Lighting Isn't Finished: Pivoting beyond the LED Bulb

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ABSTRACT

LED technology is transforming the lighting industry and utility energy efficiency programs, supplanting CFL as a primary contributor to efficiency program savings. Since the beginning of the LED bulb era, residential programs have represented over 80% of total lighting incentive spending. However, the 2020 general service lighting standard within the Energy Independence and Security Act of 2007 (EISA 2007), along with high rates of free ridership, are pushing residential LED programs into their final act. While residential potential fades, the story is just beginning for commercial and industrial. Linear fluorescent technology accounts for 78% of lamps in commercial and industrial buildings, with approximately 1.1 billion linear fixtures representing over one-third of all lighting energy consumption across all U.S. sectors. Efficiency programs have promoted high efficiency T8 solutions for over a decade, yet significant potential remains to upgrade. In addition, as of 2015, only 18% of all commercial lamps are operated with lighting controls. In particular, the U.S. Department of Energy has identified linear LED products with connected controls as the lighting measure with the largest remaining energy savings potential. With low installed penetration rates, falling costs, and high net-to-gross ratios, the measure should be an attractive one. However, the challenge is to upgrade lighting with controls to maximize both energy savings and user satisfaction. The least expensive and simplest LED options often fall short of the full energy savings potential, and are difficult to integrate with controls retroactively both from a technical and economic prospective.

Introduction

Light-emitting diode (LED) technology has disrupted the lighting industry and is rapidly transforming utility energy efficiency programs. Approximately two decades ago, the lighting market began to shift from incandescent bulbs to efficient compact fluorescent lamps (CFLs) (U.S. DOE 2010). In late 2009, a second transition began from incandescent and CFLs to LED lamps. Utility energy efficiency programs have been instrumental in the adoption of these new lighting technologies through incentives and outreach, and their customers have reaped the savings and associated benefits.

Residential lighting represents a substantial share of the annual savings claimed across utility energy efficiency program portfolios. Based on analysis of data reported by ENERGY STAR®, lighting program budgets and the total number of lighting incentive offerings trended upward between 2010 and 2015 – much of which is attributed to LEDs. During this timeframe, lighting program budgets increased by over 67% to $535 million and total lighting incentive offerings nearly tripled.

However, as shown in Figure 1, the latest reporting for 2016 and 2017 suggests that lighting program budgets may have peaked in 2015, coinciding with a timeframe of widespread adoption of LED A-lamps when these products reached the substantial price milestone of $5 per bulb pre-rebate.

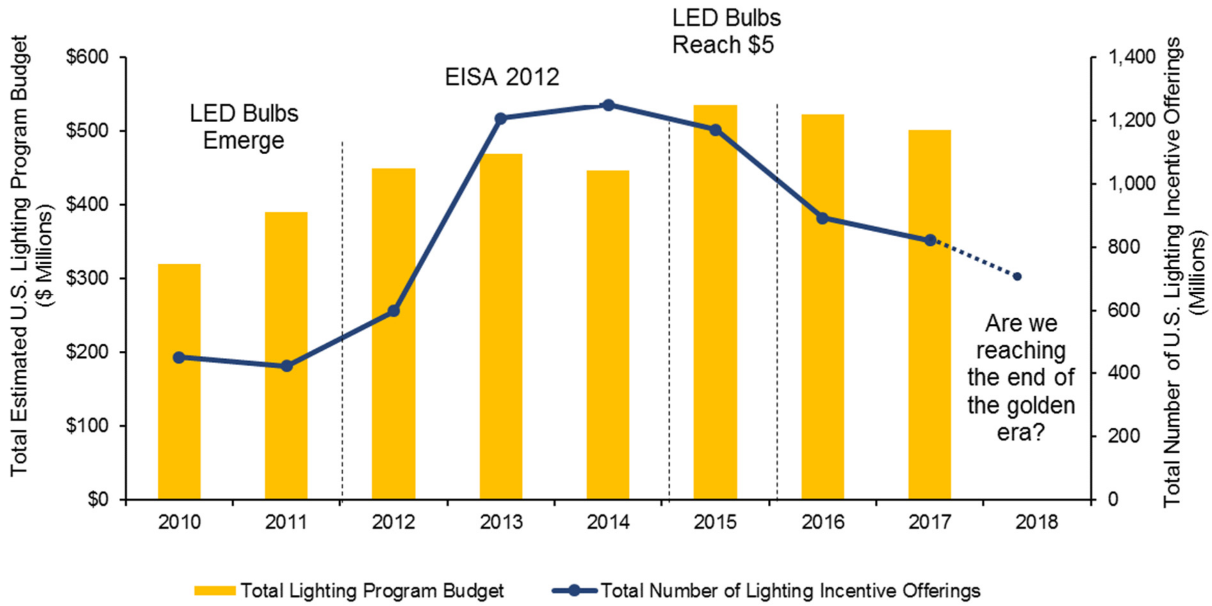

Figure 1. Total Estimated U.S. Lighting Program Budget vs. Total EE Program Budget

Internal Navigant analysis assessing U.S. utility energy efficiency budgets allocated to lighting initiatives between 2010 and 2017. Sources include (ENERGY STAR 2010-2016) and (ENERGY STAR 2017).

Since the beginning of the LED bulb golden-era, residential programs have represented over 80% of total lighting incentive spending (CEE 2013-2016). However, the pending 2020 general service lamps standard within the Energy Independence and Security Act of 2007 (EISA 2007)[1], along with high rates of free ridership, are pushing residential LED programs into their final act. Despite the decline of residential LED lamp potential, this is not the end for utility lighting programs. In fact, utilities are faced with a pivotal moment and opportunity, because as residential potential fades, the story is just beginning for commercial and industrial (C&I).

A typical lamp installed in a commercial building has five times the energy footprint of one installed in our homes (U.S. DOE 2017a). This fact is largely attributable to the longer operating hours needed to illuminate commercial spaces. In particular, linear fluorescent technology is a substantial energy culprit, and accounts for 78% of lamps in C&I buildings, with approximately 1.1 billion linear fixtures representing over one-third of all lighting energy consumption across all U.S. sectors. Efficiency programs have promoted high efficiency T8 solutions for over a decade, yet significant upgrade potential remains. Existing linear fluorescent lighting can be upgraded to LED with substantial energy savings, and most lighting within commercial spaces lack controls. The U.S. Department of Energy (DOE) has identified LED linear fixtures with connected lighting systems as the lighting measure with the largest remaining energy savings potential. With low installed penetration rates, falling costs, high net-to-gross ratios, and numerous non-energy benefits, these measures should be attractive to utility lighting programs.

Focusing on the impacts of indoor C&I lighting, in this paper, we will address the following questions:

[1] Per the Energy Independence and Security Act, general service lighting lamps sold as of January 1, 2020 must have an efficacy of at least 45 lumens per watt. If effective, the result would likely prove to be a technical limitation for incandescent and halogen lighting products and eliminate them from the lighting market.

1. What is the U.S. installed saturation of controls, LED lighting and connected lighting systems, and how significant is the remaining energy savings potential?
2. How much of the U.S. energy savings potential is available for C&I utility lighting programs?
3. How are utilities currently adapting and what strategies are being employed to transition to LED systems for linear fixture applications and connected control technologies?
4. What are the remaining barriers to the adoption of connected control technologies and how can utilities structure their programs to reap the benefits?

National Adoption of LED Lighting and Controls

Between 2001 and 2015, the national trend in lighting has been an increase in lighting inventory and efficacies, while wattages have decreased, for both the residential and commercial building sectors. As indicated in Figure 2, there is a steep decline of incandescent lighting and a pronounced shift to more efficient sources. This transition is likely due to the impacts of the 2012 to 2014 lighting efficiency standards established by EISA 2007, as well as the work of utility lighting programs across the country. In addition, installations of LED products have increased in all sectors, growing from a negligible percentage in 2001 to over 701 million units in 2015, increasing LED penetration to 8.0% of all lighting.

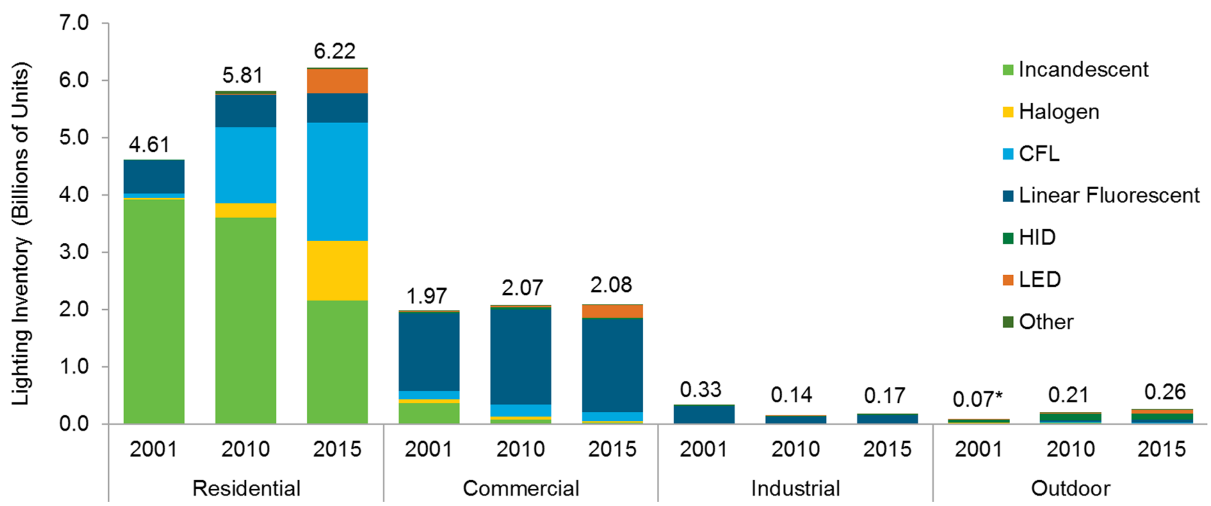

Figure 2. Comparison of Lighting Inventories by Sector and Technology Type in 2001, 2010, and 2015

Source: (U.S. DOE 2017a)

While the indoor C&I sectors combined only represents 26% of lighting installations, they represent 44% of lighting energy use.[2] The installed inventory of C&I lighting equipment is composed primarily of four technologies: linear fluorescent, compact fluorescent, high intensity discharge (HID), and LED. In particular, Table 1 highlights the importance of linear fluorescent

[2] Outdoor commercial and industrial applications also represent a significant opportunity for energy savings, however, this study focuses on the impacts of indoor LED and control installations.

lighting in the commercial sector. In 2015, linear fluorescent lamps consumed the most energy, accounting for 68% of the sector's lighting electricity consumption. HID lamps were the second largest electricity consumer – approximately 13% of the commercial sector total – followed by LED and incandescent technologies at 6% and 3%, respectively.

While many products for controlling light have been commercially available for decades, their deployment and resulting energy savings have been limited due to their complex configuration, high cost, poor interoperability, and a lack of expertise in how to effectively design, install, commission, and operate them. Lighting controls – which include various dimming and sensor technologies used separately or in conjunction with other systems, such as timers and daylighting – can yield significant energy savings because they use feedback from the lit environment to provide adequate lighting only when needed. Table 1 also shows that only 18% of total commercial lamps, are connected to controls.

Table 1. 2015 Distribution of Installed Commercial Lighting Inventory by Technology

Source: (U.S. DOE 2017a)

Technology	**% of Installations**	**Average Lamp Watts**	**Average Daily Op Hours**	**% with Controls**[3]	**% of Com Lighting Energy Use**
Incandescent	1%	67	10.6	13%	3%
Halogen	1%	60	10.9	10%	1%
Compact Fluorescent	8%	24	12.3	14%	11%
Linear Fluorescent	**78%**	**34**	**8.1**	**17%**	**68%**
High Intensity Discharge	1%	361	10.3	18%	13%
LED	11%	19	11.1	31%	6%
Other	0%	17	16.2	4%	0%
Average	**--**	**36**	**8.9**	**18%**	**--**

Connected Lighting Systems

A connected lighting system[4] is comprised of *devices*, including LED lamps and/or luminaires, as well as sensors and controllers. The sensors and controllers can either be integrated within the LED product or can be standalone systems that interact with groups of LED products. Connected lighting systems are then defined as LED lamps and/or luminaires, sensors and controllers that can exchange digital data (either wired or wireless), enabling devices within the system to communicate.

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[3] Includes the control strategies – dimming, daylighting, occupancy sensing, timers, multi-strategy systems (any combination of two, three, or four of the above-mentioned control strategies, and energy management systems.

[4] Within the lighting industry various terms are used to describe lighting systems that offer control savings through sensor-enabled intelligence. The DesignLights Consortium® (DLC) uses the term "networked lighting controls (NLCs)", while the U.S. DOE uses "connected lighting systems." In addition, there are several terms such as advanced lighting controls, luminaire-level lighting controls (LLLCs), integrated lighting controls, external systems integration, and energy monitoring which describe the features and capabilities of these lighting systems.
In this paper, the terms "networked" and "connected" are deemed synonymous, consistent with how these terms are typically treated within the lighting industry. For ease, this paper refers to these products collectively as connected lighting systems.

While still in its infancy, LED connected lighting systems deliver improved lighting quality and energy performance since they leverage multiple sensing strategies such as occupancy sensing, daylight harvesting, high-output trim, scheduling and personal area controls. The combination of these approaches has been shown to provide substantial additional energy savings beyond a static LED lighting system, increasing savings anywhere between 20% to 80%, depending on the application and use-case (DLC 2017). Connected lighting systems can also improve the energy performance and management of other building systems such as HVAC equipment, track assets such as wheelchairs in a hospital, enhance space utilization, and can potentially improve occupant health and productivity. Additionally, outdoor connected lighting systems have the potential to contribute significantly to smart city infrastructure. These functions include improved public safety and security, traffic and asset management, and broadband wireless communication networks. The U.S. DOE reports that it is likely that these additional capabilities will offer benefits that match or exceed the value of the energy savings they deliver (U.S. DOE 2017b).

Even though connected lighting systems currently comprise less than 0.1% of all luminaires in the U.S., this technology is pivotal to maximizing future potential energy savings. As shown in Figure 3 below, the U.S. DOE estimates that it represents up to 45% of total lighting energy savings potential.

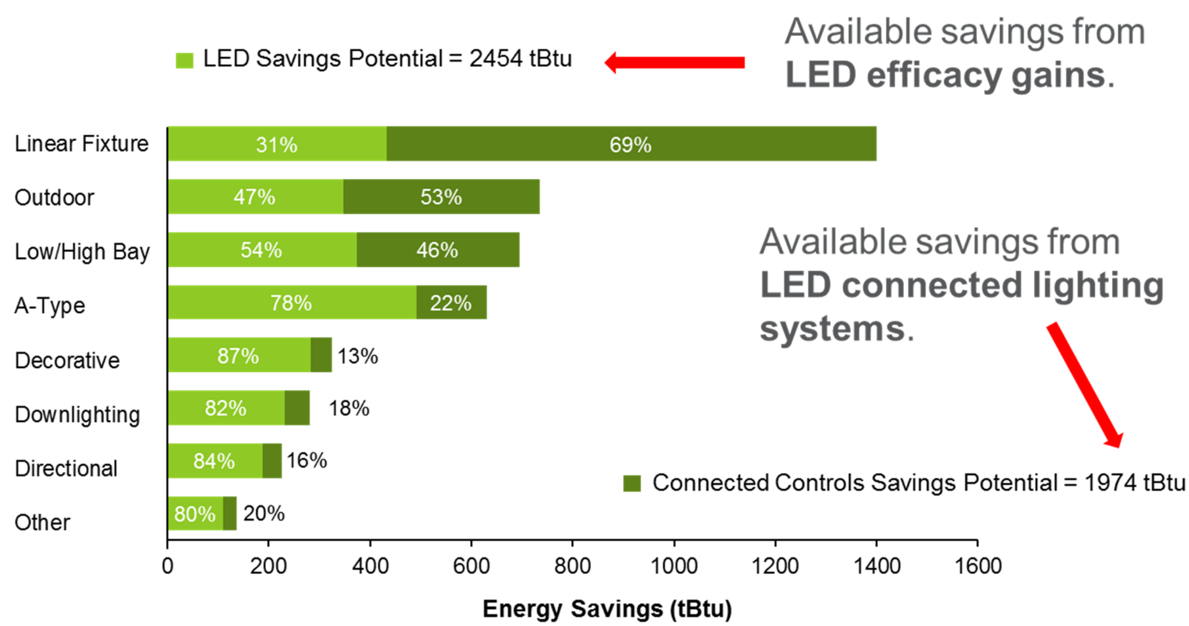

Figure 3. U.S. Energy Savings Potential of LED and Connected Lighting Systems by Application

Source: (U.S. DOE 2017c)

Potential savings for connected lighting systems (shown in dark green) represent savings beyond those that could be achieved through LED lighting efficacy improvement alone (shown in light green) (U.S. DOE 2017c). Connected lighting systems will have especially strong impacts on the savings achieved by C&I LED applications, such as linear fixture and low/high bay.

C&I Lighting Savings Potential for Utilities

With residential LED energy saving opportunities waning, it is a common misconception that all lighting measures will soon disappear from utility portfolios. On the contrary, lighting savings within the C&I sector have yet to reach their maximum potential and will be a reservoir of savings for many years to come. None of the major product categories within C&I lighting have exceeded 50% market penetration, and the single largest category (linear lighting) has only achieved an estimated 6.5% LED market penetration as of 2017. Adoption is accelerating across the board as prices continue to fall and product performance steadily improves.

Using data from the U.S. DOE on installed inventory, adoption forecasts, and efficacy improvements, the DLC estimates that C&I lighting annual energy savings will reach a peak of 19 terrawatt-hours (TWh) in 2021 as shown in Figure 4. This scenario assumes continuation of current investment levels in C&I LED product adoption by industry stakeholders, including utilities. Exterior LED products (shaded in orange) have already achieved moderate levels of market penetration, and as a result the annual savings potential from new installations will gradually decline starting as early as 2019. Meanwhile, the annual new savings from interior product categories (shaded in blue) are growing rapidly and will not reach their highpoint until the mid-2020's. The DLC analysis suggests that C&I LED savings can be acquired at or above 2017 levels for the next seven years through 2025.

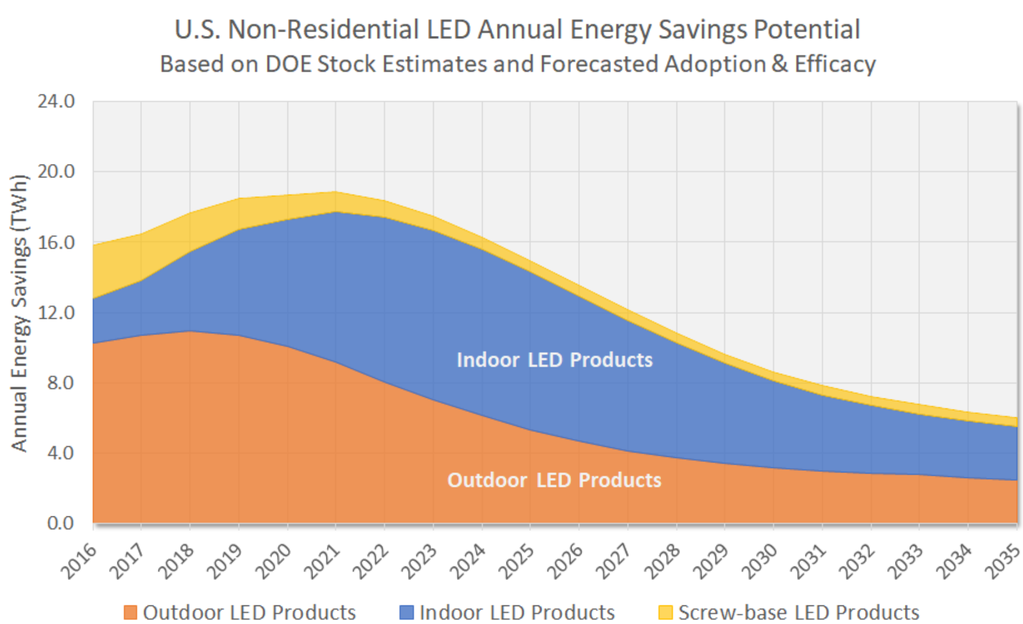

Figure 4. U.S. C&I LED Annual Energy Savings Potential

Source: (DLC 2018)

Importantly, the scenario shown in Figure 4 models only savings from LED fixtures and lamps, excluding any controls. Connected lighting controls offer added savings potential but have remained an expensive and complicated proposition for many customers, and as a result adoption has been lackluster. Making matters worse, utility promotion has been limited by high product costs and the lack of a standardized methodology for calculating savings. This path presents a risk in that utilities may never capture the savings potential offered by connected lighting controls. If C&I LED products continue to be installed without connected lighting controls, their opportunity may become stranded for 15 or more years. The ability to retrofit connected lighting control systems to already installed LED products is both expensive and challenging. Consequently, utility promotion of connected lighting controls is critical. These systems must be promoted now, during the period of rapid LED product adoption, to ensure that utilities and customers realize the full energy savings potential.

When considering a scenario of high utility support for connected lighting controls, the future of C&I lighting energy savings potential looks very strong and sustainable, as shown in Figure 5. This DLC model assumes that utilities can accelerate the adoption of connected lighting systems, pulling in the adoption curve by as much as 5 years. In doing so, significantly more systems are coupled with LED products at the time of installation, ensuring the capture of full savings potential. Due to the additional control savings, C&I lighting savings can be maintained at or above 2017 levels through the year 2030 – nearly twice as long when compared to LED fixtures and lamps alone.

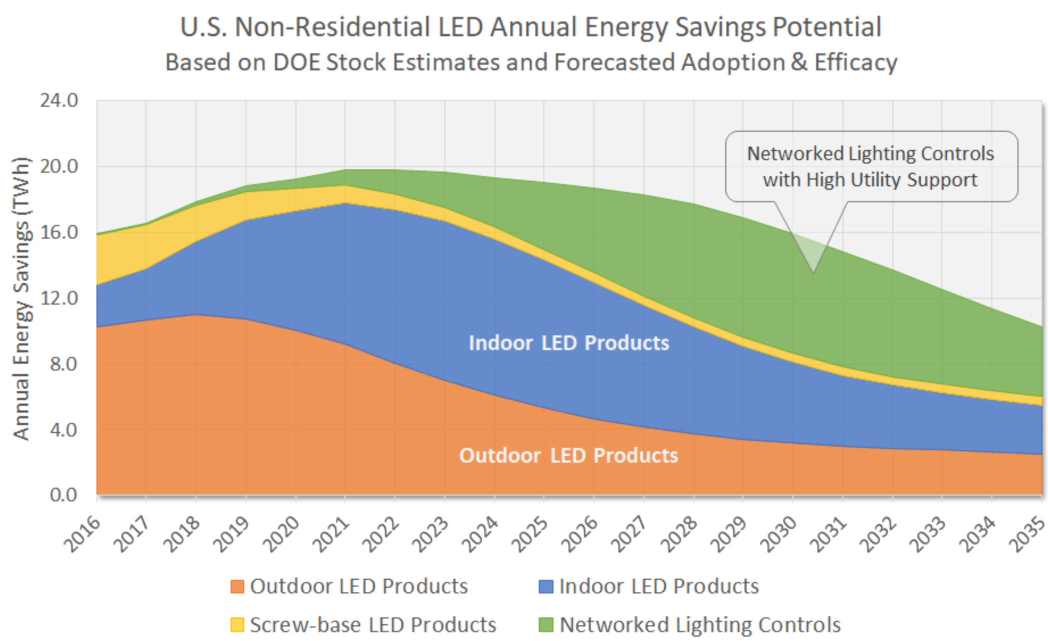

Figure 5. U.S. C&I LED Annual Energy Savings Potential with High Utility Support for Connected Lighting Controls

Source: (DLC 2018)

Looking at the cumulative annual savings potential between 2018 and 2035 by product category, it becomes clear that the largest opportunity is the linear LED category with connected controls, as shown in Figure 6. Meanwhile screw-base LED products, which have been a major source of utility savings for both residential and C&I portfolios, represent a much smaller portion of the remaining savings potential.

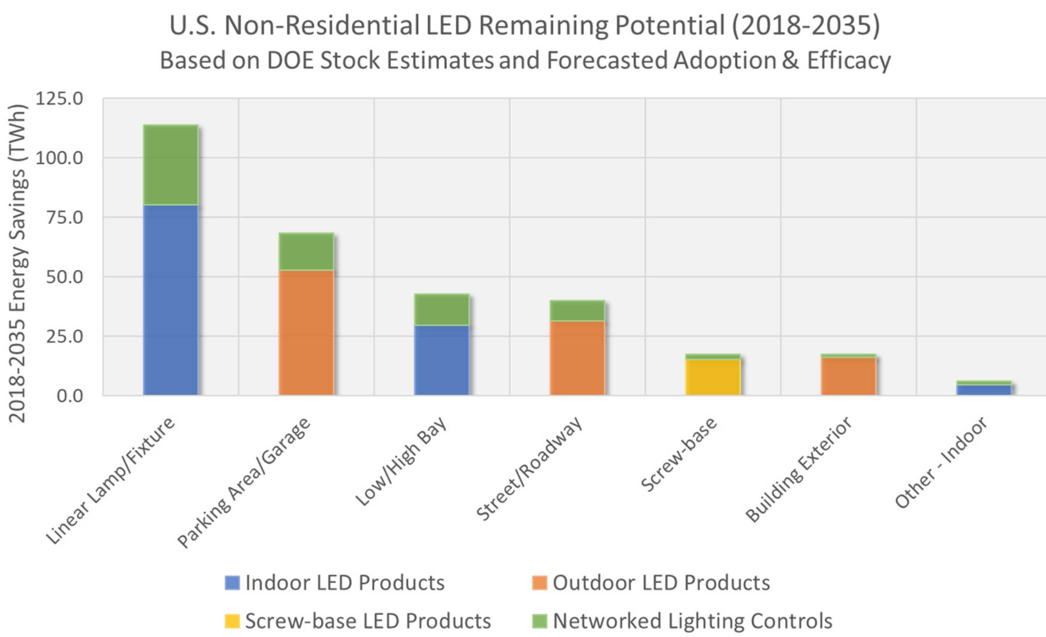

Figure 6. U.S. C&I LED Cumulative Annual Energy Savings Potential

Source: (DLC 2018)

Utility Program Strategies and Roadmaps

As discussed in the previous sections, the savings that utilities can claim from traditional lighting measures are rapidly diminishing as residential LED lighting becomes ubiquitous, and codes and standards adjust accordingly. As such, utilities are beginning to take notice of the importance of C&I LED products that offer connected lighting system capabilities. In particular, utility programs in the northeastern U.S. and the State of California – both pioneers in the energy efficiency community – have begun to modify and adapt their incentive programs to the new lighting landscape. While this section focuses on efforts by the northeastern U.S. and the State of California, other regions have incorporated, and are working to incorporate, these products and systems into their incentive offerings.

Northeast. Massachusetts, Rhode Island, Vermont, and Connecticut have robust energy efficiency programs that have kept them in the top ten of the American Council for an Energy Efficient Economy (ACEEE) State Scorecard rankings every year since 2009. In part because program administrators operate across multiple states, and in part because best practices are shared across state lines, the lighting programs for these top states are similar. In addition, these states plan and set goals on three-year cycles, making it imperative to anticipate market, technology, code, and regulatory changes. Many of the current and anticipated programmatic changes are in response to screw-in LED lamp opportunities, which have been a major source of savings, either reaching saturation[5] or becoming baseline when the EISA 2020 rulemaking becomes effective.[1] To anticipate this shift, states in the northeast have been planning to move away from screw-in LED residential and C&I products and are placing greater emphasis on

[5] In Vermont, more than 70% of screw-base sockets in businesses have been converted to CFL or LED as of 2016, according to the 2016 Vermont Business Sector Market Characterization and Assessment Study published by Cadmus.

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linear, low and high bay, and exterior lighting (such as, streetlights, canopy, and parking garage lighting). To provide multiple avenues for program participation, each state offers the following C&I service delivery paths shown in Table 2.

Table 2: C&I Service Delivery Paths used in the Northeast

Traditional Program Offerings	Program Offerings that Increase Participation	Program Offerings that Increase Depth of Savings
Custom retrofit programs	Point-of-sale midstream or upstream programs	Municipal street lighting retrofit programs
Prescriptive rebate programs	Small business programs (excluding Vermont)	Connected lighting system support and promotion
New construction programs		Lighting design assistance (Massachusetts, Vermont)

Despite having long-established programs, there remains significant energy savings potential within C&I lighting, especially for linear products. A 2016 study found that 74% of C&I lamps in Massachusetts are linear lighting applications (MA PAs and EEAC 2016), and as seen in Figure 7 below, of these linear lamp products, 68% are older 700 and 800 series T8 or even T12 (MA-EEAC 2017). In Massachusetts, most of the older linear fluorescent lamp types were found with customers who use less than 500 MWh annually (MA PAs and EEAC 2016), who are effectively served by the Small Business program. The business types found to have the least efficient linear lighting included food service and food sales, healthcare, office, public assembly and retail (MA PAs and EEAC 2016). While small business programs tend to be more expensive than other programs, they do allow for a lot of control over what is specified and installed and are still cost effective. Therefore, ensuring that small business program contractors are installing fixtures with controls whenever possible, as opposed to T8 replacement LED products (TLEDs), will maximize savings.

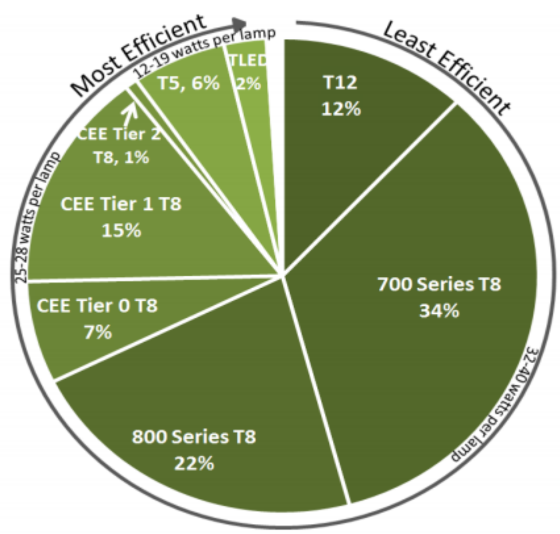

Figure 7. Northeast Linear Lamp Efficiency Distribution

Source: (MA PAs and EEAC 2016)

California. Similar to the Northeast, California has been a longstanding champion for energy efficiency which has placed the state among the top five on the ACEEE State Scorecard going back to 2006. Unique to California is their status as the first state in the country to adopt appliance and equipment efficiency standards. The authority to adopt appliance and equipment efficiency standards was bestowed upon the California Energy Commission (CEC) as stipulated under the Warren-Alquist Act, which was enacted in 1974. Over the years, California has adopted standards on more than 50 products, including LEDs (ACEEE 2017).

In particular, three new California Appliance Efficiency Regulations related to lighting became effective for lamps manufactured on or after January 1, 2018 (CEC 2017). Combined, these regulations set minimum performance and efficacy requirements not only for LED lamps, but also for incandescent, halogen and CFLs, effectively forcing the residential baseline to LED for most product categories. Due to these newly effective regulations, the California investor-owned utilities (CA IOUs) – comprised of Pacific Gas and Electric Company (PG&E), San Diego Gas and Electric (SDG&E), and Southern California Edison (SCE) – face new pressures for residential lighting savings. In addition, it is estimated that lighting electricity use in California has declined by 33% from 2007 to 2016, and in 2016 LEDs comprised 33% of residential lamp sales. With the goal of reducing residential lighting electricity use by 50% by 2018 (PG&E 2017), the CA IOUs are turning to C&I program initiatives with a new-found urgency.

Similar to the northeast, the CA IOUs offer multiple avenues for C&I building participation, including traditional deemed incentives (prescriptive), calculated incentives (custom), direct install, and primary lighting (upstream) programs for LED products as well as controls, linear fluorescent and CFLs. The CA IOUs also offer the opportunity for lighting upgrades through their Savings by Design program, which provides incentives for new construction that use integrated design analysis to optimize the interactive efficiency effects within the building.[6] In addition, the CA IOUs have a Lighting Innovation Program which evaluates advanced lighting products or program approaches that are new to the market. In 2016, such programs within the Lighting Innovations program have included, the Lighting Designer Assistance (LDA) Trial and an Advanced Lighting Control System Calculator Trial (PG&E 2017).

The CA IOU program strategy has enabled them to innovate and drive adoption of LED products in California, and particularly those going into linear applications. As seen in Table 3, of the C&I measures, LED fixtures account for the greatest portion of savings (49.2%), with over two-third coming from the deemed incentives program. While the CA IOUs have made great strides toward providing opportunities for controls and connected lighting systems, these products still represent a small percentage of gross lifetime savings.[7] However, it is worth noting that the figures below in Table 3 do not account for PG&E's LED Accelerator Program (LEDA) (operated through the third-party company Energy Solutions), which is now focused on incentivizing retrofit and new construction projects for DLC Premium LEDs in conjunction with DLC NLCs (PG&E 2018).

[6] See the Savings by Design webpage for more information: http://www.savingsbydesign.com/

[7] Depending on the building type, size, and space type, California Title 24 Building Energy Efficiency Standards can require a significant amount of lighting control deployment including occupancy/vacancy sensors, dimming, demand response, daylighting and timers. These requirements limit the opportunities for the CA IOUs to claim energy savings for lighting and control measures within California.

Table 3. 2016 Q4 to 2017 Q3 CA IOUs Gross Lifetime Savings by C&I Lighting Measure

Source: Navigant Calculations from (CPUC 2017)

Lighting Measures	Deemed Incentives	Calculated Incentives	Direct Install	Primary Lighting	Lighting Innovation	Savings by Design	Total
Total (GWh)	870	340	320	30	400	160	2,120
CFL	-	<1%	<1%	-	42%	1%	8%
Linear Fluorescent	1%	3%	73%	2%	-	<1%	12%
Other[1]	<1%	<1%	4%	-	-	67%	6%
LED Fixtures	83%	82%	6%	57%	2%	17%	51%
LED Lamps	15%	<1%	17%	41%	56%	2%	20%
LED Other	1%	14%	<1%	-	-	13%	4%

1. Includes savings from HID, induction and delamping initiatives.

Remaining Barriers and Challenges

While connected lighting systems offer the potential for significant energy and non-energy benefits, there are still remaining barriers and challenges that utility programs face to capitalize on this opportunity. These barriers and challenges can be grouped into the following categories: first cost, complexity, and education.

First Cost. One of the primary barriers to adoption for any LED product, and particularly connecting lighting systems, has been high upfront cost. While prices have dropped rapidly over the past few years, analysis of LED pricing in recent studies conducted by the CA IOUs and National Grid show on a first cost basis, connected lighting system products are typically priced 40% to 90% higher than non-controllable LED products. Figure 8 below compares the price findings of the National Grid potential study (National Grid 2018) to that of the price results for the California LED Pricing Study (CA IOUs 2018).

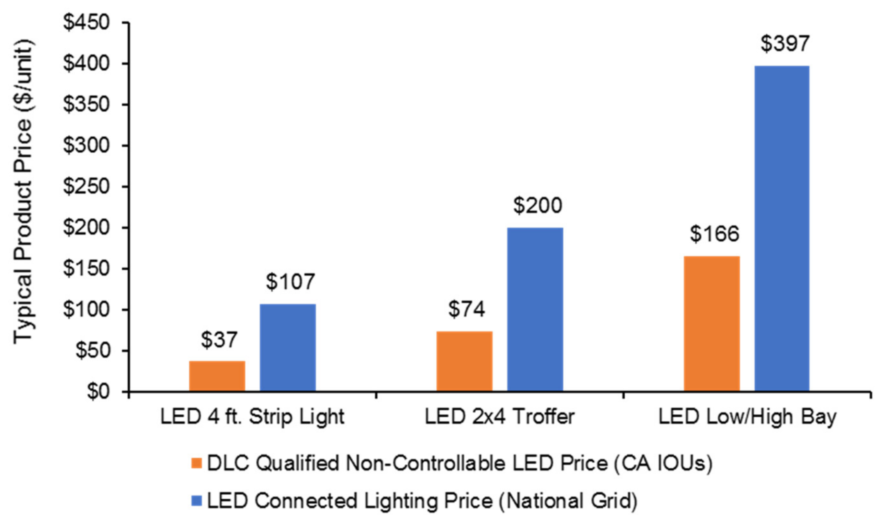

Figure 8. 2016 Q4 Price Comparison of DLC Non-Controllable and Connected LED Products

Source: Navigant Calculations from (CA IOUs 2018) and (National Grid 2018)

The challenge is to both upgrade lighting to the most efficient option possible, and to include controls to maximize both savings and user satisfaction. The least expensive and simplest LED options (such as TLED products), fall short of the full energy savings potential, are difficult to integrate with controls, and may have less desirable lighting performance.

Complexity. Historically, lighting controls have often been overly complicated and time-consuming to configure, resulting in a less than ideal performance. When moving to connected lighting systems, the challenge of complexity takes both familiar and new forms. Many contractors find it hard to master such a varied range of complexity. Unlike stand-alone light fixtures, the installation and setup of connected lighting systems can vary greatly from one manufacture to the next. This challenge, coupled with a lack of industry standards and the lack of interoperability between different control systems, often leads contractors to increase labor rates. Moreover, such systems are difficult for users to maintain and optimally utilize. Building managers and occupants find the operation of connected lighting systems can be confusing and cumbersome, depending on the product. In addition, concerns about security and hacking may also discourage building managers from pursuing connected lighting systems. As a result, significant energy savings can be left on the table. This is particularly concerning for utility programs where the energy savings potential is poorly understood, and the savings estimates can vary greatly depending on product features and building type.

Reduced configuration complexity is necessary, and increases the likelihood that deployed connected lighting systems will be correctly and consistently operating, increasing the persistence of energy savings. Connected lighting systems that offer automated configuration have the potential to significantly improve lighting system performance and increase value. Broad deployment of connected lighting systems requires that the complexity be greatly simplified – or removed – to match end user knowledge base and configuration capabilities.

Education. Among the key barriers to the adoption of any emerging technology is a lack of education. The challenge is especially difficult for connected lighting system since these products require expertise in both lighting and IT. Most of the industry value chain has knowledge in one specialty, but not the other. However, utilities are beginning to recognize this knowledge barrier. For instance, California offers a statewide initiative to overcome the knowledge barrier to more advanced lighting system installations. The California Advanced Lighting Controls Training Program (CALCTP) is a partnership between utilities, manufacturers, electricians, lighting designers and electrical contractors to promote the design, specification, installation and commissioning of advanced lighting controls. In the northeast region, utility program administrators are also gearing training towards architects, designers, vendors and contractors to increase knowledge in the marketplace in an attempt to improve knowledge and awareness of new lighting and controls technologies. And the DLC is supporting their member utilities with a training module on connected lighting systems geared towards contractors.

Connected lighting systems face an uphill battle with end users. Many customers do not understand the benefits of connected lighting systems, making the added cost seem unnecessary. Additionally, the poor performance of older traditional controls has resulted in a negative opinion of controls in general. Their adoption-stall, high upfront cost, and lack of third-party performance and benefits verification – has left many utilities uneasy about what they can expect from connected lighting systems.

Part of the education barrier is also communicating to customers the value of continued investment in lighting upgrades. For example, in the northeast, after many years of promoting High Performance T8 (HPT8) fluorescent upgrades and later low wattage fluorescent linear lamps, program administrators are finding many customers are reluctant to upgrade to LEDs. As shown in Figure 9 below, Efficiency Vermont drove a high volume of HPT8 products in the 2005-2011 timeframe (MA-EEAC 2016). As this equipment ages, it is an excellent time to reengage those customers and begin planning for the next upgrade. Since these customers have already completed a past lighting project, the lighting quantities, technologies, and operating hours are already known to the program administrators, which makes project initiation easier.

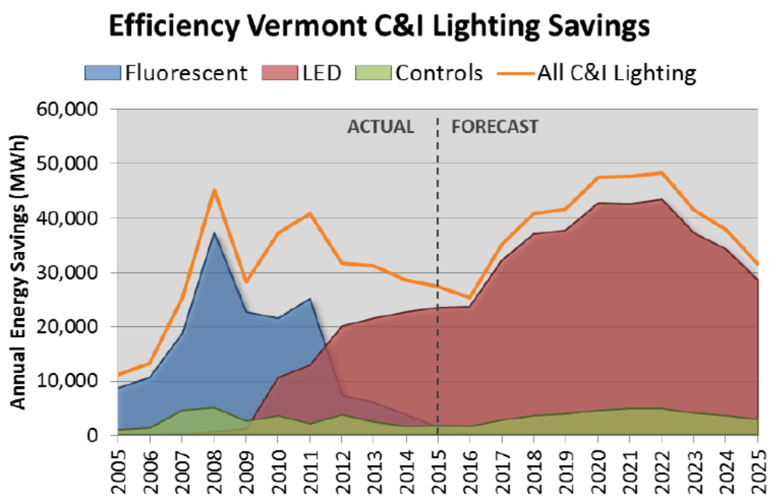

Figure 9. Efficiency Vermont C&I Lighting Savings

Source: (MA-EEAC 2016)

Conclusion

While the end may be near for residential lighting, energy saving opportunities for lighting within the commercial and industrial sectors are far from finished. Connected lighting systems can significantly increase the savings potential, but we must accelerate the adoption to occur during this time of rapid LED growth. The timing for adoption of connected lighting systems is now, since static LED installations are difficult to integrate with controls retroactively both from a technical and economic prospective. However, in order for connected lighting systems to take advantage of the LED revolution manufacturers must work to simplify the installation and operation of these systems, and develop industry standards ensure consistency and interoperability. Utilities must ramp-up their investment in outreach, promotion, education, and incentives to ensure that they, and their customers, capture the full potential. And, the entire lighting industry must to step-up education efforts to ensure contractors and end-users can install and interact with connect lighting systems seamlessly.

References

ACEEE. 2017. "California Appliance Standards." June. https://database.aceee.org/state/california.

CA IOUs. 2018. "California LED Pricing Analysis Study." Inc. Prepared by Navigant Consulting. January. http://www.calmac.org/publications/LED_Pricing_Analysis_Report_-_Revised_1.19.2018_Final.pdf.

CEC. 2017. "Regulatory Advisory - APPLIANCE EFFICIENCY REGULATIONS FOR LAMPS: EFFECTIVE DATES." March 30. http://energy.ca.gov/appliances/documents/2017-03-30_Regulatory_Advisory_Lighting.pdf.

CEE. 2013-2016. "Annual Industry Reports." *State of the Efficiency Program Industry.* http://www.cee1.org/annual-industry-reports.

CPUC. 2017. "Energy Efficiency Data Download." *California Energy Efficiency Statistics.* December 13. http://eestats.cpuc.ca.gov/Views/EEDataShelf.aspx.

DLC. 2017. "Energy Savings from Networked Lighting Control (NLC) Systems." Energy Solutions. September. https://www.designlights.org/lighting-controls/reports-tools-resources/nlc-energy-savings-report/.

ENERGY STAR. 2010-2016. "Archive of Resources for Lighting Partners." *ENERGY STAR Summary of Lighting Programs.* https://www.energystar.gov/index.cfm?c=manuf_res.pt_lighting_archive.

—. 2017. "Resources for Lighting Partners." *ENERGY STAR Summary of Lighting Programs.* https://www.energystar.gov/index.cfm?c=manuf_res.pt_lighting.

MA PAs and EEAC. 2016. "MA C&I Market Characterization On-Site Assessments and Market Share and Sale Trends Study: Volume 1 - Main Report." Inc.) DNV GL (KEMA. November. http://ma-eeac.org/wordpress/wp-content/uploads/MA-CI-Market-Characterization-Study.pdf.

MA-EEAC. 2016. "Memo - C&I Lighting Market and Technologies ." September 8. http://ma-eeac.org/wordpress/wp-content/uploads/EEAC-Lighting-Memo-20160908.pdf.

—. 2017. "Potential Innovative Options to Explore: Briefing Documents for October 31 EEAC Commercial & Industrial Planning Workshop." October 30. http://ma-eeac.org/wordpress/wp-content/uploads/CI-Workshop-2-Briefing-Document-Revised-with-Demand-1030.pdf.

National Grid. 2018. "2019-2021 Potential Study." Inc. Prepared by Navigant Consulting. TBD.

PG&E. 2017. "2016 Energy Efficiency Annual Report of Pacific Gas and Electric Company." May 1. http://eecoordinator.info/wp-content/uploads/2017/05/R.13-11-005_PGE-2016-Annual-Energy-Efficiency-Report_5-1-17-2.pdf.

—. 2018. "LED Accelerator Program 2018." http://www.ledaccelerator.com/.

—. 2017. "Residential Lighting Forecasting Analysis." TRC Energy Services. September 13. http://www.calmac.org/publications/TRC_PGE_Res_Ltg_Forecasting_9-13_Final_for_CALMAC.pdf.

U.S. DOE. 2017a. "2015 U.S. Lighting Market Characterization." *Solid-State Lighting Program.* Inc. Navigant Consulting. September. https://www.energy.gov/sites/prod/files/2017/12/f46/lmc2015_nov17.pdf.

—. 2017b. "2017 Suggested Research Topics Supplement: Technology and Market Context ." *Solid-State Lighting Program.* September. https://www.energy.gov/sites/prod/files/2017/09/f37/ssl_supplement_suggested-topics_sep2017_0.pdf.

—. 2017c. "Adoption of Light-Emitting Diodes in Common Lighting Applications." *Solid-State Lighting Program.* Inc. Navigant Consulting. July. https://energy.gov/sites/prod/files/2017/08/f35/led-adoption-jul2017_0.pdf.

—. 2010. "ENERGY STAR CFL Market Profile - Data Trends and Market Insights." September. https://www.energystar.gov/ia/products/downloads/CFL_Market_Profile_2010.pdf.