

Consortium for Energy Efficiency

# White Paper on Connected Lighting and the Integrated Home

Content based on a *Lighting for Tomorrow-*  
sponsored workshop in June 2018



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## About CEE

The Consortium for Energy Efficiency (CEE) is a nonprofit organization through which efficiency program administrator members work to promote energy efficient products, technologies, and services. Collectively, CEE members direct nearly 80 percent of customer-funded demand side expenditures in the United States and Canada, using initiatives that accelerate the development of energy efficient products and services. CEE increases the effectiveness of its member organizations by enhancing communication among program administrators and harmonizing approaches across geographies to advance energy efficiency for the public benefit. Members work together at CEE to create voluntary specifications and associated qualifying products lists for more efficient products and systems that they can promote locally through efficiency programs.

The role of CEE is to establish the important performance factors related to energy efficiency that are commonly shared across the United States and Canada and to encourage binational coordination of efficiency programs to realize additional energy savings opportunities. The CEE focus, as embodied in binational voluntary CEE market initiatives, is to stimulate market development, competition, and investment to create new energy-related value for ratepayers, contributing stakeholders, and society as a whole. A key strategy is to seize on the convergence of revolutionary advancements in technology, information management, and communication capabilities, specify conventions for major interdependent energy ecosystems, and encourage independent and voluntary market action to realize unprecedented value.

CEE works closely with other stakeholders active in the lighting and connected product spaces, including the United States Environmental Protection Agency (EPA) and the ENERGY STAR® program, United States Department of Energy (DOE) and its national labs, California Energy Commission, the National Electrical Manufacturers Association (NEMA), the American Lighting Association (ALA), Underwriters Laboratories (UL), the Air-Conditioning, Heating, and Refrigeration Institute (AHRI), and the Electric Power Research Institute (EPRI). By collaborating with these other entities, CEE is able to create a single platform for program administrators and industry that leverages the best available resources.

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<sup>1</sup> This list represents contributors' affiliation at the time of the 2018 workshop.

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# Executive Summary

## The Emergence of Connected Lighting Presents Opportunities for the Integrated Home

### Rethinking the Objectives of the *Lighting for Tomorrow* Competition

In 2018, *Lighting for Tomorrow* (LFT) tapped into the relationships with lighting stakeholders built over the past 16 years and gathered experts from across the lighting, smart / connected / integrated home (hereafter referred to as “integrated home”), and demand-side management (DSM) program industries to imagine and discuss the future of residential lighting. Through an interactive workshop, participants explored the potential of new technologies, product capabilities, and program strategies to overcome market barriers and deliver benefit to consumers and the grid.

Figure 1. Workshop Participants

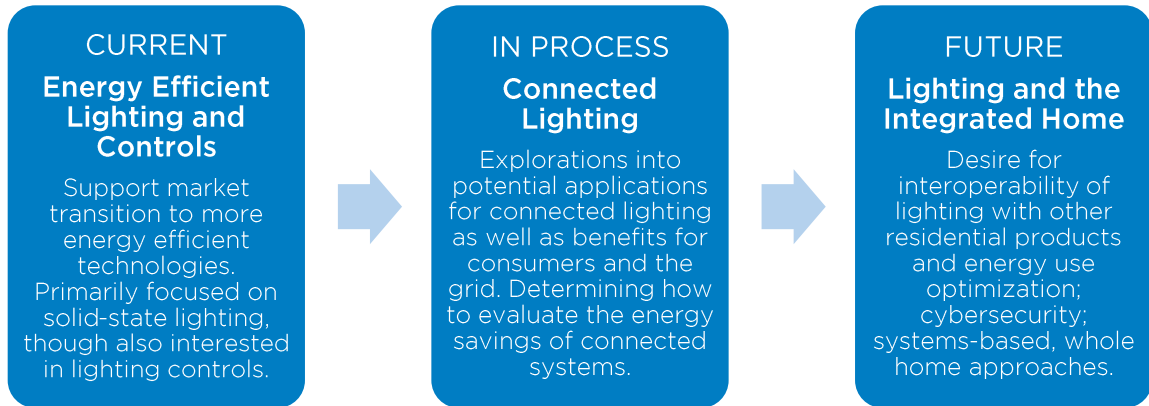


### Market Direction Indicates Opportunities for Connected Lighting

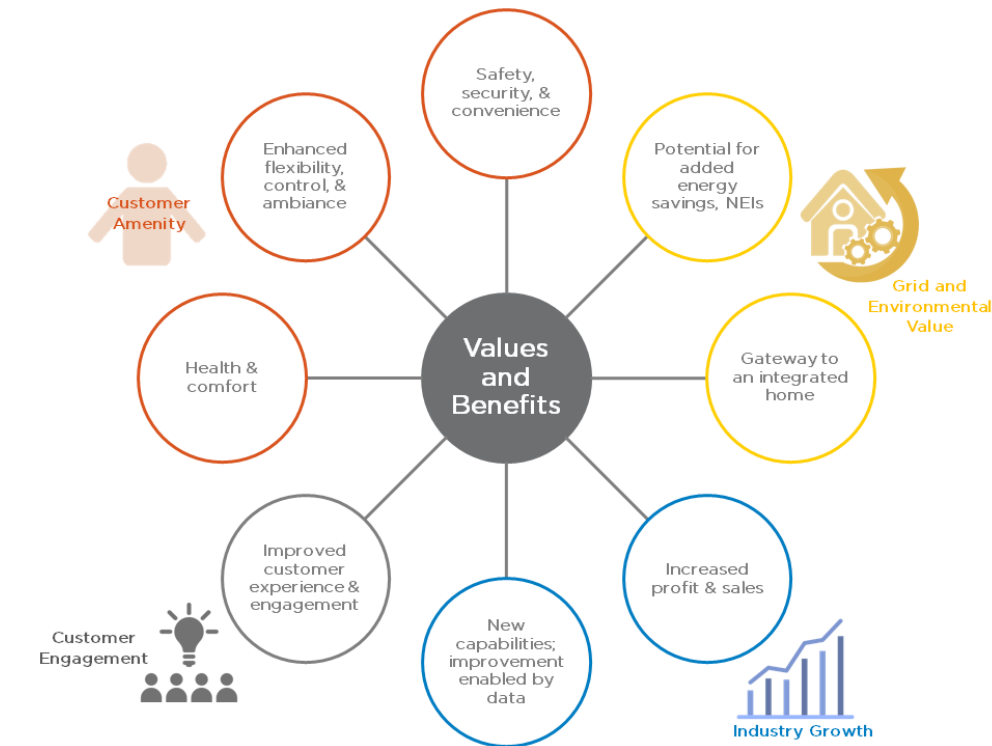
The residential lighting market is experiencing unparalleled disruption caused by company acquisitions, dramatic changes in the retail environment as online retailers expand, the entrance of new market players related first to solid-state lighting, and now connected capabilities. During this time of transition, there are varying perspectives regarding possible direction for the

connected residential lighting market. However, one thing is clear: this market is growing. The estimated revenue for connected residential lighting is expected to rise to \$4.5 billion by 2021.<sup>2</sup> Jeff Patton of GE Lighting estimates that connected residential lighting will increasingly merge into the integrated home segment. There are opportunities to encourage this growth in a way that supports the needs of consumers and program administrators.

Figure 2. Program Administrator Lighting Interests and Activities



Value Proposition



<sup>2</sup> Paul Bremner, “Global market for smart lighting and connected lighting controls reached \$8 billion in 2017,” IHS Markit, February 6, 2018, <https://technology.ihs.com/599873/global-market-for-smart-lighting-and-connected-lighting-controls-reached-8-billion-in-2017>.



While connected lighting presents potential energy savings opportunities, the primary value to CEE members lies in its ability to serve a strategy for increased customer engagement and as a part of the customer journey to an integrated home that can deliver benefits from consumer behavior change, improved measurement and verification of energy savings, and load management. Some potential benefits LFT sponsors see from connected lighting are illustrated in Figure 3, above.

### Market Barriers to Connected Lighting

Workshop participants discussed the barriers that would most significantly inhibit the uptake of connected lighting and concluded that focusing on the consumer experience is critical for successful market adoption. The variation among and limitations or benefits of platforms and communication protocols currently in the market creates considerable confusion for consumers. Lighting manufacturers are seeking ways to simplify use for consumers as well as provide new value or services through cross-industry partnerships. There are currently a few lighting products in the market that do not rely on a bridge or hub to connect with products from other manufacturers or those operating on other platforms, and more companies are exploring this option. The list on the right captures the most common platforms and protocols that lighting manufacturers have adopted. Since there are multiple proprietary platforms and protocols currently in use, manufacturers are working to develop platform agnostic devices to capture greater market share and improve customer experiences. Eventually, interoperability is expected to become more commonplace, per Pekka Hakkarainen of Lutron, but how and which platforms arise as mainstream is yet to be seen.

A few platforms and protocols used by connected lamps and controls include:

- Amazon Echo
- Apple HomeKit
- Google Home
- IFTTT
- Smart Things
- Wink Hub

Based on the workshop discussion, participants identified the top three barriers to realizing the benefits of connected lighting as:

<b>Interoperability</b>	works seamlessly with other connected devices and systems in the home
<b>Reliability</b>	consistently receives a signal and responds to commands, reconnects after a power or Internet disruption, can be updated over time
<b>Complexity</b>	consumers understand the value proposition and encounter simple installation, setup, and use

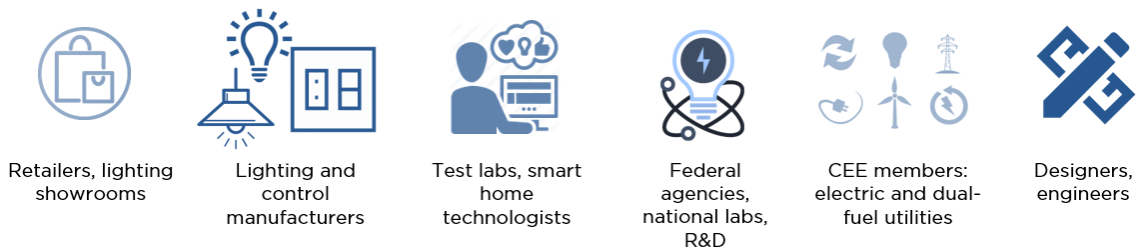
## The CEE Integrated Home of the Future

CEE has led a Connected Committee since 2012, which supports members transition to integrated demand-side management (IDSM) programs.<sup>3</sup> The Connected Committee formed the backbone for discussing the integrated home. CEE members use the term “integrated home” to describe a framework for the converging landscape of connected products within the whole house context. Their vision is of a connected, efficient home where systems such as lighting, appliances, heating and cooling, security, and home entertainment seamlessly communicate and optimize valued amenities. An integrated home may automatically address consumer preferences through established settings combined with occupancy data, energy prices, algorithms, and machine learning. This enables improved consumer experience through customized recommendations on ways to save money on energy bills, feel comfortable in their homes, contribute to more reliable energy delivery, and prevent and repair equipment failures more easily.

To learn more about the characteristics of the integrated home, see “Origins of the CEE Integrated Home Framework” on page 14.

## Key Workshop Takeaways

Figure 4. Participating Groups



Workshop participants (see Figure 1 for participating organizations and Figure 4 for categories of participants) identified the following key takeaways.

- The barriers identified are not exclusive to lighting and are applicable to all connected devices in a home. There are many new integrated home solutions available, but they all require interoperability, reliability, and simplicity.
- The lighting market should remain a focus. Given the high consumer interest, low price point, and mass-market appeal of connected lighting, as well as its presence throughout a home, **lighting is an ideal candidate to support a consumer journey to a fully integrated home.** Lighting has already given consumers a head start on understanding integrated home systems due to the lighting controls and systems that have been on the market for several years.
- LFT presents a unique market intervention strategy to increase the adoption of residential connected lighting products in the U.S. and Canada. It offers the opportunity to build upon the existing relationships between program administrators, lighting manufacturers, and

<sup>3</sup> IDSM can be defined as the integrated or coordinated delivery of three or more of: (1) energy efficiency (EE), (2) demand response (DR), (3) distributed generation (DG), (4) storage, (5) electric vehicle (EV) technologies, and (6) time-based rate programs to residential and commercial electric utility customers. Definition adapted from <https://emp.lbl.gov/publications/barriers-and-opportunities-broader>.

showrooms to enact market change. LFT also presents program administrators with the unique opportunity to influence the connected devices that manufacturers are bringing to market and encourage those products with the performance attributes that programs wish to promote through the selection of the competition categories and evaluation criteria.

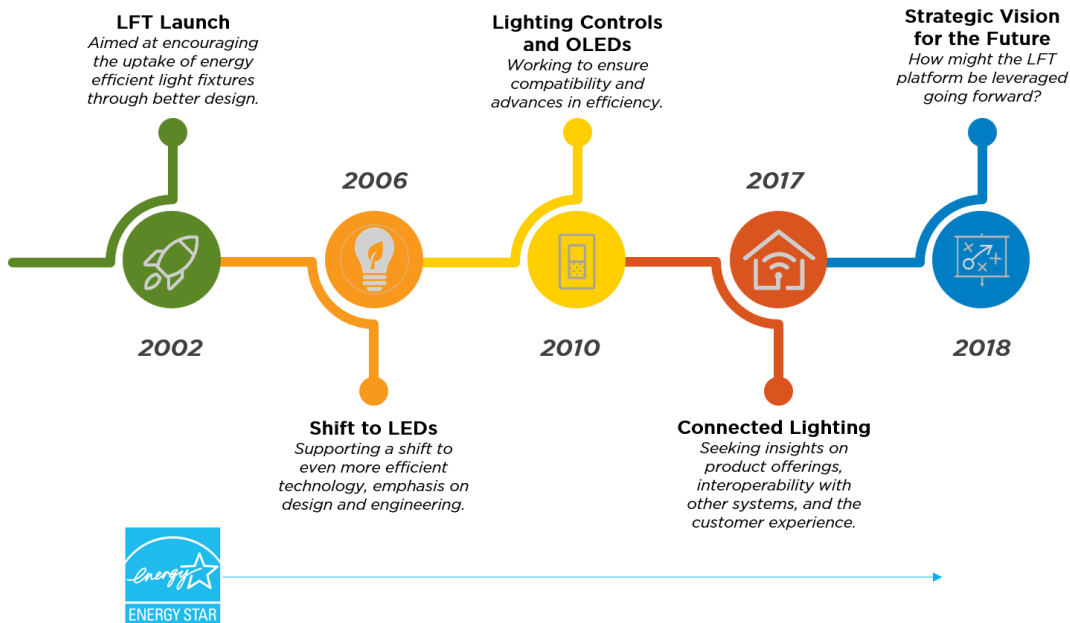
- Based on the suggestions received from the workshop, sponsors support leveraging the LFT competition model with an expanded scope in 2019. They envision a rebranding to “Lighting and Homes for Tomorrow” that will evolve and add competition categories over time.

## Introduction

### History of *Lighting for Tomorrow*

The annual *Lighting for Tomorrow* (LFT) competition, most recently administered by the [American Lighting Association](#) (ALA),<sup>4</sup> sponsoring members of [CEE](#), and [Underwriters Laboratory](#) (UL),<sup>5</sup> was launched in 2002 to overcome the greatest barrier to the adoption of residential energy efficient lighting: the lack of decorative fluorescent fixtures. Since its inception, LFT has supported well designed, energy efficient lighting products with the specific goal of increasing the availability and market adoption of ENERGY STAR certified residential lighting products. LFT provides residential lighting manufacturers the opportunity to push the industry forward and gain exposure for their brands and products among industry leaders and consumers alike. By recognizing exceptional new products, LFT seeks to meet consumer expectations and leap over market barriers that inhibit the adoption and use of energy efficient residential lighting products.

Figure 5. LFT Timeline



From 2002 through 2017, the sponsors of this unique and longstanding industry partnership considered the market barriers that inhibited the adoption and use of energy efficient residential

<sup>4</sup> ALA is the only trade association representing residential lighting manufacturers, showrooms, distributors, manufacturer representatives, component manufacturers, and industry-related companies. ALA members, totaling more than 1,200 in the U.S., Canada, and the Caribbean, are dedicated to providing the public with quality residential lighting.

<sup>5</sup> UL is a global independent safety science company with more than a century of expertise innovating safety solutions from the public adoption of electricity to breakthroughs in sustainability, renewable energy, and nanotechnology. Dedicated to promoting safe living and working environments, UL helps safeguard people, products, and places in important ways, facilitating trade and providing peace of mind. UL provides testing and certification services to industry standards, including ANSI, IEC, NEMA, FCC, and IESNA. Additionally, UL is a leading provider of Photometric Performance and EMC testing in support of well-known lighting programs such as ENERGY STAR, Lighting Facts, and Design Lights Consortium.

lighting. Sponsors worked together to create product categories and criteria that considered evolving lighting technology and strived to support its successful integration into lamps, retrofit kits, and fixtures to ensure that these products met consumer needs. Table 1 illustrates how LFT encouraged the efficiency and quality aspects of LED filament lamps and supported its inclusion in the ENERGY STAR Program.

Table 1. **How *Lighting for Tomorrow* Encouraged Efficient LED Filament Lamps**

	2014	2015	2016
<b>LFT Category</b>	No standalone category	Special entry category underscores efficiency and light quality characteristics; new bulb shapes and filament styles emerging	
<b>Percentage of All Lamp Entries</b>	3%	45%	92%
<b>Average Efficacy of Entries</b>		89 lm/W	98 lm/W
<b>LFT Product Awards</b>		Category Recognition	2 LED Filament Lamps Awarded
<b>ENERGY STAR</b>	Filament lamps not eligible for certification		ENERGY STAR expands scope to include LED filament lamps 280+ products listed as of August 2017

The emergence of some of the required elements for an integrated home has brought exciting new features and capabilities to market along with challenges for lighting and whole house interoperability. Both customers and utilities are moving into a future where the realization of incremental energy savings will come from a systems approach that includes dimming alongside integration with, and control of, other residential products. Beyond energy savings, there are potential opportunities related to comfort, health, convenience, and security. LFT continues to monitor developments in the connected lighting space and to consider the product criteria that will yield the most benefit to consumers and efficiency programs alike.<sup>6</sup>

In 2017, LFT accepted connected lighting entries as part of a standalone category for lamps, fixtures, controls, and broader systems. Entrants were asked to provide data about product or system attributes and functionality and were evaluated against criteria relating to:

- Ease of installation, setup, and use;
- Ease of continued use;
- Interoperability;
- User interface;
- Value and salability;
- Application efficiency (e.g., standby power consumption);

<sup>6</sup> CEE members use the term “connected” to describe equipment that is engineered to send and receive information, including between other equipment and systems. Products are designed to enable new value for customers and the grid, including the potential to unlock new savings opportunities that will complement traditional efficiency measures. For specific definitions, see: Michael Poplawski, “The Emergence of Connected Lighting,” October 12, 2015, [https://www.energystar.gov/sites/default/files/asset/document/4\\_Michael%20Poplawski\\_Shining%20a%20Light\\_FINAL.pdf](https://www.energystar.gov/sites/default/files/asset/document/4_Michael%20Poplawski_Shining%20a%20Light_FINAL.pdf).

- Replaceable component and field serviceability; and,
- Innovation in engineering and design.

The level of participation was relatively successful for a brand-new category: three percent of submissions were connected, and submissions included luminaires and wireless controls, among other product types. However, the diverse experts on the judging panel felt that entries overall were “holding back” and that few were meeting consumer expectations across the board. Examples of failures to meet consumer expectations included an inability to interoperate with other products in the home, complicated setup and programming, and a perceived decrease in some aspects of overall lighting quality compared to standard products.

Following the 2017 competition, sponsors determined that one of the biggest remaining opportunities for LFT to explore was connected lighting technologies within the context of an integrated home, specifically looking at the energy savings and customer engagement prospects. Lighting often represents a consumer’s first foray into creating an integrated home and may serve as a central device in these homes as new functionalities are added, such as sensing, processing, and networking.

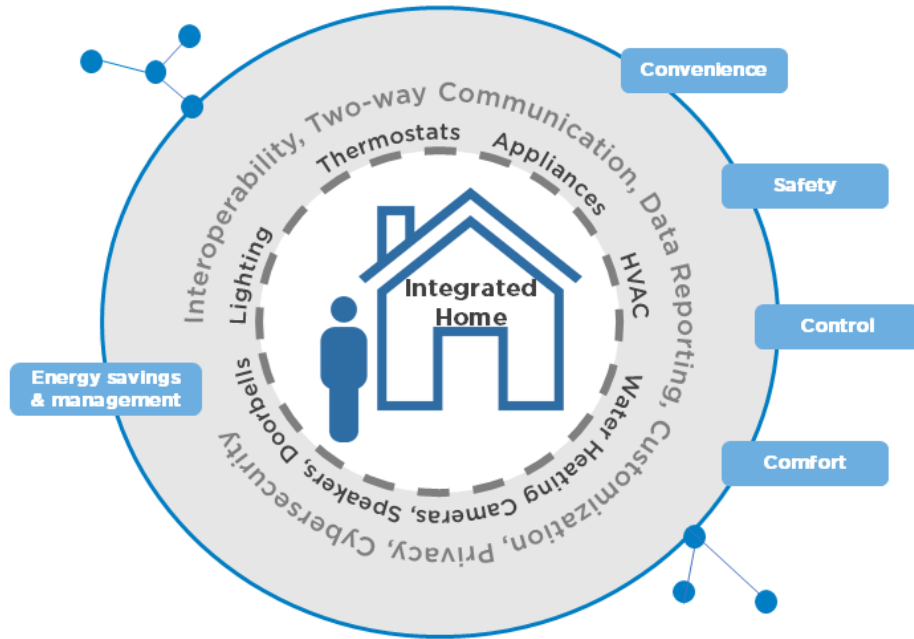
## Origins of the CEE Integrated Home Platform

CEE has led a Connected Committee since 2012, which supports members transition to integrated demand-side management (IDSM) programs.<sup>7</sup> The Connected Committee formed the backbone for discussing the integrated home. CEE members have landed on the term “integrated home” to describe a framework for the converging landscape of connected products within the whole house context. The integrated home is grid-interactive and efficient. It merges utility and customer benefits by encompassing connected technologies and communicating capabilities that have the potential to optimize the performance of the home through individual products and systems to drive improved energy management. Improved energy management may come through a combination of energy efficiency, load management (including demand response [DR]), and consumer behavior. In practical terms, the integrated home is a comprehensive portfolio of residential initiatives that can be bundled together to deliver efficiency, grid, program, and customer benefits beyond those achieved individually. The suite of product specifications that include connected criteria delivers a consistent value promise that is contingent upon individual end measures working together effectively to enable these added benefits. The integrated home, therefore, relies on the interaction, interoperability, and interactive effects between chosen products and systems. It may also leverage interactions with the user through selecting predetermined preferences or settings, learning algorithms, or prompting specific consumer behaviors. To learn more about the characteristics of the integrated home, see the [2018 CEE IP Meeting: Integrated Home Concurrent Sessions](#) resources.

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<sup>7</sup> IDSM can be defined as an evolution of DSM utilizing connectivity of products. IDSM refers to a program design type that delivers the benefits of energy efficiency to customers and demand response to the grid using the same technology intervention and/or a linked incentive while leveraging the same program delivery resources and infrastructure.

Figure 6. The CEE Integrated Home Vision



### How CEE is Advancing the Integrated Home Framework

CEE has long had a careful and trusted process in which specifications are designed through binational, consensus-based deliberations, vetted with manufacturers, and ultimately supported by the collective action of members. The various CEE committees are increasingly mindful of how connected capabilities impact energy efficiency, grid demand, and consumer experience. Table 2 details current CEE efforts aimed at advancing the integrated home for the benefit of consumers and a better-balanced grid.

### Connected Lighting as a Stepping Stone to the Integrated Home

Connected lighting can serve as a gateway to the integrated home, which provides similar value propositions as connected lighting but at a broader scale that includes much larger energy-consuming products, including:

- Providing consumers with greater awareness and tools to manage the energy use of their entire home, which can result in energy reductions from changes in consumer behavior and learning algorithms.
- Potential for load management for all devices in a home, especially when paired with advanced metering infrastructure (AMI) and time-of-use (TOU) rates.
- Evaluation benefits from increased program insight into energy use in the home.

Table 2. **Current CEE Efforts to Advance the Integrated Home**

<b>Defining Embedded Functionality</b>	Individual CEE Initiatives are developing optional connected criteria that members can leverage in their program approaches to achieve grid management, customer amenity, or other benefits. Using the <a href="#">CEE Consensus Principles for Connected</a> as a guiding framework, CEE is defining what is of current and potential value for each product to instill consistency in terminology and principle for both individual measures and toward an integrated home.
<b>Engaging with Industry</b>	In furthering its legacy of productive industry partner relationships, CEE continues to engage with a variety of stakeholders to discuss the challenges, potential collective solutions, desired capabilities, and common data elements that will help enable the integrated home vision to come to fruition. CEE collaborates with industry to help them better understand the program perspective and ultimately design products that will meet the needs of CEE members.
<b>Establishing the Program Administrator Role</b>	CEE provides a venue where members can foster their internal strategies and positions about the role an IDSM program administrator might play in the integrated home space. By exchanging program design and deployment experiences, customer engagement approaches, and best practices with peers, members gain insights that will allow them to optimize the use of ratepayer funds.
<b>Considering Behavioral Insights</b>	Even as program design and approaches might differ, behavior-based savings based on social science research and behavior program experience are gaining traction in the program community. The CEE Behavior Committee works to develop resources such as the <a href="#">Behavior Insights and Tools</a> document, which outlines how behavioral approaches can be effectively used together with connected technologies.
<b>Supporting Customer Amenity and Control</b>	The CEE Integrated Home Platform considers the implications of connected functionality for customers, including amenity unrelated to energy efficiency that may drive purchasing decisions (such as remote control or security). CEE also believes that customers should have the ultimate control of their products and data.
<b>Developing a Crosscutting Vision</b>	CEE committee work is increasingly crosscutting as the historically separate worlds of residential products, whole house, behavior, and grid management integrate. Diverse member organizations are working to define a collective vision and roadmap that will allow the Consortium to continue transforming markets for lasting public benefit.

## Impetus for the 2018 Workshop

In 2018, the LFT sponsors organized an in-person workshop in lieu of the traditional competition; the workshop focused on reassessing market needs and allowed a variety of stakeholders to examine how, as an industry, to continue transforming the current program and market climate.

While the current LFT sponsors, as well as many CEE members more broadly, believe there are still existing opportunities to transform the residential lighting market (a significant amount of inefficient lighting is still being sold, for example), other significant factors prompted the decision to consider an alternative to the traditional LFT competition. According to a 2018 survey conducted by the Lighting Research Center, “we may be experiencing the largest, most fundamental change the lighting industry has seen in our lifetime.”<sup>8</sup> Due to increased federal minimum efficiency standards, program administrators have seen the cost-effectiveness of

<sup>8</sup> Rebekah Mullaney, “Future of the Lighting Industry’ Survey Results Now Available,” Lighting Research Center, September 24, 2018, [https://www.lrc.rpi.edu/resources/newsroom/pr\\_story.asp?id=413#.W60UtmhKjcs](https://www.lrc.rpi.edu/resources/newsroom/pr_story.asp?id=413#.W60UtmhKjcs).



residential lighting programs decline. Additionally, there is a reduction in funds available to support these market transformation efforts.

Figure 7. **Workshop Purpose**



It was fortuitous that the timing of impending federal changes and the emergence of connected lighting happened to align with the project reaching its fifteenth year, which was intended to be a transition year in which LFT partners would strategically assess the future of the competition and whether its model for market transformation was still relevant and appropriate. Sponsors sought to invite experts from across the lighting, integrated home, and utility program spheres to imagine and discuss the future of residential lighting.

An interactive workshop was determined to be the optimal channel for program administrators to come together with thought leaders from the lighting and integrated home industries to discuss future opportunities for collaboration in ensuring a positive residential customer experience not only with efficient lighting technologies, but also with emerging functionalities enabled by connectivity. The primary intent was for workshop participants to explore how various stakeholders, and, in turn, the LFT platform, can harness recent developments in the lighting market to further increase energy savings and potentially offer new value streams such as energy management or non-energy impacts (NEIs).

The emergence of the integrated home brings exciting new features and capabilities, along with new challenges, to lighting and whole house interoperability. Both customers and utilities are moving into a future with a systems-based approach to both dimming and connectivity with other residential products.

## Workshop Objectives

Through the interactive LFT workshop, participants explored the potential of new technologies, product capabilities, and program strategies to overcome market barriers and deliver benefit to consumers and the grid. The objectives of the workshop were to:

- Allow invited lighting manufacturers, retailers, researchers, and relevant stakeholders to collaborate on the future of quality residential lighting and the integrated home.
- Explore lighting technology and residential program trends and expected developments, including the possibility of additional energy savings or load management opportunities.
- Explore what new functions or services beyond lighting that lighting fixtures, lamps, and switches may provide consumers in the future, such as sensing, processing, and networking.
- Consider the characteristics of connected lighting products or systems that would yield the most benefit to consumers, industry, and DSM programs alike, including NEIs.

- Discuss how various stakeholders might promote or integrate connected lighting in new ways.
- Determine the potential role of LFT going forward, including if and how a competition model structured around these concepts might be applied in 2019.

The workshop enabled program administrators and industry to take stock of the future of lighting from high-level industry, consumer, and DSM program perspectives. Sponsors believed a visionary conversation could be very valuable to help all stakeholders identify a shared purpose for energy management in the lighting and the integrated home industries. The resulting workshop agenda sought to address the following questions:

- What remains to be done to support the adoption of energy efficient technology in the residential lighting market?
- What new values and opportunities will exist due to the emergence of connected lighting? (This includes value for consumers, program administrators, manufacturers, and retailers).
- What are the barriers to realizing these opportunities? What can efficiency programs and industry partners accomplish by working together binationally to overcome these barriers?
- How can the LFT platform be leveraged to support these collective efforts?

This white paper documents the workshop discussions and key takeaways, including critical perspectives on the connected lighting market and identification of critical market or technology gaps for further research and collaboration. The defining characteristics of connected lighting and homes in the context of this work are included below.

## Part I: Initial Characterization of Connected Residential Lighting as Part of the Integrated Home

### The Current and Future Residential Lighting Market: Perspectives of Industry Actors

A critical step in considering the role of connected lighting in the integrated home realm is to first capture a representative set of observations from key market stakeholders about the state of the residential lighting market more broadly.

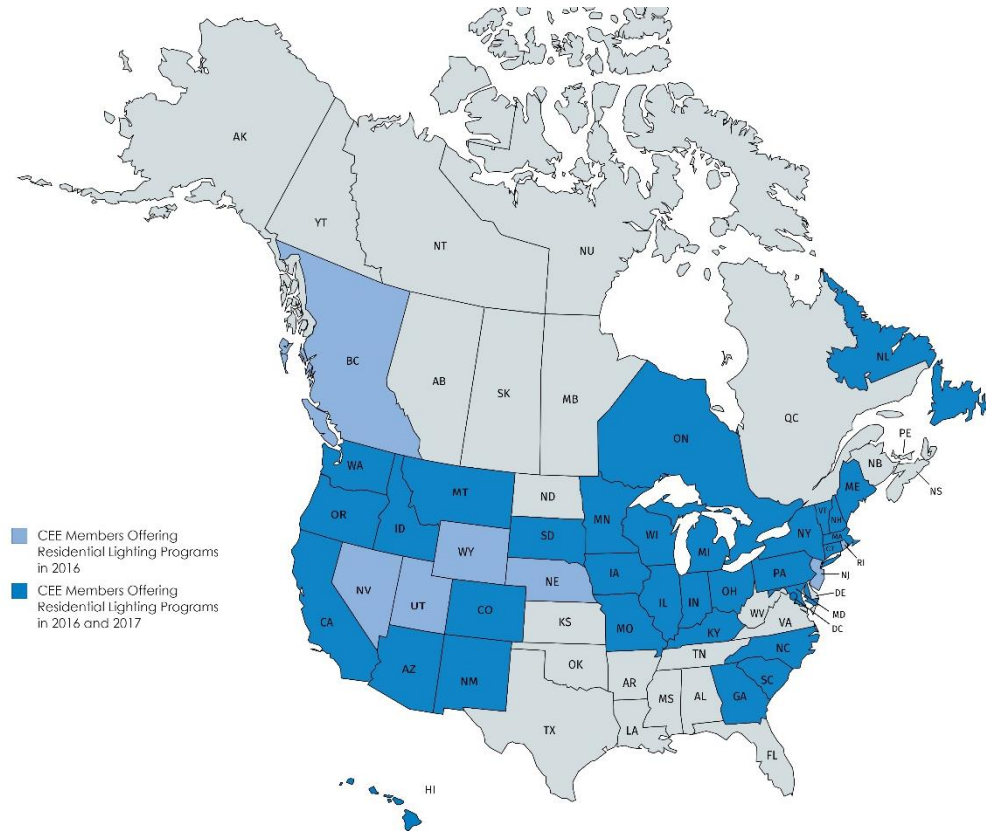
#### Program Administrators

Program administrators' incentives in the residential lighting market have begun to evolve, and there is significant uncertainty regarding their involvement moving forward. From 2016 to 2017, the total number of states and provinces with CEE members running residential lighting programs decreased by 15 percent.<sup>9</sup>

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<sup>9</sup> *CEE Residential Lighting Program Overview 2017.*

Figure 8. CEE Members Offering Residential Lighting Programs in 2016-17<sup>10</sup>



In the face of upcoming Energy Independence and Security Act (EISA) legislation at the time of the workshop,<sup>11</sup> many utilities were seeing a decline in net-to-gross savings. EPA has presented evidence that the residential lighting market is becoming saturated with efficient technology (Figure 9). According to members of the CEE Residential Lighting Committee, it is likely that within the next few years, they will no longer be able to incentivize omnidirectional LEDs and A-lamps, which together represent upwards of 50 percent of some current residential portfolios. Some program administrators generate revenue from net-to-gross returns; as incandescent replacement lamps are disappearing from the market, these program administrators are seeing a dramatic decrease in savings and revenue, spurring the need to consider new revenue streams.

<sup>10</sup> Ibid.

<sup>11</sup> While EISA legislation does not ban incandescent bulbs, the minimum efficiency standards are high enough that the incandescent light bulbs most commonly used by consumers today will not meet the new requirements. Once implemented, the Act will essentially eliminate 40W, 60W, 75W, and 100W medium screw base incandescent light bulbs. See the [Lighting Facts FAQ](#) for more information.

Figure 9. 2015-2016 LED Bulb Sales as a Percentage of Other Technologies Sold by Census Region and Division<sup>12</sup>

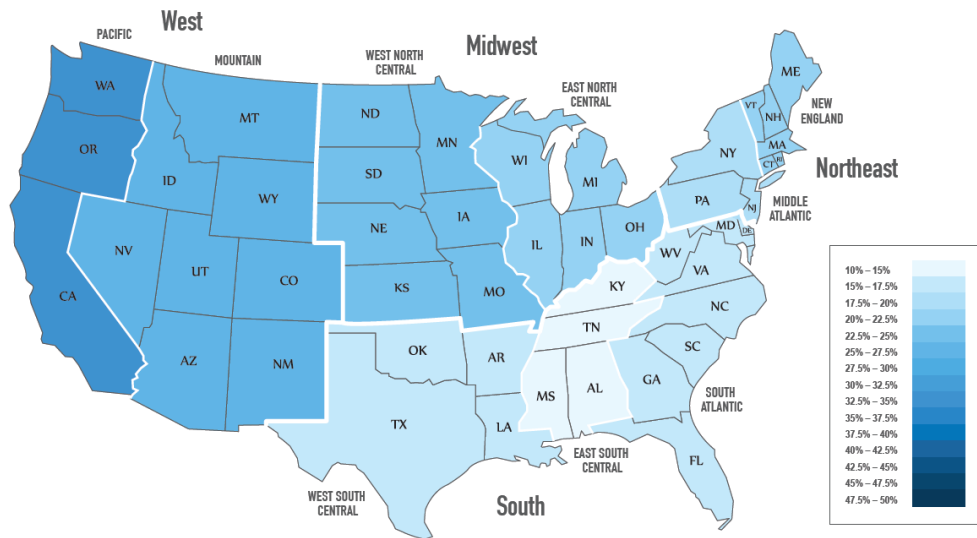


IMAGE SOURCE: ENERGYSTAR.GOV

\* data not available for Alaska and Hawaii

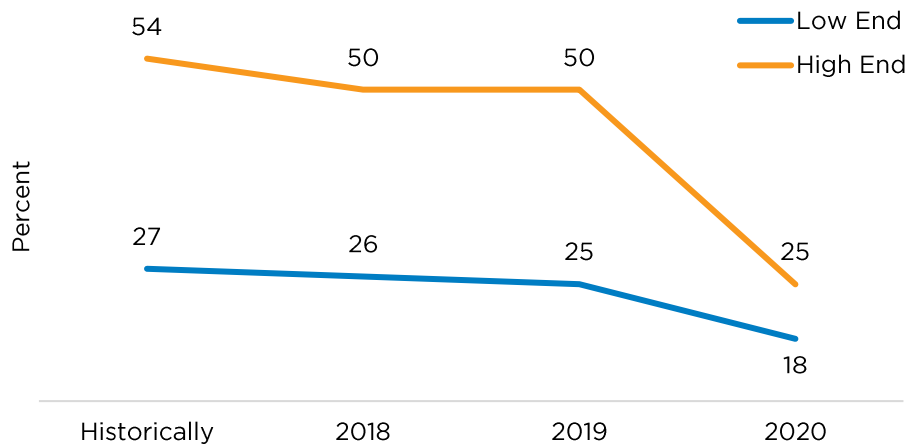
Program administrators are employing a variety of targeted strategies to compensate for diminishing residential lighting savings through 2020.<sup>13</sup> These include, but are not limited to:

- Targeting incentives and marketing to hard-to-reach populations and customer segments with lower than average LED adoption rates;
- Increasing incentives for specialty lighting products that exhibit lower LED market penetration, such as dimmable LEDs, decorative replacement lamps, 3-way A-lamps, higher lumen output products, reflector style lamps, integrated LED luminaires, and socketed fixtures that ship with LED light bulbs;
- Differentiating the higher performing products through the *CEE Specification for Integral Replacement Lamps Sold at Retail* or the *California Quality LED Lamp Specification*;
- Employing a midstream program model where incentives are supplied to the retailer to influence stocking and merchandising practices;
- Exploring new methodologies to calculate energy savings and relative baselines; and,
- Studying or piloting connected lighting, including quantification of savings from connected lighting and controls, NEIs, and the role of lighting role in a broader home energy management context.

<sup>12</sup> ENERGY STAR, "The Light Bulb Revolution," October 2017, [https://www.energystar.gov/sites/default/files/asset/document/LBR\\_2017-LED-Takeover.pdf](https://www.energystar.gov/sites/default/files/asset/document/LBR_2017-LED-Takeover.pdf).

<sup>13</sup> Based on CEE member input as well as the ENERGY STAR *Remaining Opportunities for Residential Energy Efficiency Programs: Lighting Fact Sheet*.

Figure 10. The Average Savings Percentage That Lighting Represents in Sponsors' Residential Portfolios<sup>14</sup>



### Lighting Manufacturers

The lighting market is witnessing the beginning of an efficacy plateau, per Jeff Dross of Kichler, with overall annual increase in efficacy of only a two to five percent – much smaller than in the past, when average residential lighting efficacy jumped by more than 40 percent between 2010 and 2015.<sup>15</sup> Most major manufacturers can reach 225 lumens per watt, though many in the industry consider the best balance between light output and cost to be around the 190-200 lumens per watt range. Manufacturers are now looking to tackle the lumen losses associated with preferred color temperatures and a higher color rendering index (CRI).<sup>16</sup>

Many lamp manufacturers will be hard-pressed to generate substantial revenue after 2020, especially if they wish to put cost above quality, according to Jeff Dross of Kichler. However, some products and companies are demonstrating initiative in finding new ways to compensate for losses in traditional A-lamp revenue. For example, one manufacturer has shifted the focus to higher-quality color in a premium product line. Their products are marketed as accessible interior design tools that can enrich residential environments (connecting the quality of lighting with its critical impact on the home's aesthetic and ambiance). Others are focusing on the idea of "healthy buildings"<sup>17</sup> and making lighting a component of an overall approach to making homes both energy efficient and tuned to the health and quality of life needs of the occupants.

<sup>14</sup> These results are from a survey of LFT sponsors before the 2018 workshop. Although it is a small sample that offers only rough estimates, it is indicative of general trends.

<sup>15</sup> U.S. DOE, "2015 Lighting Market Characterization," November 2017, [https://www.energy.gov/sites/prod/files/2017/12/f46/lmc2015\\_nov17.pdf](https://www.energy.gov/sites/prod/files/2017/12/f46/lmc2015_nov17.pdf).

<sup>16</sup> In general terms, CRI is a measure of a light source's ability to show object colors "realistically" or "naturally" compared to a familiar reference source, either incandescent light or daylight.

<sup>17</sup> The WELL Building Standard is an example.

According to Ron Zimmer of CABA, commercial lighting companies are also looking to consolidate. Manufacturers at the LFT workshop, such as GE Lighting, are seeking to broaden their territorial and product scope as well as buoy their purchasing, operational, development, and bargaining power. They recognize that not all companies are able to survive on their own, especially in a market pressured by the costs, competition, and confusion of how to profit in the new world of LED lighting, where prices have tumbled and products last a long time, virtually wiping out the classic replacement market as a source of revenue.

The drive to acquire and be acquired is intensified by the desire to have technologies that will be successful in an Internet of Things (IoT) future. Many people in the lighting industry believe that the IoT and its smart lighting services and products could well be the industry's future, as the old business model of selling short-life, dumb bulbs dies.<sup>18</sup> IoT includes the idea of lighting itself being provided as a service, especially where systems must be kept up-to-date as in certain types of housing, hospitality facilities, and nursing homes. This software as a service (SaaS) model is agile and may be adopted by residential customers. Another emerging business model under consideration is lighting as a service (LaaS). While LaaS models give customers a positive return on investment (ROI), this model appears to be more useful for the commercial sector than the residential sector since residential applications rarely run on ROIs.

In the residential lighting manufacturer realm, both new partnerships and new business models are being formed and adopted. For the first time, a major manufacturer has released a residential decorative fixture with voice control technology built in. The lighting business model may include simple product lines that add value by incorporating controls, fixtures, and bulbs, including residential occupancy sensors. Building on the core competencies of the lighting business of the past, some manufacturers are evolving from hardware companies to hardware, software, and service companies. Additionally, conglomerate companies like Google, Amazon, Facebook, and Apple are making significant investments to identify impact from lighting data analytics.

In this new era of partnerships and cooperation, some lighting manufacturers are finding that they will partner with previous competitors to create additional value for consumers. Revenue models are also changing; in the past, units sold was the measure of success, but, now, there is potential for the monetization of users over time with the addition of new services and capabilities enabled by connected technology.

Residential consumers want something fun, cool, and available to purchase immediately. Manufacturers have long worked with program administrators to help transform the consumer market for energy efficient products. Increasingly, consumers' perception of how "cool" and "fun" products are is driving the adoption of connected technology – leading to a need to update consumer market intervention strategies. By focusing on customer service, messaging, and

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<sup>18</sup> Lux Magazine "Welcome to the Great Lighting Industry Consolidation", Mark Halper, March 6, 2017. <http://luxreview.com/article/2017/03/welcome-to-the-great-lighting-industry-consolidation>.

interactive behavior, live feedback is becoming more important, such as with retail ratings. Moving forward, energy savings is becoming a less compelling motivator to customers compared to values like comfort, security, and other amenities.

## Lighting Showrooms

Many showrooms still stock incandescent technology alongside LEDs because consumers continue to purchase incandescent lighting and are reluctant to change. While LED adoption is on the rise, the average home is not likely to be fully LED-equipped by 2020 given the number of sockets (50 per home on average)<sup>19</sup> and slower adoption rates for specialty products like candelabra and globe lamps.

In 2016, ALA conducted a consumer research study with Home Accents Today and Progressive Business Media to gain a better understanding of how consumers think about, shop for, and buy residential indoor and outdoor lighting. They found that after big box stores like Home Depot and Lowe's, showrooms are the primary place consumers shop for lighting. Roughly half of respondents shopped at a lighting showroom and 16 percent used an in-store designer to help with their purchase. Design, quality, and amount of light were identified by customers as the most important lighting attributes.<sup>20</sup>

From the lighting showroom perspective, Tim Stumm of Lights Fantastic Dallas said there is an energized movement of "thinking beyond the bulb" in an attempt to outshine the increasing presence of big box and online retailers. To help generate this beyond the bulb thinking, showrooms are educating their employees on where consumers are finding products (for example, HGTV, Amazon, and others). To contrast with competitors, lighting showrooms are frequently moving to a layout with spaces that are designed to feel like different rooms in a home as opposed to a multiproduct display installation.

## Lighting Designers

While the residential lighting design community is small, it plays a role in the residential lighting market. There are approximately 550 lighting designers in the U.S. and Canada, of which eight percent operate within the residential sector: 23 U.S. designers and one Canadian designer who work on luxury residential projects, and 17 U.S. lighting designers and three Canadian designers for general residential projects.<sup>21</sup> Connected lighting is affording lighting designers more flexibility with regards to color and light levels and is likely significantly influencing this community.

In addition, the American National Standards Institute (ANSI), the Illuminating Engineering Society (IES), and ALA published [RP-11-17](#) in 2018, which serves as a guide standard for quality lighting design. This Recommended Practice is a guide for designing and teaching lighting

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<sup>19</sup> ENERGY STAR, "The Light Bulb Revolution."

<sup>20</sup> ALA, "Consumer Research," accessed August 16, 2019, <https://alamembers.com/Data-Research/Consumer-Research>.

<sup>21</sup> International Association of Lighting Designers, "Designer Directory," accessed September 23, 2019, <https://www.iald.org/Designers?search=true&pt=14&st=&stc=&sts=&sc=USA&ma=>.

design, including residential spaces. It describes design objectives, criteria for quantity and quality of illuminance, lighting methods, types and uses of equipment, energy use, and electrical code considerations. In addition, it presents several solutions to reduce energy consumption and avoid over-lighting.

## Key Residential Lighting Market Insights

- **The rate of change of the efficiency of residential light bulbs has grown momentarily in part because of technological developments, pricing trends, and program support.** The progression over the last five years alone has shown significant divergence from incandescent residential lighting as other technology and lighting types have emerged and replaced the once traditional fixtures in the main living areas of the home such as kitchens, bathrooms, bedrooms and living and dining rooms, per Jeff Dross of Kichler. The shifting of price floors has accelerated the replacement rate, according to Jeff Dross of Kichler and Laurie Gross of Gross Electric, Inc. There are also concerns about potential quality backsliding or decreased LED sales if efficiency programs no longer support LED adoption with incentives.
- **More consumers are adopting LEDs, but there are opportunities to further increase adoption. Purchasing drivers may not always include energy efficiency.**
  - LED adoption is not occurring consistently throughout the market. LEDs are much more common in new construction than existing homes, and there remains uncertainty about the renter's segment, per a discussion at the workshop between Michael Estrin, Tara Bolen, and Lisa McLeer.
  - Changes in federal standards or state energy codes may increase adoption, but the main drivers for consumers to purchase LEDs may be unrelated to efficiency. For example, consumers mainly switch to LED under-cabinet lights due to heat.
  - There is value added (for example, NEIs) from better quality light and color. Depending on the design, LEDs can enable more human-centric lighting. Human-centric lighting emphasizes light for health and well-being, and there is a growing body of research to support its importance.<sup>22</sup>
- **From a technical perspective, achieving higher performance is a balancing act.** While historically high efficacy of up to 225 lumens per watt is now technically feasible, a delicate balance is required to maintain lighting quality in tandem. The progression of higher efficacy products appears to be starting to plateau, per Jeff Dross of Kichler.
- **Light quality is still an area for growth.** There is a continued need to ensure quality lighting and controls across the board or efficient, connected lighting and the integrated home experience will suffer. A lingering presence of a "good enough" mindset for LED quality and issues such as glare could detract from consumer experiences.
  - With the introduction of low-priced LEDs, flicker has again become an aspect of concern for a portion of the user-community, specifically those most impacted by

<sup>22</sup> The [Lighting Research Center](#) is a leader in human-centric lighting research. *Lighting Research & Technology* journal includes several articles on human-centric lighting, and a 2016 editorial recognized the growing emphasis on the idea. There also exists a [Human Centric Lighting Society](#), an advisory committee that shares research and expertise on a contract basis and at annual summits.



flicker, such as migraine sufferers or those with photosensitive epilepsy.<sup>23</sup> While work on a comprehensive flicker metric is proceeding, there is currently no widely accepted standard.

- **Consumers are unfamiliar with the nuances of LED technology.** There is a critical need for consumer education regarding existing quality metrics, ability to determine the light source and lighting control compatibility, and performance (output, color tuning) to ensure continued customer satisfaction, per Chris Wolgamott of NEEA. Additionally, contractors and installers need education about the technology; with greater understanding, they would be more likely to install LEDs, rather than actively resist. Tara Bolen of Duke Energy stated that CEE member utilities, with their comprehensive knowledge of their residential customers, could play an important role in this effort.
- **LEDs appear to be instrumental in the future development of an integrated home.** There are more possibilities for connected functionality with LEDs and, combined with increasingly inexpensive sensor technology that could leverage non-lighting functionality, this adds to the momentum of connected lighting systems.
- **IoT is dramatically impacting this market, leading to significant shifts in program design, revenue models, and business models, per Bob Smith of Eaton Lighting.** There needs to be careful consideration of how to successfully integrate connected functionality into lighting products, as well as new service models to deliver a positive consumer experience.

## Assessing Connected Lighting Trends and Identifying Potential Value Streams

There are varying perspectives regarding the state of the connected residential lighting market, disruption caused by company acquisitions and the entrance of new market players, and the role and relative significance of connected lighting compared to other trends. However, one thing is clear: the residential connected lighting market is one of the highest growth areas for lighting (expected to rise to over \$4.5 billion in 2021 at a compound annual growth rate of 30.5 percent from 2017 to 2021),<sup>24</sup> and the integrated home segment is growing and involved in most aspects of daily life.

Navigant views the primary challenge to the uptake of connected LED lighting as an absence of general consumer understanding of the value proposition.<sup>25</sup> However, as 2017 IHS Markit research posits, “the residential smart lighting market is one of the highest growth areas. This rapid growth will be led by wider consumer adoption of smart home offerings...The residential smart lighting market will continue to see high growth rates through 2021, due in large part to an

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<sup>23</sup> ASSIST, “Flicker Parameters for Reducing Stroboscopic Effects from Solid-state Lighting Systems,” Volume 11, Issue 1, May 2012, <https://www.lrc.rpi.edu/programs/solidstate/assist/pdf/AR-Flicker.pdf>.

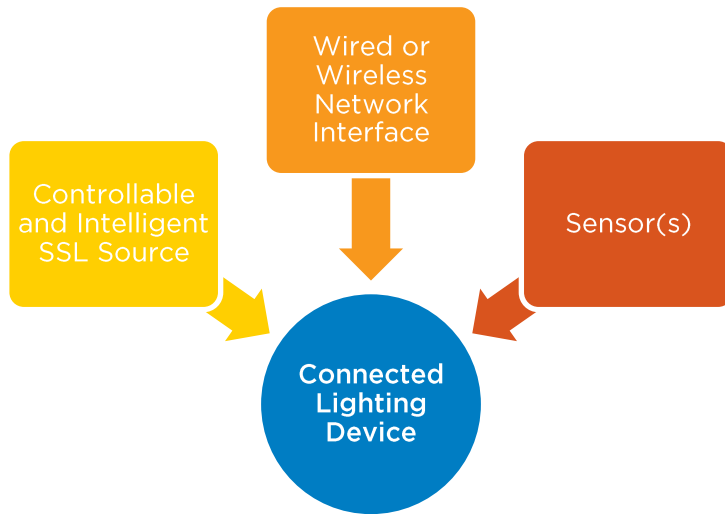
<sup>24</sup> Ibid.

<sup>25</sup> Navigant Research, “Market Data: Residential Energy Efficient Lighting and Lighting Controls,” 2018, <https://www.navigantresearch.com/research/market-data-residential-energy-efficient-lighting-and-lighting-controls>.

increase in smart home hubs. The flexibility of smart lighting in homes increases alongside the additional functionality smart-home hubs provide.”<sup>26</sup>

The emergence of connected lighting has been described as a “perfect storm” of conditions. Beyond the growing adoption of solid-state lighting, other significant technology trends are driving performance improvements and cost reductions, including advances in computing, mobile technology, intelligence (such as microcontrollers), network interfaces, and sensors. Additionally, a focus on systems and data and the emergence of cloud storage and computing contribute to the growth of connected lighting.<sup>27</sup>

Figure 11. **Components that Enable Connected Lighting**<sup>28</sup>



**Expected Revenue and Penetration**

U.S. integrated home revenue is expected to show an annual compound growth rate (CAGR 2018-2022) of 14.9 percent, resulting in a market volume of \$34 million by 2022 – of which lighting products could represent as much as \$2.98 million.<sup>29</sup>

When it comes to U.S. market penetration rates, smart lighting products are expected to continue their upward trajectory. Smart lighting penetration rose from 10.4 percent in 2016 to 17

**Connected lighting products are expected to reach a market volume of nearly \$3 million by 2022.**

<sup>26</sup> Paul Bremner, “Global market for smart lighting and connected lighting controls reached \$8 billion in 2017.”  
<sup>27</sup> Michael Poplawski, “The Emergence of Connected Lighting,” ENERGY STAR Products Partners Meeting, [https://www.energystar.gov/sites/default/files/asset/document/4\\_Michael%20Poplawski\\_Shining%20a%20Light\\_FINAL.pdf](https://www.energystar.gov/sites/default/files/asset/document/4_Michael%20Poplawski_Shining%20a%20Light_FINAL.pdf).  
<sup>28</sup> Adapted from Michael Poplawski, “The Emergence of Connected Lighting.”  
<sup>29</sup> Statista, “Smart Home Report 2019,” December 2018, <https://www.statista.com/outlook/279/109/smart-home/united-states>.

percent in 2018 and is expected to reach nearly 34 percent by 2022.<sup>30</sup>

### Pathways for Connectivity

CEE members have historically advocated for multiple pathways for connectivity to give consumers choice and increase the opportunities for DSM program enrollment. To understand the connected lighting market, it is prudent to first document the variety of ways devices are communicating, where the smart capabilities are housed and why (for example, in a control or switch versus within the lamp or fixture), and the communication protocols that are being used.<sup>31</sup> Table 3, below, illustrates some of the many communication protocols related to the integrated home and indicates which have had known implications for connected lighting products. The selected protocols and respective platforms employed by industry stakeholders vary, likely driven by internal business model decisions; there has not yet been a single protocol around which the lighting industry has converged.

The variation among protocols and understanding the relative limitations or benefits of each is confusing for average residential customers. Lighting manufacturers are seeking ways to simplify use for consumers or provide new value or services through cross-industry partnerships. For example, Lutron has added wireless hubs for centralized control and integration of simpler, code-compliant devices, such as plugs and switches. In residential systems, these hubs can act as a bridge and allow interplay with non-lighting devices (even those using different communication protocols) such as smart thermostats, voice assistants and smart speakers, and smartphone apps. There are few examples of inherently interoperable lighting products and systems that do not rely on some sort of bridge or hub to connect with products from other manufacturers or those operating on other platforms. In other words, the development of bridges and multi-system components may make it unnecessary for the consumer to know or understand what particular systems or protocols their connected lights or devices use.

Table 3. Two-way Communication Protocols<sup>32</sup>

Protocol	Wired	Wireless	Applied in Residential and/or Non-residential Lighting
Bluetooth		X	X

<sup>30</sup> Ibid.

<sup>31</sup> In many respects, the commercial market is more mature and cataloged; for example, DOE national labs have already conducted a literature review and product matrix to describe the current landscape of devices and capabilities. When it comes to orchestrating multiple devices in a single building, for commercial applications there is often a building automated system (BAS) that controls systems such as heating and cooling equipment (HVAC), CCTV, access, fire alarms, and lighting; typically, a central workstation enables remote access to conduct energy management. In residential applications, some of the key aspects of a connected whole-home system are control panels, connected ballasts and wireless adapters, connected switches and keypads, sensors, and retrofits for LEDs.

<sup>32</sup> Additional references include IoT For All's *Smart Home Protocols Explained*, SafeWise's *Home Automation Guide for Beginners*, Newegg Insider's *Understanding Smart Home Communication Protocols*, Top Ten Reviews' *A Guide to Home*

Bluetooth Low Energy		X	X
NFC		X	X
OpenADR		X	X
Thread		X	X
Wi-Fi		X	X
ZigBee		X	X
Z-Wave		X	X
Ethernet	X		X
UPB	X		X
X10	X		X
CEBus	X	X	X
CTA-2045	X	X	
KNX	X	X	X

A database formerly maintained by CEE member [Consolidated Edison](#) provided significant insight into how the residential connected lighting market operates, with over 400 products included in mid-August 2018. Consolidated Edison estimated that this database represented about 50 percent of the overall market share of these products. The database illustrated that there was interest in controlling residential lighting devices at both the switch and control level, as well as from the lamp or fixture itself.

Lighting control devices (such as dimmers, switches, and outlets) and connected lamps each represented about half of the 103 lighting products listed in the database.<sup>33</sup> There were a number of security and integrated home providers operating in the space alongside traditional lighting manufacturers and start-ups. It is also interesting to note that common integrated home platforms differ by product; while lighting control devices are most likely to use Apple HomeKit, Google Home, Amazon Echo, or Samsung SmartThings, connected lamps are most likely to use Amazon Echo, Google Home, and Wink. Approximately 10 percent of lighting products in the database required a proprietary hub.

Connected control devices and lamps included in the database shared similar features with respect to sensors, energy usage data, app control, and scheduling/automation abilities (Figure

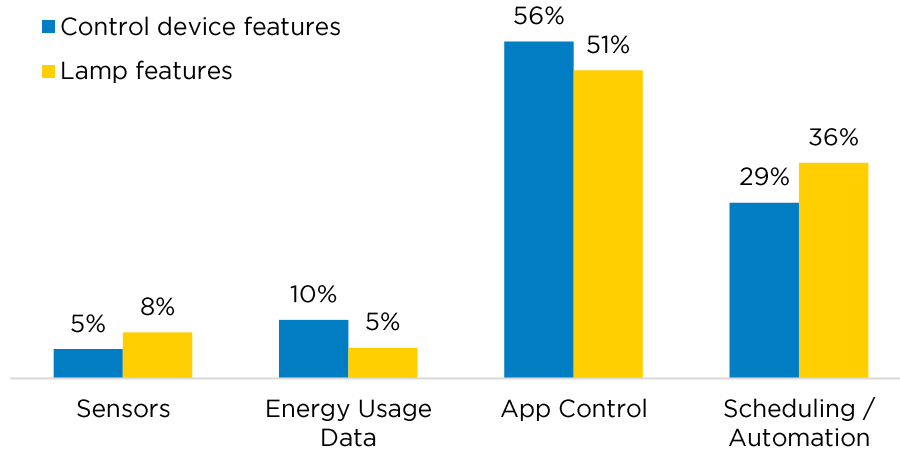
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*Automation Protocols*, Electronics Notes' *Connectivity: Wireless & Wired*, and Link Labs' *Bluetooth Vs. Bluetooth Low Energy: What's the Difference?*.

<sup>33</sup> Based on ConEd smart home database access on August 14, 2018.

12). Connectivity trends across both products are also similar; Wi-Fi is the most common way to connect, followed by Bluetooth.<sup>34</sup>

Figure 12. Features of Connected Control Devices and Connected Lamps<sup>35</sup>



### Product Capabilities

The different functionalities associated with connected lighting and their associated values vary among manufacturers, retailers, designers, and consumers; several use cases highlight the potential benefits for stakeholders that go beyond illumination, outlined in Figure 13.

Figure 13. Examples of Connected Lighting Functionality Beyond General Illumination

Sensing	Audiovisual	Processing	Networking	Other
<ul style="list-style-type: none"> <li>•Temperature</li> <li>•Occupancy</li> <li>•Daylight harvesting</li> <li>•Air quality</li> <li>•Motion (security)</li> <li>•Humidity</li> <li>•Sound</li> <li>•Integrated sensors</li> <li>•Glare control</li> </ul>	<ul style="list-style-type: none"> <li>•Speaker</li> <li>•Music</li> <li>•Microphone</li> <li>•Camera</li> <li>•Voice assistant/voice control</li> <li>•Customization</li> </ul>	<ul style="list-style-type: none"> <li>•Radio frequency/ RF-enabled</li> <li>•Control panels and algorithms</li> <li>•Internal monitoring</li> <li>•Diagnostics and fault detection</li> <li>•Data transmission and analysis</li> </ul>	<ul style="list-style-type: none"> <li>•Signal boost or extension</li> <li>•Gateways/ hubs</li> <li>•Routers</li> <li>•Li-Fi</li> <li>•Connected ballasts, controls, and wireless adapters</li> <li>•Open APIs</li> </ul>	<ul style="list-style-type: none"> <li>•Energy storage</li> <li>•Automatic dimming</li> <li>•Lighting/ HVAC interaction</li> <li>•Automation (e.g. IFTTT)</li> <li>•Color tuning</li> <li>•Timers, scheduling</li> <li>•Remote control</li> <li>•Lighting as a Service (LaaS)</li> </ul>

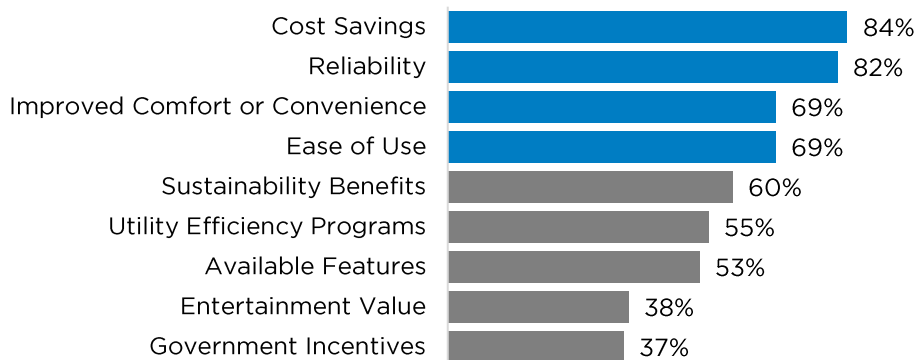
<sup>34</sup> Ibid.

<sup>35</sup> Ibid.

## Consumer Drivers

Numerous consumer research efforts have shown that price, comfort, convenience, and safety consistently rank among the top influences in the purchase of smart / connect / integrated home products and solutions, although energy and resource management are also important factors.<sup>36</sup> Harbor Research, as part of an integrated home roadmap research project with the Continental Automated Buildings Association (CABA), broke down several purchasing considerations and use cases further, as illustrated below.

Figure 14. **Consumer Considerations When Buying Smart Home Products**<sup>37</sup>



<sup>36</sup> See similar studies by Harbor Research, Deloitte, and McKinsey.

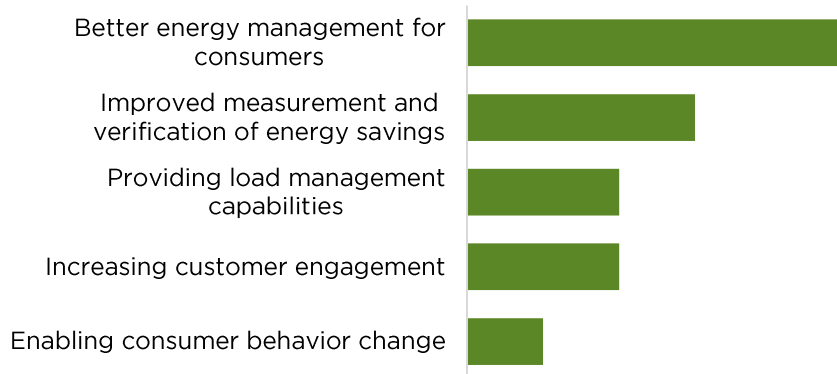
<sup>37</sup> Adapted with permission from Harbor Research, "Connected Home Roadmap," CABA, 2018, <http://www.caba.org/documents/Presentations/CHR-Intro-Webinar/lib/playback.html>.

# Potential Benefits of Connected Lighting

## Program Administrator Benefits

Program administrators see many potential benefits from an integrated home, as illustrated below.

Figure 15. **What Potential Benefits Does Your Organization See from an Integrated Home?**<sup>38</sup>



## Potential for Energy Savings

While connected lighting is not inherently more efficient than other lighting, there are potential pathways for realizing energy savings through automating and optimizing control functionality, such as using occupancy data to turn off lights when not in use and dimming light levels based on sensing ambient light. In addition, connected lighting may achieve energy savings through behavioral changes, such as learning when customer choose to dim lamps or reduce hours of use. However, there are also scenarios where energy use could increase, either due to consumers choosing to operate their lighting more often or from background or standby power draw. Connected lamps include integrated transmitters with constant power draws of up to one-half of a watt. Some lamps also require bridges that allow them to communicate with hubs (for example, Amazon’s Echo or Samsung’s SmartThings); bridges also draw around one-half of a watt. Finally, while hubs are likely to be considered external to connected lighting, they also require a background power draw.

Although connected lighting is not inherently efficient, this does not mean that connected lighting cannot generate savings. Connected lighting manufacturers are already working to reduce standby power usage by eliminating or minimizing the number of bridges required, combining lighting systems as part of an integrated home solution, and reducing per-lamp draw. There are also supplemental strategies for encouraging a reduction in energy use such as

<sup>38</sup> These results are from a survey of LFT sponsors before the 2018 workshop. Although it is a small sample that offers only rough estimates, it is indicative of general trends.

employing auto dimming, geofencing, motion or daylight sensors, rotating security lighting patterns (instead of always on), and the reinforcement of energy savings behavior.

Figure 16. **Connected Residential Lighting Savings Theory: Illustrative Scenarios**<sup>39</sup>

Scenario 1					
	8W LED	0.4W Bridge	0W Hub	Total System	Breakeven
<b>Active Light</b>	8W x 3 = 24W/h	0	0	24W/h	80% Reduction
<b>Standby Energy Calculation (24 hours)</b>	0.4W x 1 x 24 = 9.6W/h	0.4W x 1 x 24 = 9.6W/h	0	19.2W/h	n/a

Scenario 2					
	3 x 8W LED	0.4W Bridge	0W Hub	Total System	Breakeven
<b>Active Light</b>	8W x 3 = 72W/h	0	0	72W/h	53% Reduction
<b>Standby Energy Calculation (24 hours)</b>	0.4W x 3 x 24 = 28.8W/h	0.4W x 1 x 24 = 9.6W/h	0	38.4 W/h	n/a

However, the benefits of connected lighting likely go beyond energy savings and can serve as part of a strategy to increase customer engagement or act as a stepping stone to an integrated home, which can deliver benefits from consumer behavior change, improved measurement and verification of energy savings, and load management. Program administrators at the LFT workshop shared that connected lighting may serve other organizational objectives besides energy savings, including DR, carbon reduction, increased program participation, and other revenue streams.

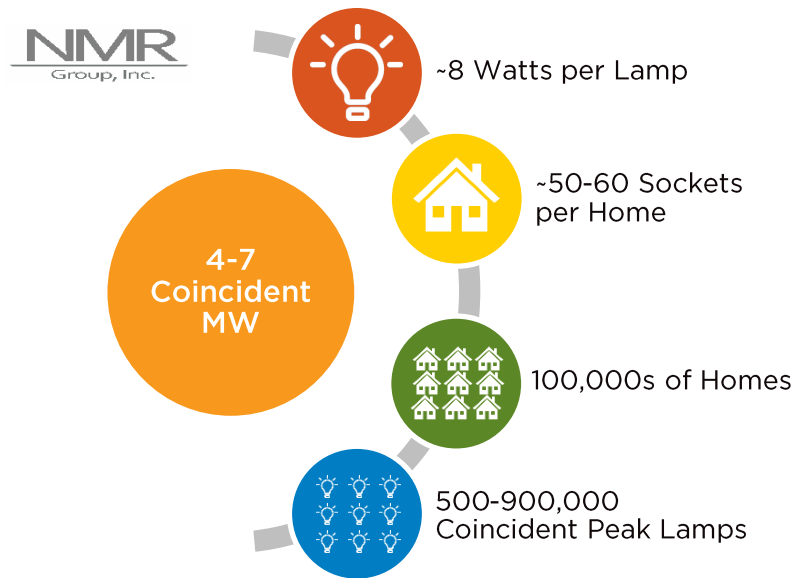
The DSM program shift from simple energy usage reduction to active demand management (from kWh to kW) could be supported by connected LEDs. If there is an easier way to dim lighting, turn lights off, or use battery backups during peak energy use times, this will have grid benefits in the aggregate. As more regions look to implement time of use or dynamic pricing rate

<sup>39</sup> Developed in collaboration with the NMR Group. Recently, they have seen a trend of manufacturers eliminating bridges, which decreases the standby load and increases energy savings potential.



structures, there are also potential customer benefits in terms of reduction in energy costs, though savings are likely to be small. The time and location of energy usage matters and will grow in importance to utilities moving forward.

Figure 17. Demand Response (DR) Opportunity<sup>40</sup>



A few workshop attendees saw some potential value in enhancing lighting quality for the customer.

Particularly, there may be an increased likelihood of positive consumer experiences with energy efficient lighting that has adjustable color, chromaticity, and light levels, as well as a reduced need for consumer education efforts on purchasing the desired light output, color temperature, and color rendering. However, more sponsors saw value in building relationships with industry and customers, increasing customer participation in other programs, and improving customer satisfaction.

*“Though residential lighting coincidence is low, millions of sockets and hundreds of thousands of coincident peak lamps can equate to significant megawatts; for example, 100,000 homes with 5-6 million sockets total could potentially equate to 4-7 coincident megawatts. Demand response strategies specific to lighting could include dimming to lower light levels or turning off certain lights; in conjunction, demand response participation aspects (such as consumer override or opt-in messaging) would be important considerations for programs.”*

— NMR Group

### Enhanced Customer Engagement

Connected lighting may serve as part of a program strategy to increase customer engagement with utilities. One example could be pairing connected lighting with other devices, like smart thermostats, through online platforms. Online platforms have been designed to increase customer engagement and move towards becoming a “trusted energy advisor.” While 60 percent of consumers see their utility as an important source of information on energy efficient products,

<sup>40</sup> Developed in conjunction with the NMR Group.

only 25 percent of consumers feel like their utility is currently doing enough.<sup>41</sup> Online platforms offer another way for utilities to engage with their customers. Many online marketplaces offer extensive information on the product categories offered, and utilities can provide instant rebates easily.<sup>42</sup> For example, Commonwealth Edison launched an online marketplace as part of their strategy towards becoming the “utility of the future.” They see the “utility of the future” as one that delivers innovative products and services to increase customers’ convenience and provides customers with greater control over their energy use.<sup>43</sup> Another important consideration of connected devices is the role they play in offering complementary load management value; “a growing number of interoperable products arriving in consumers’ homes...are a gateway to addressing a larger portfolio of electric end-uses, allowing consumers to become part of the residential demand response ecosystem.”<sup>44</sup>

### Consumer Benefits

In the past, consumers and lighting designers have been restricted to a small number of color options, as well as what can be done with lights in a home – they are either on, dimmed, or off. With the evolution of lighting technology and the introduction of connected lighting systems, consumers now have the ability to control their lighting in a myriad of ways, yielding several significant benefits.

#### Health and Comfort

Connected lighting offers consumers the ability to select the optimal light levels and colors to serve a variety of functions, including energize, concentrate, read, or relax.

Exposure to short-wavelength (blue) light at night has been shown to suppress melatonin production, thereby disrupting the internal body clock, which can affect sleep and overall wellbeing.<sup>45</sup> Connected lighting can help avoid this because it can be programmed or directly controlled to provide warmer colors and lower light levels in the evening. This gradual reduction in brightness and color adjustment can aid in the production of melatonin, providing better quality sleep. The opposite effect is also possible, where lights can be programmed to gradually brighten in the morning and even synchronized with an alarm to support a consistent sleep-wake cycle.<sup>46</sup> According to several laboratory studies and field demonstrations conducted by the

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<sup>41</sup> Enervee, “Enervee Score® 2.0: Making energy efficiency actionable.” Accessed September 19, 2019, <https://enervee.com/score/>.

<sup>42</sup> Smart Grid, “Is Your Utility the New Amazon for Energy?” accessed September 19, 2019, <http://www.whatissmartgrid.org/featured-article/is-your-utility-the-new-amazon-for-energy>.

<sup>43</sup> Smart Energy Consumer Collaborative, “ComEd Marketplace: A Next-Generation Digital Platform for Consumers,” ComEd, accessed September 20, 2019, [https://smartenergycc.org/wp-content/uploads/2017/12/SECC-ComEd-Marketplace-Case-Study-Final.pdf?mc\\_cid=c9848e0ff0&mc\\_eid=a648063a9b](https://smartenergycc.org/wp-content/uploads/2017/12/SECC-ComEd-Marketplace-Case-Study-Final.pdf?mc_cid=c9848e0ff0&mc_eid=a648063a9b).

<sup>44</sup> PLMA Thermostat Interest Group, “The Future of ‘Bring Your Own Thermostat’ Programs,” PLMA, March 2018, <https://www.peakload.org/assets/Groupsdocs/PractitionerPerspectives-UtilityBYOTPrograms-March2018.pdf>.

<sup>45</sup> Lighting Research Center, “Light at Night”, accessed August 21, 2019, <https://www.lrc.rpi.edu/programs/lightHealth/LightAtNight.asp>.

<sup>46</sup> Bright Ideas, “Benefits of Smart Lighting: 6 Benefits of Having Smart Lighting,” LEDHut, accessed August 21, 2019, <https://www.ledhut.co.uk/blog/6-benefits-smart-lighting/>.

Lighting Research Center, long-wavelength red light has recently been shown to increase objective measures of alertness at all times of day.<sup>47</sup>

### **Safety and Convenience**

Consumers are no longer restricted to controlling their lighting from a wall switch. With a smartphone app, consumers have the convenience of being able to control and monitor connected lights from anywhere in their house or the world.

Connected functionality also enables a number of security features. Consumers can pre-program or remotely set their lights to behave as though their home is occupied by mimicking typical usage patterns even when they are away to reduce the incidence of break-ins. Depending on the manufacturer, connected lighting devices can work with smart security systems such as cameras, smoke detectors, and doorbells, all of which can be accessed via smartphone and managed remotely. Functionalities like geo-fencing, scheduling, photo and occupancy sensing, and remote access prevent consumers from ever coming home to a dark residence. By utilizing motion sensors, lights will only switch on when someone walks into the room, which can be ideal for hallway or landing lights, especially in the middle of the night.

### **Energy Savings**

Connected functionality is typically paired with LED technology, which is estimated to be around 80 percent more efficient than traditional incandescent bulbs.

It is common to forget to turn off a light before leaving home. With connected lighting, consumers can check if they have left a light on or even receive a notification when a light is on while the house is unoccupied. They then have the option to turn it off remotely – turning off lights when not in use can lead to energy savings, especially for a period of extended absence. Additionally, light sensors can be used to automatically adjust the brightness of the lighting according to how much natural light is available in the room, known as daylight harvesting, which can also yield energy savings.

### **Enhanced Ambiance, Décor, and Entertainment**

In addition to health, well-being, security, convenience, and energy savings benefits, additional control and flexibility provide consumers with desired ambiance and entertainment features. Connected lighting makes it simple to dim any lights and adjust color from warm white to cool bright daylight to provide the desired ambiance for a particular room and time of day. It also enables consumers to decorate with light by temporarily changing the color of walls and ceilings with lighting. The possibilities are endless, and the If This Then That (IFTTT) platform allows the consumers to dream up just about anything with pre-built recipes. Some examples include

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<sup>47</sup> Lighting Research Center, “Light, Alertness, and Performance,” accessed August 21, 2019, <https://www.lrc.rpi.edu/programs/lightHealth/LightAlertness.asp>.

having your favorite sporting team colors flash when they score or increasing the brightness when it is raining outside.

### Lighting Manufacturers

The high-tech reality of LEDs has enabled the lighting industry to think about interesting or more advanced ways to use light sources. Despite the challenges associated with lighting and connectivity, there have been advances and changes in the direction of residential lighting since its invention. From a manufacturer's perspective, connected lighting is transformative. With the integrated home as the path forward, their business is changing from a consumable business to a durable business, much like the transformation of the light bulb.

Manufacturers' business models are shifting to accommodate the changing market and consumer preferences. Younger consumers are more likely to purchase connected lighting,<sup>48</sup> and younger customers expect companies to communicate personalized information through their preferred channels.<sup>49</sup> The integrated home brings new benefits into the marketplace, which puts many manufacturers into a "start-up" mode; some manufacturers are working with companies like Quirky to infuse new business model ideas and accelerate growth within internal teams.

### Voice Control and Automation

Smartphone and voice command system adoption rates are on the rise,<sup>50</sup> providing an expected catalyst for connected lighting growth. Some manufacturers believe that if connected lighting is to be adopted at the same rate, it will need to be simple to use and install. For example, if voice-controlled homes are to be successful in the future, manufacturers will need to make multi-ecosystem compatible goods (for example, Amazon Alexa/Echo, Google Home, and Apple HomeKit). The concept of voice in the integrated home may prove to be extremely important for the future development of connected light switches, hubs, and more. In the same way that data can be captured at the device level to inform product learning algorithms for operation, the data from voice control could theoretically be used to create rules for scheduling and coordinating the energy consuming technology so the home can essentially run by itself within the preferred comfort and amenity parameters of a specific consumer. The data could also enable consumers to look historically or in real time at the impact of the coordination of lighting to see if they saved any energy (a behavioral science concept called feedback).<sup>51</sup> The system may further provide recommendations for behavioral or use modifications to achieve specific energy consumption goals.

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<sup>48</sup> Allison Zisko, "LED Lighting Adoption Rising," HFN, July 19, 2016, <https://www.hfndigital.com/industry-news/led-lighting-adoption-rising/>

<sup>49</sup> Smart Energy Consumer Collaborative, "ComEd Marketplace: A Next-Generation Digital Platform for Consumers."

<sup>50</sup> According to [Statista estimates](#), smart phone ownership in the U.S. in January 2018 was up to 77%; [Forbes reports](#) that in June 2018, 20% of the U.S. population had access to smart speakers.

<sup>51</sup> Feedback typically refers to the provision of energy usage or cost information in an engaging way that encourages the customer to respond to this information by taking action or providing information in return, with the end goal of spurring behavior change that will reduce energy consumption in that customer's home or business.

The responsibility of ensuring connectivity and interoperability falls on the manufacturer, not homeowner; considering this, some manufacturers are attempting to take a completely platform agnostic approach. With the rise of voice command and smartphones, lighting wall switches and remote controllers may largely disappear from their traditional locations in the home and primarily serve as a backup control in a less conventional location. However, there is still a long path to that future as voice controllers need better voice comprehension and manufacturers need multi-ecosystem compatibility.

### **Sensor Technology**

A growing number of lighting manufacturers are incorporating residential occupancy sensors into products. These and other sensors can be adapted in a multitude of ways. Most lighting companies maintain premium product lines, which now often include connected products with additional capabilities such as light bulbs that include smoke detectors, carbon monoxide monitors, occupancy sensors, or multiple sensor functions integrated into a single product.

### Retailers

Given that connected technology is complicated, the market is moving away from do it yourself (DIY) models to do it for me (DIFM) models. Showrooms and others demonstrate this change through an increase in integrated home installation packages.

ALA conducted a survey of its lighting showroom members and found that 45 percent of showroom members did not sell connected lighting, 45 percent did, and 10 percent were unsure of what constituted connected lighting products. According to ALA members, there is an opportunity for showrooms to be counted on by consumers as personalized connected lighting (and perhaps even integrated home) experts, as opposed to non-customized or online suggestions, thus giving showrooms an additional opportunity to increase their relevance among a broader consumer base. According to one showroom manager, the lighting showroom is not about the lightbulb anymore – it is about creating a better life in the home using lighting. Showrooms are experimenting with new connected products and approaches to make the showroom space more relevant and engaging.

### Lighting Designers

For some lighting designers, high-end residential homes make up as much as 65 percent of business, illustrating the significant divide between “common” and high-end consumers. While designers are still very much aware of the typical issues and questions that arise with average connected lighting or home installations, it is not clear in their view whether connected products are about saving money or enabling convenience. Additionally, some question whether it is the same driver or drivers across both types of consumers. Some designers believe their clients would prefer that connected products or systems are easy to use and readily accessible, and there is an undeniable push from the perspective of connected products having a “cool factor.” However, these desired elements from the consumer side may or may not align with the priorities of the lighting designer, who may focus on simplicity, reliability, compatibility, and

enhancing the performance of lighting. From the designer perspective, the quality of the lighting as a standalone aspect is vital; no amount of control capability or cool features will overcome all negative attributes if the lighting is of poor quality.

Connected lighting systems for residential spaces are often plug load oriented and can easily be controlled, which is generally a less expensive approach than hard-wired systems (and thereby may weather changes in residence, if a new occupant dislikes the connected lighting in the home). In the same fashion that connected thermostat entities, such as Nest, have been able to describe their products to customers extremely simply, designers hope that the lighting industry will consider similar ways to inform and bring value to customers. Furthermore, designers also hope that the lighting industry will contemplate cross-compatibility across their products and systems for the sake of making it easy for average customers to piece together or take ownership over an existing integrated home solution.

## Key Takeaways Identified by Workshop Attendees

- **LED technology engagement may be a good indicator of consumer interest in connected products and how much they are willing to pay.** There is segmentation from the manufacturer marketing perspective regarding consumer engagement with LEDs.
- **There is a division between high-end connected lighting and systems and those that are ‘normal’ mass market products.** Higher-end homes installing more intricate, expensive systems do not care about the energy savings as much as the “cool factor.” For the mass market to get involved with connected products, it may be prudent for industry stakeholders to engage with voice assistant ecosystems given the widespread adoption; these ecosystems could potentially be leveraged to optimize energy savings in the future.
- **Voice control for lighting is not a viable replacement for a standard light switch but is likely more accessible than control via smartphone application.**
- **The proliferation of voice control technology is already having implications for lighting and the integrated home.** There are several reasons why voice command systems are becoming so popular so quickly: easy access to music, shopping, energy home management, a new way to control connected lighting that does not involve opening an app, and more. What is unknown is the potential for security and privacy invasion and whether voice control will win out as the central integrated home “hub” at a mass-market level.
  - Workshop participants also observed that voice-controlled technology could prove monumentally helpful for those with physical, audial, and visual disabilities, as well as the aging population. These are some emerging markets that would be good targets for those offering smart controls.
- **Advances in sensor technology have led to increased adaptability and product amenity.** The trend of adding sensors to products is accelerating due to decreasing sensor technology costs. The lighting industry, as with other residential product industries, has both mass-market products as well as premium products. “Premium” in the lighting context frequently refers to connected products that offer additional value, such as light bulbs that include smoke or carbon monoxide detectors, occupancy sensors, and more.
- **Energy savings is still a draw for customers and industry stakeholders.** Savings potential helps utilities and efficiency programs create incentives and support adoption. With

the rise of connected products and integrated home adoption, in tandem with LED adoption trends, some utilities are considering a shift to a kW approach as opposed to the traditional kWh perspective. Despite diminishing savings growth over baseline, technological advances may enable the ability to turn products off at certain times depending on pricing or grid signals. In the lighting context, this might mean new product capabilities such as battery backup so that lighting is not disturbed during a grid event. The timing and location of energy use matters, and utilities will become increasingly sensitive to measuring that as a metric of success.

- **The potential benefits of connected lighting vary among stakeholder groups, but the overarching opportunities are enriched engagement with customers and the ability to support positive consumer experiences with connected technologies.**
  - Consumers and designers benefit from enhanced flexibility, comfort, ambiance and aesthetic, health, convenience, safety and security, reliability, and customization.
  - Manufacturers benefit from the ability to gain insights about consumer use, ability to improve products based on data collected, increased sales, and partnership opportunities with other stakeholders to provide new or additional value or services.
  - Retailers benefit from an increased ability to meet consumers' unique needs through functionality (such as, adjustable colors and light levels), an ongoing relationship with customers, a potential channel for customer education, and increased sales.

## What Challenges Does Connected Lighting Present?

### Market Barriers Created by Connected Devices

In the current market, certain barriers identified by workshop attendees constrain the mass market adoption of connected lighting devices and the realization of potential benefits. Some of these challenges include communicating the value proposition to consumers effectively, product or system pricing, complexity (the need for additional components such as hubs or controls, installation, setup, and use challenges), reliability and resilience, interoperability of products, cybersecurity, and data privacy. While price and consumer understanding are likely to be addressed over time, the challenges associated with complexity, interoperability, reliability, and security are of primary importance.<sup>52</sup>

### Complexity

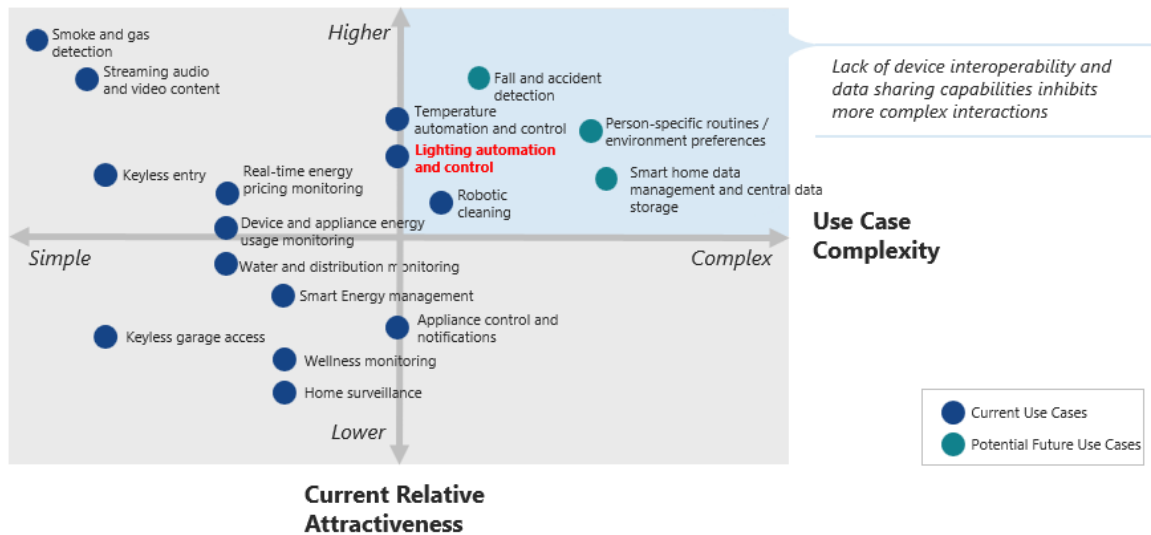
The 2017 LFT Competition, which included a category for connected lighting entries, saw two encouraging trends. The first was a drive for simplicity of set up and use. Some luminaires, for example, may be mounted and wired as usual and controlled by a simple switch or dimmer as required. Their connected features are activated via a wireless control or cell phone app. Simplicity encourages the second trend, which is to have the communications protocols involved invisible to the installer or user. The smart device makes the needed data translations automatically using one of several communication protocols described previously in Table 3.

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<sup>52</sup> The showroom and energy provider networks have an additional challenge in the distribution of these connected products; the electronics industry (electronics stores and mass merchants selling electronics) are vying for consumer business in integrated homes as well.

However, in addition to adjusting light levels and color, consumers can now set scenes, control their lights remotely, and connect them with other home systems (including security, heating and cooling, and entertainment). The added capabilities make the installation, setup, use, (and ultimately, optimization) of integrated home devices characteristically complicated, inhibiting mass market adoption.

Figure 18. End Customer Smart Home Use Cases<sup>53</sup>



**Interoperability with Other Products and Systems**

Almost 75 percent of consumers who said they plan to purchase an integrated home device deem it essential that it connects seamlessly to other products in their home electronic network.<sup>54</sup> According to Parks Associates, interoperability challenges have caused hang-ups in integrated home market growth, including “inconsistent and limited connectivity capabilities, lack of contextual richness of data expensive devices with long lifespans, and point-to-point integration strategies that quickly become unmanageable.”<sup>55</sup> Many integrated home stakeholders, including program administrators, echo this sentiment.

<sup>53</sup> Reproduced with permission from Harbor Research, “Connected Home Roadmap,” CABA, 2018, <http://www.caba.org/documents/Presentations/CHR-Intro-Webinar/lib/playback.html>.

<sup>54</sup> Parks Associates, “Nearly 75% of consumers planning to buy smart home devices value interoperability with other products in their home,” June 5, 2018, <https://www.parksassociates.com/blog/article/pr-06052018>; Dan Alaimo, “75% of smart home device purchasers value interoperability,” June 14, 2018, <https://www.retaildive.com/news/75-of-smart-home-device-purchasers-value-interoperability/525476/>.

<sup>55</sup> Harry Wang, “Interoperability: Realizing the Promise of the Connected Home,” Parks Associates, May 5, 2016, <https://www.parksassociates.com/newsletter/article/hs-may2016>.



Although interoperability represents a key challenge to the adoption and use of smart products, it has also spurred the development of myriad open standards-based communication protocols to allow devices, services, and applications to communicate and exchange data (refer to Table 3 for common protocol examples). While there is still a strong presence of proprietary or closed-system technology, a growing contingent of manufacturers are considering how their business models may interface with other brands and platforms. One example is the Samsung SmartThings ecosystem, which can integrate with over 400 non-Samsung products.

## Reliability

The lighting industry is well aware of the importance of lighting to safety and well-being, and the ALA is a participant in the IES-led process to develop a Design Guide for Resilient Lighting. In addition, program administrators see the value in resiliency; for example, the California Public Utilities Commission (CPUC) and the California Energy Commission (CEC) launched a Zero Net Energy Action Plan for all new homes to be Net Zero Energy by 2020, which would be complemented by resilient lighting efforts.<sup>56</sup>

*“Of growing concern are the statistics that point to an increase in the amount of power failures occurring in the U.S. Having battery- and solar-powered lighting that provides illumination for up to 8 hours on a single charge would help alleviate some of those difficulties.”*

— Terry McGowan

If connected lighting and its non-connected counterparts do not address resiliency, a glitch could turn the whole system to chaos due to the complexity involved. If the lights go out and consumers cannot use voice commands, there must be a physical backup switch for lighting control. The lighting industry is seeking to address resiliency and the associated safety implications.

## Cybersecurity

Consumer research studies indicate that security concerns are a major deterrent for integrated home adoption. According to UL, “the widespread use of connected smart home devices and systems has also provided an attractive platform for targeted cyberattacks by hackers and other unscrupulous operators.”<sup>57</sup> UL cites product design and implementation as the most common cause of cybersecurity vulnerability, which generally falls into one of five categories: poor product design, non-secure communication protocols, inadequate password or authentication procedures, limited software updates or patching, and improper device or application use. In conjunction with federal efforts like the U.S. Department of Homeland Security’s “Strategic

<sup>56</sup> Enlightenment, “The Time Is Right for Resilient Lighting,” October 31, 2017, <https://www.enlightenmentmag.com/inside-lighting/time-right-resilient-lighting>.

<sup>57</sup> UL, “Cybersecurity Considerations for Connected Smart Home Systems and Devices,” 2017, [https://industrie4-0.ul.com/wp-content/uploads/2018/02/UL\\_Cybersecurity\\_SmartHome\\_White\\_Paper\\_en.pdf](https://industrie4-0.ul.com/wp-content/uploads/2018/02/UL_Cybersecurity_SmartHome_White_Paper_en.pdf).

Principles for Security the Internet of Things,” test agencies have begun to develop standards to help mitigate cybersecurity risks. UL’s Cybersecurity Assurance Program (UL CAP) provides “verifiable criteria for assessing the cyber vulnerability of network-connectable products and systems. Specifically, the UL 2900 series, *Standard for Software Cybersecurity of Network-Connectable Devices*, is applicable to a broad range of interconnected devices and systems, and is intended to provide testable cybersecurity criteria to assess software vulnerabilities and weaknesses, minimize exploitation, address known malware, review security controls and increase overall security awareness.”<sup>58</sup>

The six considerations identified by workshop participants to evaluate utility readiness to incentivize connected lighting (in order to mitigate deployment risk) if there are measurable energy savings are:

1. Cybersecurity (from a systems perspective),
2. Ongoing support for reliability and security,
3. Ease of operation and commissioning,
4. Scalable to technology,
5. Affordability, and
6. In channel and in stock.

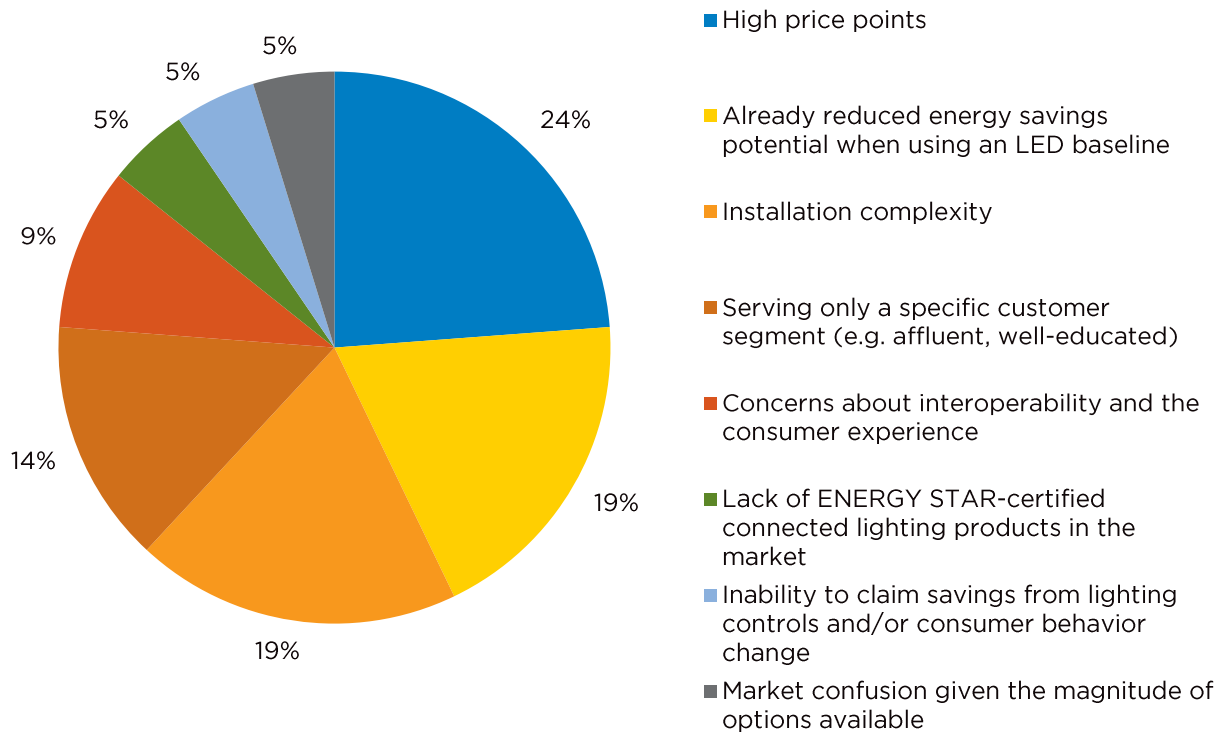
### Challenges for Program Administrators

Program administrators have faced challenges to date when it comes to incorporating connected lighting into their programs; examples include the lack of data regarding incremental energy savings from connectivity, inability to claim savings from lighting controls and consumer behavior, a lack of ENERGY STAR certified connected lighting devices, high price points, concerns about interoperability and the consumer experience, and only serving a specific customer segment (mainly affluent and well-educated customers) versus all utility customers. A survey of the 2018 LFT sponsors (Figure 19) illustrates the spectrum of challenges that DSM program administrators believe are inhibiting the ability to widely promote consumer adoption of connected lighting products in the same way they have traditionally done with energy efficient lighting technologies.

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<sup>58</sup> Ibid.

Figure 19. What Challenges Are Preventing Your Organization from Supporting Connected Lighting?<sup>59</sup>



### What is the Role of Data and Smart Meters?

For many programs, connected lighting is not only an opportunity for energy savings, but also for customer engagement. With certain products, energy usage data may increase the ability to automatically adjust use based on a customer’s typical patterns if the device utilizes learning algorithms. Another primary benefit of providing usage data through individual products or smart meters is that customers can see the relative impact of their behavior on consumption. According to the U.S. Energy Information Administration (EIA), more than half of electric customers had smart meters installed in 2016,<sup>60</sup> and about 88 percent of smart meter installations were for residential customers.<sup>61</sup> These meters use different protocols – some are open standards while others rely on proprietary technology.

Some utilities maintain that to maximize the potential benefits of an integrated home, consumers need a smart meter since AMI gives authorized third parties, such as utilities, access to interval data about energy usage. According to Emmett Romine of Powerley, several utilities have seen sustained energy savings of two percent on average and up to 8-10 percent in real time from

<sup>59</sup> These results are from a survey of LFT sponsors before the 2018 workshop. Although it is a small sample that offers only rough estimates, it is indicative of general trends.

<sup>60</sup> U.S. EIA, “Nearly half of all U.S. electricity customers have smart meters,” *Today in Energy*, December 6, 2017, <https://www.eia.gov/todayinenergy/detail.php?id=34012>.

<sup>61</sup> U.S. EIA, “How many smart meters are installed in the United States, and who has them?” *Frequently Asked Questions*, accessed August 16, 2019, <https://www.eia.gov/tools/faqs/faq.php?id=108&t=3>.

customer behavior change. The key mechanism for savings is giving customers frequent feedback through an engagement platform and helping them set a budget for their electricity bill. Powerley is one such example of a company that works with utility program administrators, such as DTE Energy, to provide an energy bridge for customers that enables a platform interface based on AMI data.<sup>62</sup> The goals of a holistic home energy management tool are to first, provide data that utilities can take advantage of, and, second, give program managers a tool where they can see how the energy is used in the home. For example, Emmett Romine explained that Powerley provides a link to the smart grid that enables a rich environment for both customers and utilities, and lighting is a part of that bigger ecosystems. Data is useful for promoting energy savings only if it is provided to a consumer as an actionable message or used to trigger an automated response.

Evaluating the influence of these platforms on energy savings is a distinct challenge. For example, a utility needs to retain a customer for at least a year to more confidently prove energy data and engagement benefits. Converting behavioral changes to measurable energy savings has proven difficult; program evaluation approaches vary, whether based on energy savings over the device lifetime, billing data, customer comparisons, and more. Third-party program evaluators are value conscious and they want to understand the next iteration of customer engagement and usage platforms to better understand potential revenue streams. Regulators manage utility play in the integrated home space, so they are looking for point solutions for energy savings. If customers know the utilities are doing something on their behalf, the utilities can engage with customers and potentially gain their trust, according to Emmett Romine of Powerley.

Overall, CEE members agree that data associated with how an integrated home is operating can provide value for multiple stakeholders and intended purposes. Information that is remotely accessible by both the DSM program administrator and its customers can enhance channels of communication that facilitate actionable energy management. The CEE residential connected product specifications are beginning to include the core minimum elements necessary to support customer engagement and energy management platforms. These requirements are central to enhancing program administrators' ability to meet evaluation goals. They are also key to demonstrating value to relevant market actors such as the real estate industry, financing entities, appraisal groups, health and safety advocates, and home improvement allies.

### **What are Program Administrators Currently Doing with Connected Lighting?**

Program administrators are starting to think beyond traditional residential lighting incentives, considering new activities such as direct partnerships with the lighting industry, design competitions, absorbing lighting into a whole house program, or as an element of a consumer engagement platform. To date, these administrators have been incorporating connected lighting

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<sup>62</sup> Powerley is mentioned here as a representative example of a larger industry; others were invited but chose not to participate.

into their programs through online platforms and bundling with other offerings like smart thermostats, as well as conducting research.

Figure 20. Which of the Following Activities has Your Organization Been Pursuing for Connected Lighting?<sup>63</sup>

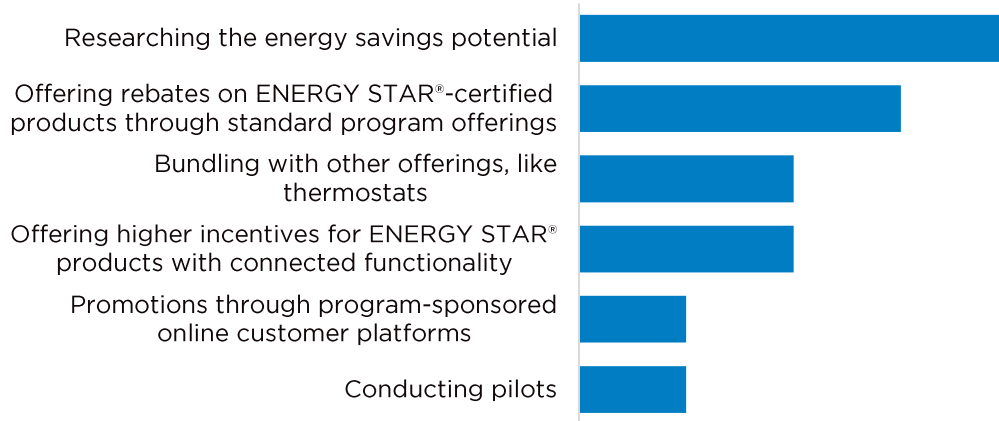


Table 4. CEE Member Connected Residential Lighting Research

2016
<a href="#">Efficiency Vermont smart light pilot</a> to map, define, and measure the interactions of home energy management system (HEMS) hubs and connected devices; plan to pursue a characterization for additional savings from smart/connected products in the future.
<a href="#">Energy Savings from Five Home Automation Technologies: A Scoping Study of Technical Potential</a> by Fraunhofer CSE.
2017
<a href="#">NYSERDA HEMS savings validation pilot</a> .
2018
<a href="#">ComEd</a> , <a href="#">Eversource</a> , <a href="#">Focus on Energy Wisconsin</a> (see <a href="#">Appendix H of their evaluation report</a> ), <a href="#">National Grid</a> , and others.
New England states lead in assessing the savings potential from connected devices, <sup>64</sup> including the above pilots from <a href="#">National Grid</a> and <a href="#">Eversource</a> as well as research from Navigant on <a href="#">connected thermostats and other technologies</a> .

### Progress Made to Address Barriers

The landscape of industry partnerships and organizations involved in the connected lighting space is constantly evolving. Positive steps have been taken to address the identified barriers through the development of industry-accepted standards and protocols.

<sup>63</sup> These results are from a survey of LFT sponsors before the 2018 workshop. Although it is a small sample that offers only rough estimates, it is indicative of general trends.

<sup>64</sup> Spencer Fields, “Utility energy storage pilot programs: what you need to know,” EnergySage, August 16, 2019, <https://news.energysage.com/utility-energy-storage-pilot-programs-what-you-need-to-know/>.

There are several organizations with residential lighting protocols, such as the Institute of Electrical and Electronics Engineers (IEEE) standards for Wi-Fi, Bluetooth, Thread, and ZigBee; the International Telecommunication Union (ITU) standard for Z-Wave; and The Connected Lighting Alliance (TCLA) recommendation for ZigBee (see Table 3 for additional examples).<sup>65</sup> The telecommunications industry has used a similar protocols process, but there are still communication and translation issues across the multiple smartphone platforms. Using railways as a historical example, consumers expect interoperability much like they expected junctions and connections on rail lines during the nineteenth and twentieth centuries. However, first, the rail industry had to standardize the railroad gauge size. While the lighting industry is on the right track with the aforementioned communication protocols as well as cybersecurity protocols from NIST, IEC, UL, ANSI, and others, there is still a need for all stakeholders to converge around and support industry standards.

## Key Barriers to Connected Lighting Adoption

- **Lighting is still not well understood, connected or not**, per Peter Romaniello of Conceptual Lighting. A lack of knowledge by the general public or continuing reports of security problems with connected products could lead to an overall negative perception of connected lighting.
- **Rapid advances in technology make it difficult to commit to a single platform or product ecosystem; some manufacturers are attempting a “platform agnostic” approach for connected products.** Product manufacturers are increasingly incorporating multiple popular platforms and adding capabilities such as Amazon Alexa and Google voice control. Many stakeholders reject the concept of picking a single platform as it is unreasonable to expect every consumer to consistently prefer only one platform provider. While voice command-based systems are currently largely plug-and-play, there may be future issues that arise from a retrofit perspective. For example, the lifetime of a product, could be only a couple years as a result of user disinterest and technological improvements, according to Jeff Patton of GE Lighting.
- **The installed connected lighting products or systems may increase home resale values, though they may also pose unique challenges for subsequent homeowners.** Although integrated homes may have an edge when it comes to resale value, according to Terry McGowan of ALA, this requires more education about the use and value of connected products and systems for both new homeowners and realtors. There have been reports of real estate agents selling ‘smart home kits’ that include thermostats, front door locks, lighting, and a couple of other items to home sellers to give the space a baseline connected profile.<sup>66</sup> Simplicity will likely be key, given that hyper-customized systems will not appeal to all buyers.

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<sup>65</sup> TCLA was not a standards development organization; it was an industry alliance founded by six companies that grew to 25 organizations and operated between 2012-2017. Once TCLA believed it had accomplished its goal of recommending the best and most usable protocol (ZigBee), its activities concluded.

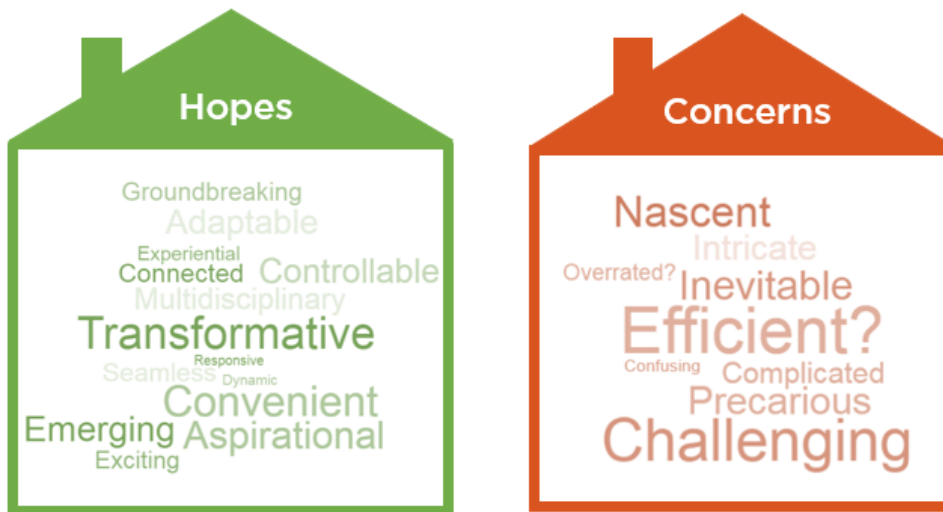
<sup>66</sup> Discussed by members of the CEE Existing Homes Working Group in June 2017.

- **It remains an open-ended question whether the connected capabilities should reside in the bulb, fixture, dimmer/switch, system, or a hub.** Fragmentation exists in the market, and there is no indication that a clear front-runner will emerge in the near term.
- **Alignment among codes and standards is critical.** The mass market is starting to adopt connected products. However, true momentum will only be achieved at the whole house level once privacy and cybersecurity are satisfied for customers, according to Ron Zimmer of CABA.
- **Interoperability remains a critical challenge.** Consumers want residential lighting to be linked or have the potential to link with other connected devices, and an increasing number of installers are requesting to be trained and educated on the products and protocols. Currently, connected lighting is part of a broader home ecosystem; hubs and gateways are becoming increasingly multilingual in an attempt to seamlessly link various products that may be using different communication protocols. If residential lighting systems become hubs in the integrated home, it will potentially redefine other home systems, such as HVAC.
- **Connected lighting and controls will likely serve different program objectives than historical light bulb replacement programs.** Beyond energy efficiency, connected lighting may play a role as part of a strategy to increase customer engagement, serve as a stepping stone to an integrated home that can deliver benefits from consumer behavior change, allow for improved measurement and verification of energy savings, or support load management objectives.
- **For some program administrators, smart meter data is a key part of understanding the benefits of an integrated home** for both programs and customers. Energy use data for devices in the home enables greater program and customer insight into individual end uses and overall performance of the home, enabling customized recommendations for pursuing additional efficiency measures or specific consumers actions.
- **Program administrators and the lighting industry may be in a prime position to drive the mass market integrated home adoption movement,** although companies outside of lighting are quickly moving down this path as well, per Chris Wolgamott of NEEA.

## Part II: Considering Future Collective Impact

Connected lighting holds much promise, but there are significant barriers to adoption that need to be addressed before the full realization of these benefits. The one-word descriptions of connected lighting provided by attendees at the very beginning of the workshop (summarized by Figure 21) effectively illustrate both the potential and challenges faced by the industry today.

Figure 21. Describing the “Integrated Home” In One Word



The workshop provided important context for identifying potential areas for future collaboration. Determining whether there could be a role for another competition relies on if it will advance collective needs. Below is a summary of key considerations regarding the current landscape that informed the group’s thinking regarding how to best pursue opportunities.

- Resilience
- Occupancy sensing
- Interoperability
- Affordability
- Reliability
- Cybersecurity
- Simplicity
- Standby energy use
- Purposeful data sharing
- Energy dashboard or display
- Interactions with HVAC or other home systems
- Enabling customer engagement
- Auto-dimming
- Optimizing light levels
- Cool, fun, or inspiring products and services
- DIFM vs. DIY
- Amassing users or units
- Lighting as a service
- Optimizing functionality via controls
- Participating in the various ecosystems in the home
- Making connected lighting a viable tool for the mass market
- Ensuring products are in-channel and stocked
- Setting standards for controls
- Ease of installation
- Location of connected controls (bulb, switch, or fixture)
- Showrooms are moving from furniture stores to electronics stores



## Identifying and Addressing the Greatest Barriers to Connected Lighting

As previously discussed, connected lighting can provide a lot of value to a variety of different players. However, for any realization of this value, the consumer must first purchase and then use their connected lighting device. Workshop participants spent time identifying the barriers that would most significantly inhibit the uptake of connected lighting and concluded that focusing on the consumer experience is the most critical to the market adoption of connected lighting.

During the workshop, participants identified and ranked the largest barriers to the adoption of connected lighting.<sup>67</sup> The top three barriers to the successful adoption of connected lighting were identified as:

1. **Interoperability** — works seamlessly with other connected devices and systems in the home. Participants suggested that interoperability becomes a concern after a consumer has three smart devices in their home. At that point, they no longer want to manage them individually, and if they provide related functionality or relevant inputs, they will want them to communicate with one another. For example, occupancy sensing capability is a key input for lighting, HVAC, and security systems, and one signal should be able to be shared with all devices.
2. **Reliability**, including “future proofing” — consistently receives a signal and responds to commands, reconnects after a power or Internet disruption, and can adapt to avoid obsolescence through mechanisms such as software updates. If devices are unreliable, the consumer experience will suffer.
3. **Complexity** — consumers understand the value proposition and experience simple installation, setup, and use. While the myriad of new features is exciting, these capabilities need to be as simple as possible to be successfully employed by consumers. In summary, if a consumer can’t seamlessly operate, rely upon, or understand how to install, set up, or interact with the connected devices in their home, they are less likely to use them, tell their friends about them, and purchase them in the future.

As the group brainstormed effective strategies to overcome these barriers, they observed that these barriers are not exclusive to lighting and are applicable to all connected devices in a home. There are many new integrated home solutions available and all require interoperability, reliability, and simplicity. When different integrated home players have a shared customer, then they have a shared interest. For example, if lighting becomes a critical part of energy management in the home and it performs poorly, it hurts the entire integrated home industry.

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<sup>67</sup> A complete list of all values and barriers identified by the group can be found in **Error! Reference source not found.**

## Opportunities for Collective Action

The group considered which of the identified barriers would benefit most from collective efforts of the residential lighting industry and program administrators, and what particular actions would be the most effective.

The group assessed that interoperability and reliability were likely best addressed through industry standards processes, which often requires collaboration between individual manufacturers, trade associations, and CEE members. In addition, program administrators could provide incentives to encourage manufacturers to develop interoperable and reliable devices and ecosystems. For example, CEE attempts to address interoperability through optional connected criteria for many residential products that require the use of open standards and multiple pathways to connect.<sup>68</sup>

With regards to complexity, there is a significant role for all market actors to educate and message on connected devices in a consistent, coordinated fashion. While consumers are likely the primary focus, if contractors and installers are not educated about a technology, they will fear it and actively avoid installing it. There is an important opportunity to be consistent with definitions as well as language on how lighting will relate to an integrated home.

The group identified certain gaps in research that could benefit all parties if explored thoughtfully. Particularly, there is an industry-wide need to quantify the actual value of connected lighting for consumers and to identify the specific interoperability and installation needs that must be addressed to enable wider consumer adoption. It is important to understand the agility of the market and gauge what is truly desired by customers. For example, there is value in separating the features consumers are willing to pay for versus those that are superfluous. This research could help in the development of consistent messaging on the value proposition of connected lighting to consumers, including both energy efficiency and NEIs.<sup>69</sup>

Workshop participants developed a list of potential ideas to pursue:

- Support connected lighting capabilities research. This could include a residential literature review similar to the PNNL [State of Commercial Lighting Project](#), as well as developing a connected product database with help from industry;
- Encourage more active program administrator participation in communication protocol work by industry;
- Build traction for criteria, labels, and marketing of HEMS;
- Document and enable coordination of program administrator pilots that include connected lighting;

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<sup>68</sup> CEE Consensus Principles for Connectivity.

<sup>69</sup> Consumer research has shown that energy efficiency is rarely the primary driver for a purchase, but it is part of an overall value proposition; consumers make an emotional decision to buy a product, and the fact that it is energy efficient can help them rationalize their purchase.

- Develop consistent messaging and educational resources for consumers, distributors, retailers, contractors, and installers;
- Create an integrated home test method; and,
- Host future connected lighting or integrated home workshops or enable continued discussions on this topic in another format.

### Program Administrator Perspective on Lighting and the Integrated Home in 2019 and Beyond

Program budgets available to research energy savings from connected lighting, continue to promote LED technology, and leverage DR potential are small. It is more likely that programs could fund work on an integrated home, which includes lighting. Given high consumer interest, low price point, mass-market appeal, and its presence throughout a home, connected lighting is an ideal candidate to support a consumer journey to a fully integrated home. An integrated home can potentially serve many organizational objectives, including DR, carbon reduction, increased program participation, and additional revenue streams.

Program administrators see value in connected lighting through energy savings, marketing, and demand savings, and have identified that the integrated home can deliver benefits from consumer behavior change, improved measurement and verification of energy savings, as well as load management. The list below includes additional program insights.

- Connectivity is a promising avenue to maximize any remaining energy savings from residential lighting, primarily through dimming, occupancy sensing, remote access, and scheduling. More research is needed to prove out any such savings.
- While the market is moving well on its own, programs can leverage connectivity as an added selling point or “cool factor” to support the adoption of LEDs.
- Although lighting is not a large load when looking across an entire home’s energy-consuming devices, lighting could be a promising candidate to deliver demand savings scaled across many homes and aggregated. A small reduction in general light levels (not task lighting) is often not perceived by consumers.
- Identifying and supporting the key elements of successful connected lighting has implications for the larger integrated home industry. A consumer’s experience and success managing their connected lighting will be an important factor in their willingness to adopt other connected devices and move to an integrated home. Progress towards interoperability will have a positive market impact.

### Mapping a future Role for *Lighting for Tomorrow*

Workshop participants were asked to consider the potential of a competition for lighting systems that integrate with HVAC systems or other aspects of the integrated home to achieve new energy savings. The premise is that the interaction of connected residential lighting and other systems in the home will lead to energy savings, peak demand reduction, and increased customer realization of benefits.

Workshop participants contemplated how they might be able to leverage the existing LFT platform to define interoperability consistently across the industry, build in interoperability and reliability into future products, and understand how to best message the value proposition of connected devices. PNNL shared details regarding recent evolution of the Next Generation Luminaire (NGL) competition, newly christened the [Next Generation Lighting Systems](#) (NGLS) competition, to inform the group's thinking.

### Lessons Learned from Commercial Applications: Next Generation Lighting Systems

Historically, the PNNL competition followed an identical model as LFT and is often referred to as its sister competition on the commercial side. NGL was challenged by evaluating the controls and systems as they had previously done with luminaires. With a focus on controllability, serviceability, and connected systems, in 2016 the competition transitioned from NGL to NGLS. That year they had four major connected systems and evaluated each system in the same room. After 2016, NGLS moved to evaluate connected lighting systems exclusively. As of 2018, they now have 12 lighting systems installed for evaluations. NGLS is set up to address the installation barriers and configuration complexity. If the installers cannot install and set up the system properly, then the system will not work for mass-market lighting.

PNNL provided some recommendations if LFT decided to pursue a similar pathway.

- Expand the group of people involved in the conversations to include those conducting connected lighting pilots.
- Work more closely with manufacturers. NGLS employed an iterative process where manufacturers were highly involved and were able to observe and learn.
- Narrow the scope and focus on what the competition does best. NGLS did not focus on interoperability specifically, but rather on lighting system program threats. They defined the submission categories narrowly to initially focus on products marketed as easy to install, which allowed them to define a worst-case scenario for enabling for mass market adoption and scalability. They also held different judging events to enable separate evaluations of installation, performance, and user acceptance.
- Be consistent. The judging needs to be consistent in terms of spaces, evaluation teams, and protocols to make a comparison.
- Set realistic and impactful goals. Since NGLS is trying to solve installation and configuration challenges, the judges watched the installation process to evaluate the systems. There is a real value add to the market by being able to provide installation insights.

## Recommendations

### Leverage the Strengths of the *Lighting for Tomorrow* Competition Model

Workshop attendees agreed that LFT presents a unique market intervention strategy to increase the adoption of residential connected lighting products in the U.S. and Canada. It offers the

opportunity to build upon the existing relationships between program administrators, lighting manufacturers, and showrooms to enact market change. A design competition supports the market introduction of connected devices in the home that not only deliver energy and demand savings, but also meet the consumers' expectations in terms of interoperability, reliability, and simplicity while continuing to satisfy the traditional demand for functionality and appearance. Through supporting a positive consumer experience, LFT can cultivate positive associations with connected devices and increase market demand.

LFT also presents program administrators with the unique opportunity to encourage advancements in the connected devices that manufacturers bring to market and provide a boost for products with the performance attributes programs wish to promote through the selection of the competition categories and evaluation criteria.

The respective roles of key actors in bringing a competition to fruition vary by their strengths and expertise.

**Program administrators** are directly involved in developing the competition categories and evaluation performance criteria. In particular, sponsors of the competition can focus manufacturers on the connected product types and features they would like to see entering the market. Sponsors can also encourage manufacturer product development efforts through evaluation criteria that support efficiency, interoperability, reliability, and simplicity.

Historically, project sponsors are involved in the judging process; to judge entries, a contingent of sponsors along with a broader group of industry experts meet to evaluate entries in person and handpick connected products that offer innovative features and use cases that can be easily accessed by the consumer. Lastly, programs promote these winning products directly to consumers.

**Manufacturers** participate by developing, entering, and bringing to market high quality, well designed, and innovative products. They pay attention to the product categories offered by LFT as well as products promoted by efficiency programs. Many choose to make product enhancements based on feedback from the judging panel and consider the features of winning products in future design iterations or new product development. Finalists will achieve ENERGY STAR certification when applicable and promote their LFT award within their industry and to consumers.

**Retailers**, such as select ALA lighting showrooms, are invited to participate on the judging panel to ensure that the innovative products entering the market are saleable. After the winners are selected, ALA lighting showrooms receive copies of the LFT award brochure and many look to sell and feature these award-winning products.

LFT continues to build on the momentum from previous competitions and remains a sought-after accolade in the lighting world. By promoting winning products through lighting programs,

showrooms, and other channels, the competition signals to industry the desirable traits and functionalities needed not only for program endorsement, but also for widespread adoption.

## Transitioning to a Connected Lighting and Homes Competition

Based on the suggestions received from the workshop, sponsors support leveraging the LFT platform and employ a competition model with an expanded scope in 2019. They envision a rebranding to “Lighting and Homes for Tomorrow,” which would evolve and add competition categories over time. In 2019, the competition would have two categories: 1) connected lighting devices and 2) non-lighting connected devices that integrate with lighting systems. The first category could include any connected lighting devices, such as luminaires, lamps, lighting controls, and switches. The second category would be open to any devices that somehow interact with lighting. Some likely candidates include thermostats, smart plugs, voice assistants, home theaters, and security systems.

Sponsors believe a competition model will provide insight into the products and capabilities currently available in the market and identify truly innovative features and use cases that will be compelling for program administrators and consumers. This model rewards leadership in open standards, interoperability, and data sharing.

The judging criteria for such a competition are envisioned as focusing on the following aspects:

- **Energy Savings** – All products are expected to have the capability to report energy consumption; this feature will be verified and the energy use documented. Manufacturers will also be asked to provide energy use data and a range of potential energy savings based on specific use scenarios. Standby power will be considered, as well as energy consumption of any associated bridges or hubs.
- **Functionality** – As part of the submission process, all connected product capabilities would be identified and documented by the manufacturer. Certain functionalities would be expected, such as energy consumption reporting, operational status reporting, and remote management. The competition would seek to identify and reward innovative functionalities. Manufacturers will be required to provide all the potential use cases for a device or system in order to demonstrate added value for either consumers or program administrators.
- **Interoperability** – Manufacturers will share how their product interacts with other connected devices in a home. They would document which communication protocols are used, what partnerships are formed, and what other devices their product is intended to interact with (see Table 3 for protocols used and page 9 for a list of common platforms).
- **Reliability** – Manufacturers must explain if and how a product reconnects to the connected ecosystem following a power or internet disruption. Judges will also consider whether the product offers more than one pathway for the consumer to connect. For example, devices relying solely on a Wi-Fi would likely be awarded fewer points, as they present a risk for consumers without a reliable connection. Lastly, manufacturers will indicate whether the product or system is “future-proof” and has some capability of being updated over time.

- **Aesthetics and Innovation in Design** – Judges will consider the unique or innovative elements of the entry’s design.
- **Data Sharing** – Manufacturers must indicate what data the product can generate, what data is shared with the consumer and how it is communicated, as well as whether there is an opportunity to share information with authorized third parties.
- **Simplicity** – A manufacturer must demonstrate that their product is simple for a consumer to use.
  - **Ease of installation** – based on the clarity of installation instructions, simplicity of the tools required, and actual installation experience by UL staff.
  - **Ease of set-up** – based on the clarity of set up instructions, number of steps required, and having to establish a new account and password.
  - **Ease of use** – based on the simplicity of user interfaces, including apps (may include app ratings).
- **Replaceability and Field Serviceability** – Manufacturers will indicate whether the entry is capable of being updated over time and explain how, including software updates and hardware repair.
- **Security** – manufacturers would indicate what cybersecurity measures are in place and whether the product is UL 2900 compliant.
- **Consumer Education and Messaging** – Manufacturers will be required to provide all marketing materials and highlight product value propositions, including videos. Judges will assess how well the product meets these claims as well as identify messaging trends across entries, which can be used to support efforts to improve the consistency of messaging for connected products.
- **Value / Mass Market Appeal** – The judges will consider the design, form factor, and price point of entries based on the amenity provided to consumers, assess whether the device is scalable for residential applications, and determine its overall value proposition.
- **Light Quality** – For lighting entries, manufacturers will provide lighting performance information, which the judges will use as a reference point when evaluating the in-person appearance of lighting quality with respect to its intended application. Uniformity of light, lumen output, diffusion, color temperature, flicker, and other attributes of lighting quality are still important factors for supporting customer adoption and satisfaction.
- **Innovation in Engineering** – Judges will consider the unique or innovative elements of the entry’s engineering. The competition is seeking ideas that go outside the box or experiment with new ways to build products.

## Closing Remarks

Many market barriers remain to be addressed in order to realize the benefits of connected lighting and integrated homes, and the LFT competition is well positioned to address the barriers identified by workshop participants. Expanding the LFT competition is a promising pathway; additional industry collaboration is also necessary. CEE looks forward to pursuing a *Lighting and Homes for Tomorrow* competition with partners ALA and UL, as well as potential new partners. CEE intends to continue a dialogue with stakeholders on the topics captured in this whitepaper.

## Appendix A Abbreviations

AHRI	Air-Conditioning, Heating, and Refrigeration Institute
ALA	American Lighting Association
ANSI	American National Standards Institute
API	Application Programming Interface
CAP	Cybersecurity Assurance Program
CEC	California Energy Commission
CEE	Consortium for Energy Efficiency
CPUC	California Public Utilities Commission
CRI	Color Rendering Index
DIFM	Do it for me
DIY	Do it yourself
DOE	U.S. Department of Energy
DR	Demand response
DSM	Demand-Side Management
EIA	U.S. Energy Information Administration
EISA	Energy Independence and Security Act
EPA	U.S. Environmental Protection Agency
EPRI	Electrical Power Research Institute
HEMS	Home Energy Management System
IALD	International Association of Lighting Designers
IDSM	Integrated Demand-Side Management
IoT	Internet of Things
kW	Kilowatt
kWh	Kilowatt hour
LaaS	Lighting as a Service
LFT	<i>Lighting for Tomorrow</i>
NEIs	Non-energy impacts
NEMA	National Electrical Manufacturers Association
NGL	Next Generation Luminaire
NGLS	Next Generation Lighting System
PNNL	Pacific Northwest National Laboratory
ROI	Return on Investment
SaaS	Software as a Service
TOU	Time-of-Use
UL	Underwriters Laboratories