively (Figure 4). Considering interior use fixture types only, this represents 64% of energy consumption.[12] Therefore, LLLCs are currently available in form factors that demand the most power.

[12] From Figure 4, general purpose, directional, decorative, linear, other, and low/high bay are considered interior fixture types.

Figure 4: Total U.S. Lighting Installations, Energy Consumption, and LED Lighting Energy Use[13]



Competitive landscape

The LLLC landscape is rapidly evolving, with various products emerging to meet the growing demand for advanced lighting control systems. CEE has assessed other products that may complement or compete with LLLCs to gain a comprehensive understanding of the competitive market. LLLCs disrupt both the lighting and controls markets by embedding controls within luminaires, replacing both light fixtures and connected controls.

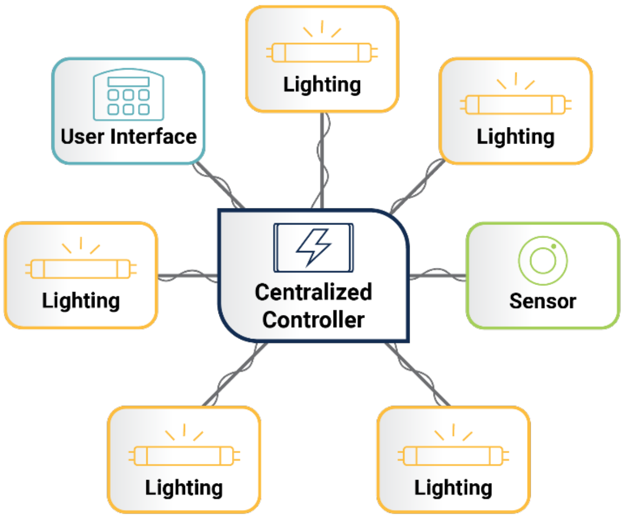
[13] Yamada, Penning, Schober, Lee, and Elliot, "Energy Savings Forecast of Solid-State Lighting in General Illumination Applications" (Washington, D.C.: Navigant Consulting, 2019). Available here.

Of the different options for lighting controls available, solutions can typically be divided into two primary categories: standalone and networked (NLCs).

Standalone controls like dimmers, line voltage photocells, timers, and line-voltage occupancy sensors are hardware-based solutions with little to no software or ability to integrate with other systems. All communication is analog with standalone controls and there is no central controller. Benefits of this technology include simplicity, component availability, and cost. Downsides include lack of remote diagnostics and reporting, limited functionality, and the need to rewire if spaces are reconfigured or used differently.

NLCs, of which LLLCs are a subset, include many types of technologies and systems that may be centralized, distributed, or a hybrid of the two.

Figure 5: Centralized System Architecture



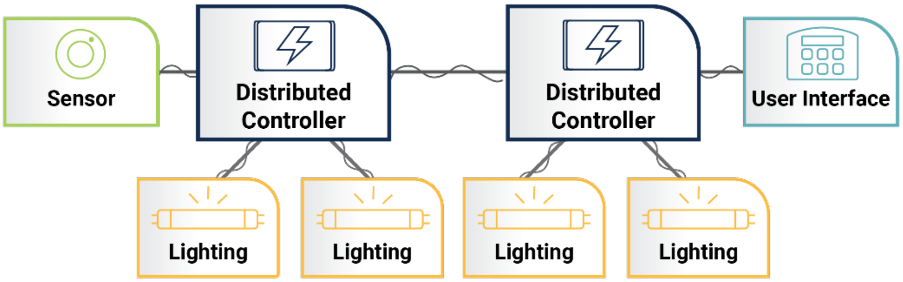
Centralized systems, shown in Figure 5, house most of the lighting control equipment in a concentrated location, often in electrical rooms. Groups of luminaires, referred to as lighting zones, are each wired to this equipment on unique home runs.

Since the increased adoption of dimming fluorescent lighting and later LEDs, NLCs have moved away from centralized panel-based systems because many commercial applications no longer require as much physical space as dimming resistive loads like incandescent and halogen lamps.[14]

[14] Resistive loads are typically phase-dimmed using triacs, relays that rapidly open and close faster than the human eye can detect, resulting in lower perceived light levels. To do this, heat sinks are used, which take up a lot of space, so those systems were primarily centralized. These are still somewhat common in restaurants and other hospitality applications where general-purpose lamps are the primary load type for aesthetic purposes. While these applications are not a focus area for this initiative because of the form factor of luminaires typically used, this context informs the evolution and competitive use cases of different lighting controls architectures.

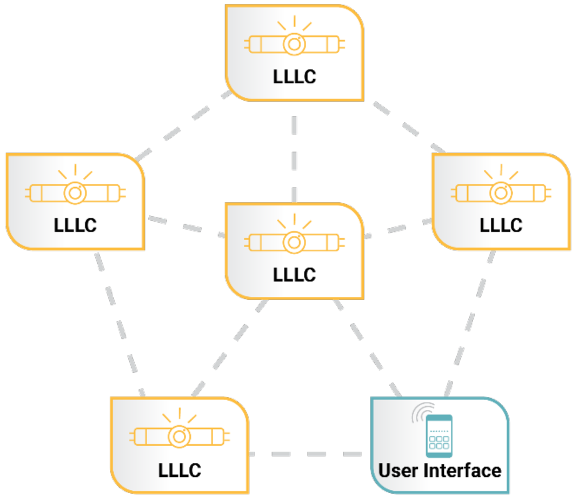
While today digital dimming has become the norm around the globe, enabling two-way communication with luminaires and individual addressability, the U.S. remains saturated with analog 0-10V dimming, which has limited capabilities and features. Today, digital and analog dimming systems are available in centralized, distributed, and hybrid architectures and tend to be selected based on project requirements or the specifier's preference.

Figure 6: Distributed or Hybrid System Architecture



Distributed systems typically have zone controllers housed throughout a space, often in the ceiling adjacent to the luminaires they control. Hybrid systems either have a mixture of the two or have multizone controls in a few concentrated locations, splitting the difference. A simplified version of both system architectures is described by Figure 6.

Figure 7: Wireless Mesh System Architecture



LLLCs are very distributed systems where each individual luminaire contains a controller and a sensor and requires very few additional components to connect to. Most LLLC systems available utilize wireless communication — mesh networks, like the one shown in Figure 7, are a common type of wireless architecture. Some manufacturers' NLCs are compatible with their LLLC offerings whereas others use distinct systems with no integration.

The gap between standalone and networked solutions on the market is wide with regards to complexity and associated functionality. As discussed in the Software, system limitations, and feature parity section of this document, there are features currently available with some NLCs that are not available for LLLCs. LLLCs may be poised as the in-between solution to bridge the gap between budget-minded and high-end applications using standalone controls and feature-rich NLCs, respectively. Or they may continue to evolve, approaching parity with those highly customizable NLCs. Most likely, different manufacturers' systems will diverge from one another, following both approaches.

Currently, the DLC's QPL lists 50 indoor LLLC systems from 38 manufacturers out of a total of 74 qualified NLC systems. This number continues to grow. However, interoperability is generally limited within selected systems except for retrofit kits, which offer broader luminaire compatibility.

Baseline product

Existing building stock

There are no lighting controls in most existing buildings in Minnesota. 57% of commercial space in Minnesota does not have lighting controls, which means lights turn on and off using only switches and/or breakers.[15] Largely dependent on the time of last permitting, smaller portions of existing building stock have lighting controls employed, mostly auto-on/off motion control utilizing standalone occupancy sensors.

Competitive products in this portion of the market are mainly LED fixtures. Retrofits of less efficient technologies have been occurring over the past decade, largely replacing like-for-like or relamping existing fixtures. Most of these replacements are not installed with controls.[16] Comparatively, the incremental cost for LLLCs is $49 for entry point products and LLLCs save 63% of energy, on average.[17,18]

New construction and major renovations

For new projects requiring permitting, lighting controls are required by energy code. In the past few decades, energy codes in Minnesota began requiring lighting controls including bi-level

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[15] See Energy Savings & Evaluation plan.

[16] Energy code (ASHRAE 90.1-2019) requires compliance if fixture replacements affect more than 20% of the connected load, but this is not commonly enforced.

[17] Kate Buck, Dan Hannigan, Yao-Jung Wen, and Zdanna King, "2022 Luminaire Level Lighting Controls Incremental Cost Study" (Oakland, CA: Energy Solutions, March 2023). Available here.

[18] Yao-Jung Wen, Emily Kehmeier, Teddy Kisch, Andrew Springfield, Brittany Luntz, and Mark Frey, "Energy Savings from Networked Lighting Control Systems with and without LLLC" (Oakland, CA: Energy Solutions, September 2020). Available here.

control, auto shutoffs, and daylight harvesting. In Minnesota, current energy codes also require manual-on restrictions in some spaces.[19,20]

Today, these requirements are typically achieved in new construction and major renovation projects through use of an array of standalone and networked lighting controls systems.

Market Description

Target market

The target market for LLLCs includes the commercial and industrial building sectors. This market is sizable and poised for growth. Reports indicate that the North America Commercial LED lighting market, including LLLCs, is currently valued at $7.4 billion USD, with a projected growth to $12 billion USD by 2025, at a CAGR of 10%.[21] This growth is driven by increased awareness of energy efficiency, government regulations favoring sustainable lighting solutions, and the demand for advanced lighting control systems. Detailed insights into Minnesota's market are provided in the market characterization report in the appendix, covering trends, customer preferences, and market dynamics, offering a comprehensive view of LLLC market opportunities and challenges. A summary of the target market is provided in the table below.

Table 1: LLLC target market summary

Sector (e.g., residential, commercial, industrial, etc.)	Commercial & Industrial
Existing buildings and/or new construction	New construction and existing buildings (major renovations and retrofits)
Technical savings potential	2,490,000 MWh

[19] Manual-on, as opposed to auto-on, describes the sequence of operation where, upon occupancy of a room, the motion sensors do not turn lights on. Instead, lights must manually be turned on by the occupant at a user interface. Motion sensors still turn lights off after a room has been vacated. Manual-on operation saves more energy than auto-on does.

[20] Trends in these codes are toward more granular zoning for motion control in open offices, which bodes well for LLLCs as they provide the infrastructure for fixture-by-fixture control, regardless of circuitry.

[21] Mordor Intelligence, "LED Lighting Market in North America: North America LED Lighting Market Size." Available here.

Market dynamics and path to purchase

Key players in this market are primarily LLLC manufacturers, comprising lighting and control system manufacturers like AcuityBrands, Lutron Electronics, Cooper Lighting, and RAB Lighting. These manufacturers have integrated LLLC capabilities into their existing product portfolios, capitalizing on their established market presence and distribution channels.

The path to purchasing LLLC systems varies depending largely on whether the project involves retrofitting or new construction/major renovation. In both cases, electrical contractors (ECs) usually procure LLLCs from local electrical distributors who, in turn, purchase them from manufacturers while serving as intermediaries. These distributors sometimes offer added services such as project management and material warehousing.

In new construction and major renovation projects, architects typically initiate a bid process known as design-bid-build or spec-bid-buy after completing designs. General contractors (GCs) solicit bids from trades, including ECs, to establish project costs and submittal documentation for selection. ECs assess material prices through the supply chain and estimate labor costs. The pricing for lighting and lighting controls can be bundled or separated, depending on project requirements and the interests of the parties bidding. Distributors often consult with manufacturer's representatives (“reps” or “agents”) when pricing these projects. Reps are third-party sales agencies representing manufacturers in specific regions. They collaborate with manufacturers to produce strategic quotations. Typically, reps earn commissions from manufacturers for projects specified, sold, or built within their geographic territories.

Upon receiving quotes, distributors add their commission and present the contractor with a quotation. The EC includes labor and commission costs in their proposal submitted to the GC in the hopes of winning the project.

In retrofit projects, the process is similar but often lacks a general contractor or architect. Contractors typically compete for projects by submitting quotations for materials and labor directly to the building owner or their representative.

For new construction and major renovations:

- Lighting designers and electrical engineers typically specify lighting and controls.
- LLLCs are likely to be included on a project if they are specified without substitutions and there is sufficient budget for lighting controls.
- LLLCs may be included on a project if the sales agency facilitating the quotation for a project chooses to use LLLCs to meet the specification requirements if the corresponding electrical bid is selected by the GC.
- LLLCs may be requested specifically by the building owner or their representative, but such practices are rare.

For retrofits:

- Electrical or lighting contractors typically specify the lighting and controls.
- Contractors rely on their distributors and sometimes the manufacturers rep (depending on their relationships) to identify the right system for their application.

- LLLCs may be requested specifically by the building owner or their representative, but this is unlikely.
- LLLCs may be included on a project if the contractor convinces their customer that it is worth the incremental cost or insists that this is the best way to comply with the required energy code.[22]

An exception to the above processes occurs occasionally, when systems integrators, persons or companies who specialize in connected systems like these, are responsible for coordinating various components and subsystems. This is usually because of existing relationships with building owners with large real estate footprints or where a vision for a building is primarily a connected one; these projects typically involve more advanced data and systems integration use cases. Their specialty typically ensures seamless integration and functionality compared to unspecialized electrical trades. The systems integrator's expertise may replace the need for multiple stakeholders, as they handle tasks such as design, product selection, installation, integration with other building systems, testing, and programming. They also often have direct relationships with manufacturers and purchase their equipment directly, bypassing local distribution and manufacturers reps. Systems integrators may be contracted by anyone facilitating the project (building owner, IT department, general contractor, etc.). These market actors are less likely to be dedicated to a particular geography and may work on projects around the globe.

PROGRAM LOGIC

Long-term vision

The LLLC initiative envisions a future where granular lighting controls, particularly LLLCs, are not just important but central to transforming the lighting market. Our goal is for LLLCs to lead the way in the standard practice of implementing lighting controls in commercial and industrial buildings across Minnesota. This shift will happen faster than the natural market progression, driven by our strategic focus on overcoming market barriers. LLLCs will serve as the default foundation for connected buildings, providing access to diverse data leading to reduced HVAC use and enabling demand-responsive lighting for enhanced grid resilience while simplifying the lighting controls design, installation, and operation. As a result, commercial ratepayers will increasingly turn to LLLCs to manage peak demand and reduce costs, making them integral to Minnesota's energy efficient future.

Market barriers and opportunities

To understand the market and develop the market support strategies outlined in this plan, we distilled the most significant and influential market barriers and opportunities. The barriers are

[22] Energy code compliance and enforcement in retrofit projects is not very common today.

aspects of the existing market that inhibit scaling the technology and opportunities are key external market trends that can be leveraged to grow the product category.

Barriers

Numerous barriers exist in the market. For the purposes of this plan, we've narrowed down and identified four key barriers that will be considered in developing our market support strategies. These barriers were identified in the Market Characterization process and are as follows.

1. Lack of awareness of product category and understanding of value proposition

LLLCs are relatively new to the market and many market actors (electrical contractors, distributors, etc.) are not familiar with the term. Those who are familiar with the technology are not aligned on nomenclature or don't have a comprehensive understanding of their benefits. This lack of awareness hinders their use. In spec-bid-buy projects, labor estimations are likely higher than necessary without adjustments for this time-saving technology, which could be due to the lack of familiarity. In retrofits, they are not recommended by contractors, likely for that same reason.

2. Lack of compelling value proposition for some applications

Interviews with building owners and other representatives of this customer group indicate that even when aware of the value proposition, it is not compelling enough for some applications. In these cases, barriers to adoption depend on customers' resources to delegate to projects. Beyond the cost of implementation, adopting new technology requires investing time — therefore, low priority projects like efficiency upgrades do not occur readily without additional incentive.

3. Lack of technical skills

The complexity of LLLC systems and their integration with existing lighting infrastructure demand a certain level of technical expertise, including knowledge of networking protocols, wireless communication, and system troubleshooting. However, many professionals in the lighting industry may not possess these specialized skills, which can hinder widespread adoption of LLLCs. The lack of technical skills poses challenges in designing, installing, and maintaining LLLC systems, leading to inefficiencies, potential errors, and limited system performance.

4. High upfront cost

As indicated in the market characterization report in the appendix, the upfront cost, or even just the perception of an incremental cost, deters the use of LLLCs on more projects. The incremental cost of LLLCs over LED fixtures is a barrier from it from being included on more retrofit projects. The high first cost may be a barrier in spec-bid-buy projects where light fixtures and lighting controls are not packaged into a single price in competitive bids and LLLCs may be compared to the cost of LED fixtures without considering costs for controls.

Opportunities

There are significant opportunities that can be leveraged in the market to hasten technology adoption. Based on the Market Characterization research and team knowledge, we've identified the following key opportunities that have informed the development of our market support strategies.

1. Profit potential

LLLCs present an opportunity for market actors through differentiation in the commercial construction industry. This is because of the reduced timeline required for LLLC implementation compared to other lighting controls solutions. In all projects, value-added services and lighting-as-a-service (LAAS) models can facilitate long-term relationships and generate recurring revenue on projects.

2. Building energy codes

LLLCs are positioned for widespread adoption due to the required use of lighting controls by building energy codes. They are advantageous over other ways to meet code because they simplify design and increase flexibility as needs change.

3. Growing demand for energy efficient lighting post market adoption of solid-state lighting

LED lighting has become standard for energy efficient lighting due to its energy saving capabilities and long lifespan. As market saturation of LED retrofits approaches, there is a growing demand for energy efficient lighting solutions by lighting retrofit companies and utility programs after-market adoption of solid-state lighting. LLLCs save lighting energy by turning off or dimming when light is not needed or adjusting to the appropriate light level based on ambient light conditions, reducing energy consumption and utility bills for consumers. Through scheduling, remote control, and demand response capabilities, there is opportunity to leverage LLLCs to reduce peak demand at commercial facilities.

4. Changes in utilization of commercial buildings since COVID-19

Office attendance among workers is approximately 30% lower than pre-pandemic levels.[23] According to a study by McKinsey, employees work from the office 3.5 days a week, with the lowest rates in the professional services, information, finance, and management industries.[24] Across industries, employees at larger firms generally spend less time in the office. Demand for office space has declined accordingly. This leaves many workplaces adjusting their use of space. The flexibility of LLLC reconfiguration as well as their occupancy data analytics are

[23] Jan Mischke, Ryan Luby, Brian Vickery, Jonathan Woetzel, Olivia White, Aditya Sanghvi, Jinnie Rhee, Anna Fu, Rob Palter, André Dua, and Sven Smit, "Empty Spaces and Hybrid Places: The Pandemic's Lasting Impact on Real Estate" (McKinsey Global Institute, 2023). Available here.
[24] Ibid

features highly valued by owners of commercial office space. This non-energy benefit is also compelling to property management firms who can easily include lighting for tenant fit-outs.

5. Market actors are interested in LLLCs

As indicated by our market characterization report, market actors including specifiers, manufacturers reps, contractors, and distributors are interested in LLLCs and many believe in their upward trajectory in the future of the lighting industry. The market is open to the technology; substantial convincing won't be necessary by this initiative to motivate the market to change. This initiative is primed to help the market actualize this change.

Market support strategies

The following activities address the barriers and leverage the opportunities to achieve our long-term vision in the Minnesota market.

As the team embarks on market support strategies, more intelligence about the market will be gained, the impact of the strategies will become better known and the market itself may evolve or shift. In order to optimize impact of the initiative, the team will adapt and potentially shift market support strategies over time. These changes will be carefully considered, documented and brought to the coordinating committee on an annual basis.

1. Drive pilots and leverage installations, publish case studies

An early action for this initiative is to drive the inclusion of LLLCs on lighting retrofit projects. This will develop installer experience and comfort with the technology. To highlight these pilots and projects naturally occurring in the market, we will publish case studies celebrating successful outcomes and share insights on how to overcome obstacles. We will also leverage sponsored pilots to:

- Expose specifiers to LLLCs through tours.
- Design, implement, and document assessments of specific applications/strategies like
  - Wireless emergency testing labor savings,
  - Demand response (potential peak reduction, cost and implementation assessments),
  - Stairwell and corridor applications, and
  - A comparison of energy savings gained by different sized daylight harvesting and motion control zones.

2. Ensure comprehensive training and tools are available for specifiers, installers, and programmers

The most critical action to overcome the barriers to widespread market adoption is to ensure that comprehensive training and education is embedded to the market. Early in market development, this initiative will sponsor and drive attendance to comprehensive, educational trainings. Over time, we will also develop supplemental guides and tools for market actors to successfully understand and communicate about the technology including information on functionality, benefits, design, estimation, programming, and implementation. This activity will identify and highlight existing resources as well as develop them where there are gaps in concert with existing market actors.

In Minnesota, manufacturer's representatives are under pressure from the lighting controls manufacturers to provide training to the supply chain. Without standardization across the industry, different manufacturers use different language and installers and other market actors are left confused by the inconsistencies between product lines. There is a need for training and education offered and delivered by parties not associated with specific manufacturers. The trainings sponsored by this initiative will augment existing market trainings and enable manufacturer-agnostic problem solving.

This education and awareness will be supported by local project examples and real-world product applications. One way we will facilitate local installations is through collaboration with the DLC's LAN-Local project. This project specifically targets small business retrofit applications, streamlining the equipment selection process by providing bills of material for projects that do not require a local specifier. Additionally, the DLC is exploring the possibility of piloting their tool and integrating it with prescriptive retrofit incentive programs offered by utilities. CEE will facilitate and support this collaboration, leveraging the team's expertise and resources to drive the successful implementation of LLLCs. By working together, CEE can accelerate the adoption of energy efficient lighting controls and maximize the benefits for small businesses and utility incentive programs alike. These projects will then be used in education and awareness efforts.

3. Establish installation support mechanisms

To de-risk early adopters' first projects using LLLCs, CEE will leverage our relationships across the market and provide a central location to develop, document, and communicate best practices. Support will include:

- Connecting installers and programmers with the relevant technical support contacts,
- Listening to and documenting the challenges installers face in their lighting controls installations and associated successful solutions,
- Connecting installers with others who have successfully overcome similar challenges,
- Facilitating project management, guiding market actors in obtaining project-specific training, discussions, documenting requirements and problem solving, and
- Creating tools, templates, and guides.

4. Identify and deeply engage with qualified lighting controls professionals

By identifying individuals with competency in implementing lighting controls systems through trainings and successful projects, this initiative plans to celebrate and communicate these accomplishments. One long-term vision of this activity is to create a project registration platform where connected lighting projects demonstrate savings to a larger audience. In this way, incentives could potentially be tied to realized savings and create a feedback loop between utilities, system performance, and even peak demand mitigation and response.

Building on the learnings from the California Advanced Lighting Controls Training Program (CALCTP), whose initiative aimed to increase the use of lighting controls in commercial buildings and industrial facilities through education, the initiative will use this network to identify the partners successfully implementing lighting controls solutions. Membership requirements will drive attendance to trainings and promote effective implementation of LLLCs to successfully realize energy savings.

5. Collaborate with industry to define and categorize qualified products consistently, ensuring default configurations are incorporated

The industry lacks consistent terminology for and definitions of LLLC, confusing market actors. To enhance market clarity, we'll engage with the DLC, IES, and other stakeholders to establish uniform qualification requirements and, to the greatest extent possible, definitions. We'll also ensure that LLLCs are inherently energy efficient by collaborating with the DLC to set minimum default operation requirements. Furthermore, in partnership with the DLC and manufacturers, we'll identify and document current limitations, motivating manufacturers to match existing network lighting control capabilities and provide essential system selection information.

In addition to aligning qualifications, expansion of this tool to incorporate such limitations will bolster the success of other activities within the initiative, primarily as a technical resource for system design.

6. Collaborate with utilities and program implementers to differentiate, increase, align, and promote incentives and maximize grid value

To reduce the first-cost barrier to LLLC adoption in the energy efficiency driven retrofit market, CEE will collaborate with IOU programs and implementers to ensure LLLC program support and incentives, building leadership buy-in to prioritize the technology. Identifying incentive roadmaps to deploy over time to shift focus from loads to controls, we will collaborate to determine strategies for increased adoption of LLLCs as a more efficient subset of NLCs to increase use of lighting controls in retrofits. Leveraging the opportunity to manage peak demand through demand responsive lighting is another way that LLLCs maximize grid value; differentiated incentives for demand responsive lighting systems in one way this might be achieved.

7. Create marketing strategy and tools to promote LLLCs and build awareness among end users/building owners

This initiative will develop messaging and customer resources for our partners (utilities, contractors, specifiers, etc.) to help promote the adoption of LLLCs among building owners, property managers, and individual commercial tenants. The goal is to communicate the benefits of LLLCs (both energy and non-energy) and create materials including audio, video, written, and visual communications highlighting LLLCs within the landscape of cost savings and the smart, connected buildings of the future. Since these customers are the primary decision makers in the retrofit market, not in new construction and major renovations, and we expect incremental cost to decline as traction builds in those areas, this activity will be a longer-term focus.

8. Collaborate with key partners to drive Energy Code adoption

Ensuring that new versions of building energy code continue to be adopted in Minnesota is critical to the long-term success of transforming the lighting market to advance controls adoption in new construction and major renovations. Current trends include reduction in square footage illuminated and controlled jointly by motion control, which strengthens the value proposition of LLLCs. There is also an opportunity to increase compliance of existing codes, especially in retrofits.

PARTNERS AND ROLES

For this work, the ETA initiative plans to build partnerships and collaborations with key stakeholders to drive the market transformation of LLLCs. These partnerships collectively form a strong network of stakeholders, enabling us to effectively drive the market transformation of LLLCs. Through collaboration and shared expertise, CEE aims to accelerate the adoption of energy efficient lighting solutions and create a sustainable future for the lighting industry. These partnerships will help us reach trade allies, identify early adopters, increase awareness and competencies, and drive widespread adoption of LLLCs across Minnesota.

Utility stakeholders

Minnesota utilities funding ETA are key stakeholders that serve on the ETA Coordinating Committee. Representatives of these utilities are also invited to serve on the Evaluation and Cost-Effectiveness Advisory Committee and the Market Strategy Advisory Committee. These utilities include:

- Xcel Energy
- Minnesota Power
- Otter Tail Power
- CenterPoint Energy
- Minnesota Energy Resources

Since this initiative technology is part of the electricity market, the utilities most impacted by this initiative include:

- Xcel Energy
- Minnesota Power
- Otter Tail Power

ETA is working with each of these utilities to leverage their expertise, resources, and influence in the electricity market to drive the market transformation of LLLCs and add value for their customers. Ways we plan to work in partnership include:

- Promote and develop messaging for LLLC rebates.

- Collaborate on pilots.
- Provide training and support to program providers, such as commercial audit vendors, on LLLCs.

Through these partnerships, the ETA initiative seeks to create a supportive ecosystem that accelerates the adoption of LLLCs and maximizes their energy-saving potential.

ETA is also working with other utilities to broaden the impacts of this work. These utilities have shown interest in the market transformation program and actively support the adoption of LLLCs; CEE looks forward by collaborating with utilities, such as Green River Energy, to establish plans within the state that deliver value to each of their markets, considering their unique layout and needs. All the interventions CEE has planned will impact the same supply chain that affects the smaller COUs.

Other market transformation initiatives

The Northwest Energy Efficiency Alliance (NEEA) is a regional organization committed to promoting energy efficiency in the Northwest. The organization has been doing market transformation for LLLCs since the technology was in nascent development and not yet commercially available. Through our partnership with NEEA, CEE can learn from their experience, expand our reach and influence, collaborate on strategy, and drive the adoption of LLLCs nationally.

Running another LLLC Market Transformation initiative, in nearby in Illinois, Ameren further strengthens the efforts at the national level and acts as a partner to our initiative in Minnesota. Illinois is the only other state in the Midwest outside of Minnesota that has an explicit framework for market transformation programs. Partnering with their implementer, Resource Innovations, will drive adoption on the national level, like our collaboration with NEEA. Other Illinois utilities are looking at establishing an LLLC initiative as well.

The DesignLights Consortium (DLC)

DLC is a trusted resource for evaluating and qualifying high-quality, energy efficient lighting products. Collaborating with DLC allows us to align our initiatives with their standards and recommendations, ensuring the market transformation of LLLCs. Collaborating on the maintenance of the QPL and expanding the identification of capabilities and limitations will further develop the product offering from manufacturers to meet the needs of the market and achieve widespread adoption. Involvement with their programs like LAN-Local will simplify the product selection process for retrofit applications and drive utility program use through incentives.

Other partners

Among primary collaborators are the Department of Energy who runs the Integrated Lighting Campaign, dedicated to developing and promoting advanced lighting technologies. Alliance with the Pacific Northwest National Labs brings cutting-edge research and resources to the table, further enhancing our program's efficacy. Additionally, the Lighting Systems Technology

Research Team (LS TRT) complements our efforts by contributing their expertise in developing advanced lighting systems.

Partnering with the Peak Load Management Alliance (PLMA) aligns with the initiative's focus on LLLC's potential for reducing peak demand.

In addition to these key partners, we aim to establish and strengthen collaborations with various industry groups, programs, associations, electrical contractors, and trade schools to create a robust ecosystem for the adoption of LLLCs. Some of these entities include:

- The Illuminating Engineering Society (IES)
- The OneStop Efficiency Shop
- Building Owners and Managers Association (BOMA)
- National Electrical Contractors Association
- The Electrical Association
- Anoka Technical College

Together, this network of partnerships forms the foundation of our mission to transform the market and promote energy efficient lighting solutions.

SAVINGS POTENTIAL

CEE anticipates a high level of savings potential with this initiative. A study by NEEA and DLC found an average control factor of 0.63 using LLLCs meaning they can result in 63% additional energy savings compared to no controls.

If all applicable luminaires used in commercial and industrial buildings in Minnesota are converted to LLLCs or installed on construction projects over the next 20 years, the potential energy savings would be 2,490,000 MWh. Additional detail on this can be found in the Energy Savings & Evaluation plan in the Appendix.

RISK MITIGATION PLAN

Risks are inherent to any project. However, we have identified key anticipated risks and developed mitigation strategies. These are described in Table 2 below.

Table 2: LLLC risk mitigation matrix

"IF" this happens	"THEN" this will occur (impact)	Probability (High/ Medium/ Low)	Impact (High/ Medium/ Low)	Risk response: (Accept/ avoid/ mitigate/ transfer)	Response plan
If lamp and ballast replacements are chosen over fixture replacements	Demand for new light fixtures like LLLCs is limited	H	H	Mitigate	Work with utilities to transition incentives from loads to controls
If incentives don't cover the incremental cost	• Retrofits remain un/under-controlled • Smaller energy savings occur	H	H	Mitigate	Promote incentives based on incremental cost
If value proposition is rejected by installers	Installers will: • not propose the technology for projects • propose alternatives when LLLCs are specified or • pad their bids to account for the perceived value	L	H	Mitigate	• Training and education • Installation support program • Network interventions will all work to address this possibility. In addition, identifying the best applications for earliest adoption will aid installers in gradually expanding the technology within their project portfolios.
If LLLCs are installed that do not meet minimum operational requirements	• Energy savings aren't realized • Lights don't meet building occupant needs	M	M	Mitigate	• Incentivize and require default programming for qualification (listing on QPL)

"IF" this happens	"THEN" this will occur (impact)	Probability (High/ Medium/ Low)	Impact (High/ Medium/ Low)	Risk response: (Accept/ avoid/ mitigate/ transfer)	Response plan
and are not programmed	• End users have poor experience • LLLCs garner a poor reputation				• Require proof of programming for eligibility for incentives (possibly through qualified lighting control professional network)
If DLC does not maintain QPL	• Product category difficult to differentiate and identify • Qualification for incentives is difficult	M	M	Accept	The QPL is not a perfect tool for to identify if a fixture qualifies as an LLLC and since most installations have some non-LLLC fixtures, it wouldn't significantly change how CEE proceeds
If manufacturers/ reps do not allow installers to purchase LLLCs without purchasing factory start up services	Installations will be more expensive, incremental costs will be higher	M	M	Mitigate/ Accept	This is already happening with some manufacturers' systems. Our intention is to increase access by demonstrating the skill of qualified lighting controls professionals, where such individuals would be able to enable projects to be quoted without factory start-up services included
If LLLCs are programmed to	Smaller energy savings occur, on par with other NLCs	H	L	Mitigate	Address in training and through communication of

"IF" this happens	"THEN" this will occur (impact)	Probability (High/ Medium/ Low)	Impact (High/ Medium/ Low)	Risk response: (Accept/ avoid/ mitigate/ transfer)	Response plan
operate in large groups					recommended best practices

TRANSITION PLAN

The LLLC initiative team will establish a comprehensive metrics tracking system to assess the progress of the initiative and adapt strategic interventions as needed. Periodic updates to the LLLC logic model will occur throughout the Market Development phase to reflect changes in market dynamics, including the removal of barriers and identification of new opportunities. These interventions will promote sustained acceleration in the adoption of LLLCs to make the technology the standard when implementing lighting controls in commercial and industrial buildings in Minnesota.

As the LLLC initiative's market development strategies mature and demonstrate their intended impact, the team will closely monitor the growth of LLLCs, key progress indicators, and the evolving policy landscape. This ongoing assessment will guide the decision to gradually reduce the intensity of market development activities. The transition phase will involve transferring critical functions to the market itself and initiating the Long-Term Monitoring and Tracking (LTMT) phase. During LTMT, the focus will shift to tracking and analyzing sales to measure energy savings, while market support activities are phased out. The transition from the resource-intensive market development phase to the resource-efficient LTMT phase will be based on careful monitoring and assessment to determine the most opportune timing. The decision to transition to LTMT will be reviewed and approved by the LLLC initiative's coordinating committee.

APPENDIX A. MARKET CHARACTERIZATION

See Market Characterization Report

Appendix B. Energy Savings and Market Evaluation

See Energy Savings and Market Evaluation Plan