Pacific Northwest
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PNNL-29165

Interior Lighting Campaign

2015 – 2019 Results

September 2019

MA Myer
LJ Sandahl
TA Beeson
TL Gilbride
TL Shoemaker

U.S. DEPARTMENT OF ENERGY

Prepared for the U.S. Department of Energy
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Pacific Northwest National Laboratory
Richland, Washington 99354

Summary

The Interior Lighting Campaign (ILC) is a public-private partnership that was established to support the development and market adoption of high-efficiency lighting and control systems in commercial buildings – first with troffer lighting and later additional lighting applications. The campaign combines information sharing (best practices, lessons learned, expert guidance, etc.) and technical assistance with qualitative and quantitative data collection. Progress and results are shared at annual recognition events and through the campaign newsletter, website, and other channels. Organizing members have included the U.S. Department of Energy (DOE), the Building Owners and Managers Association International, the Illuminating Engineering Society of North America, International Facility Management Association, the U.S. General Services Administration, and the interNational Association of Lighting Management Companies. Pacific Northwest National Laboratory manages the ILC on behalf of DOE.

Since launching in 2015, 92 participants, each representing one or more sites, have joined the ILC and pledged to install or replace their lighting with high-efficiency lighting systems. These participants manage buildings in several building sectors, including retail, healthcare, office, hospitality, educational, industrial, federal, state, and municipal. To date, the ILC received data on almost 4,000 sites with information about operating hours, numbers of light fixtures, wattage of light fixtures, and lighting controls. Additionally, participants in the ILC have surpassed the 2019 ILC goal and installed or pledged to install or replace more than 3.5 million light fixtures. The ILC has detailed data on 90% of these light fixtures. Table S.1 shows the growth in terms of participant joins and savings since the start of the program.

Table S.1. ILC Quick Facts: 2015-2019

	2015	2016	2017	2018	2019*	Total
Number of New Participants	21	37	15	14	5	92
Number of New Supporters	108	32	16	19	5	180
Recognized Participants	-	13	13	15	10	51
Number of New Luminaires	308,779	315,195	667,281	1,557,669	696,261	3,545,185
Site Energy Savings (million kWh)	35	59	140	408	157	799
Source Energy (trillion BTUs)	0.35	0.61	1.43	4.16	1.60	8.15
Electricity Dollar Savings (million $$)	$3.70	$6.23	$14.79	$42.13	$16.59	$84.42
Note: *As of August 2019						

In 2020, the Interior Lighting Campaign is scheduled for conclusion, having achieved its intended goals. In 2020, an Integrated Lighting Campaign will be introduced with a focus on the integration of lighting with other building elements and systems, leading to additional energy, and other performance benefits.

Acknowledgments

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Acronyms and Abbreviations

BOMA	Building Owners and Managers Association
DLC	DesignLights Consortium®
DOE	U.S. Department of Energy
GSA	U.S. General Service Administration
HVAC	heating, ventilation, and air conditioning
IES	Illuminating Engineering Society
IFMA	International Facility Management Association
ILC	Interior Lighting Campaign
IoT	Internet of Things
L&E	Lighting & Electrical
LED	Light-emitting diode
LEEP	Lighting Energy Efficiency in Parking
LMC	Lighting Market Characterization
LPE	Lighting Project Evaluator
NALMCO	interNational Association of Lighting Management Companies
NGLS	Next Generation Luminaire Systems
PNNL	Pacific Northwest National Laboratory
SEA	Smart Energy Analytics
SPB	simple payback
SPD	spectral power distribution

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1.0 Introduction

Lighting represents the largest end use of electricity in commercial buildings and is often targeted for energy savings through energy-efficient light sources, sensors and controls, and advanced lighting technologies. From 2015 to 2035, a total cumulative energy savings of 62 quads[1] – equivalent to nearly $630 billion in avoided energy costs – is possible if the U.S. Department of Energy (DOE) Solid-State Lighting Program goals for light-emitting diode (LED) efficacy and connected lighting are achieved. Commercial buildings represent some of the greatest saving opportunities because of their long operating hours and the potential to implement control systems, where savings potential is enormous (DOE 2016).

Since 2012, the DOE's Commercial Buildings Integration Program within the DOE Building Technologies Office has introduced four technology adoption campaigns for energy-efficient commercial building technologies in coordination with national laboratories and industry partners: 1) the Lighting Energy Efficiency in Parking (LEEP) campaign focused on high-efficiency parking facility lighting; 2) the Advanced Rooftop Campaign focused on high-efficiency roof-top air conditioning units with advanced controls (www.advancedrtu.org); 3) the Interior Lighting Campaign (ILC) focused on high-efficiency interior lighting (www.interiorlightingcampaign.org); and 4) the Smart Energy Analytics (SEA) campaign focused on energy management and information systems (smart-energy-analytics.org).

This report provides an overview of the design components and results achieved from one of these initiatives—the ILC. The ILC was introduced in 2015 to help speed the adoption of high-efficiency lighting and control systems in commercial buildings. The ILC combines technical assistance with qualitative and quantitative data collection, and recognition for exemplary performance. Participants are encouraged to share their progress and projects with the ILC, and results are presented at an annual recognition event and through the campaign newsletter and website. Organizing Committee members include the DOE, the Building Owners and Managers Association International (BOMA), the Illuminating Engineering Society (IES), International Facility Management Association (IFMA), the U.S. General Services Administration (GSA), and the interNational Association of Lighting Management Companies (NALMCO).

Since launching in 2015, the campaign has grown year over year; 92 sites have now participated, including retail, healthcare, office, hospitality, educational, industrial, federal, state, and municipal buildings. Participants of the ILC have installed or replaced more than 3.5 million fixtures with high-efficiency lighting systems that are saving more nearly 800 million kWh of electricity per year. That's enough to power 74,700 U.S. homes annually.

At the time of this report, the ILC was wrapping up its final year of documenting and recognizing achievements related to the installation of specific categories of LED luminaire and controls systems, and was moving toward a new focus on the integration of lighting system with other building systems such as heating, ventilation, and air conditioning (HVAC), plug loads, and the Internet of Things (IoT).

1.1 ILC Key Dates

Table 1 provides a brief timeline of key campaign activities to date.

[1] Quad refers to quadrillion British thermal units (Btu) of source energy

Table 1. Timeline of the ILC with Goals and Accomplishments

Date	Activities
Aug 2013	DOE decides to move forward with a campaign focused on high-efficiency lighting troffers and controls. Project planning begins.
May 2015	ILC launches; announced at 2015 Better Buildings Summit. Five organizing partners: IES, IFMA, BOMA, GSA, DOE. Set a goal of 100,000 high-efficiency troffers planned or installed.
Oct 2015	Surpassed initial goal of 100,000 troffers with 300,000 planned or installed* Set new goal of 1 million troffers.
June 2016	First ILC recognition event held during BOMA International Conference in Washington, D.C. 13 participants recognized in 12 recognition categories.
Jan 2017	Surpassed goal of 1 million high-efficiency troffers with1.29 million planned or installed.
June 2017	Second ILC recognition event held during BOMA International Conference in Nashville, TN. 11 participants and 2 supporters recognized in 12 recognition categories.
Oct 2017	Added new luminaire types: high-bay, low-bay, and suspended linear lighting systems and controls. Set new goal of 2 million high-efficiency luminaires planned or installed.
June 2018	Surpassed goal of 2 million luminaires with 2.8 million planned or installed (mostly troffers; some high-bay, low-bay, and suspended linear).
Aug 2018	Third ILC recognition event held during IES Annual Conference in Boston, MA. 15 participants recognized in 12 recognition categories. Set new goal of 3.5 million luminaires planned or installed.
Dec 2018	NALMCO joins organizing committee.
Jan 2019	New innovative categories announced.
July 2019	Surpassed goal of 3.5 million luminaires planned or installed.
Aug 2019	Fourth ILC recognition event held during IES Annual Conference in Louisville, KY. 10 participants recognized in 12 recognition categories.
Note: *One organization submitted more than 100,000 troffers	

1.2 Background

DOE has a long history of supporting energy efficiency in lighting, including research that has advanced the development of LED lighting technology. Over the years, LED systems have been adopted in a steadily increasing list of lighting applications, due in part to DOE's leadership and partnerships with industry.

Outdoor lighting was an application where LED lighting and control systems found early success. The LEEP campaign, the Municipal Solid Street Lighting Consortium, and the Outdoor Lighting Accelerator are examples of DOE programs that helped early adopters more easily adopt outdoor LED lighting systems by offering them tools and resources that addressed technical and market barriers, and by giving them access to direct technical assistance from lighting experts at DOE's Advanced Lighting Laboratory, Pacific Northwest National Laboratory (PNNL). DOE documented successes and lessons learned from these early adopters, which were then used to inform others facing similar challenges—thus helping to speed adoption to the larger community of users.

Although not limited to LED technology, the ILC was envisioned in 2014 just as LED technology was becoming viable as a light source for interior applications. However, LED interior lighting systems were still new to the market, relatively untested, and expensive on a first-cost basis. DOE had already invested in developing interior lighting resources like the High-Efficiency Troffer Lighting Specification, which was developed in partnership with industry to help define performance characteristics of high-efficiency troffer lighting systems.

Years earlier, LEDs had raised the bar for energy-efficiency and had proven to be disruptive to the existing industry best practices in exterior lighting, and DOE was concluding a campaign focused on high-efficiency exterior lighting and controls – the LEEP campaign. While the campaign was technology neutral, most of the sites recognized by the campaign for energy performance were LED or LED with associated controls. At that time DOE and its partners had determined that the LEEP campaign had fulfilled its mission of serving as a bridge helping to reinforce the viability of the new technology and assisting end users, and exterior high-efficiency lighting systems were becoming well established in the market.

In order to determine if timing was right for an interior-focused lighting campaign, and, if so, which early applications would be most impactful in terms of efficiency and size of the installed base, DOE conducted several investigations. DOE research found that commercial building owners, including those participating in DOE's Better Buildings Lighting & Electrical (L&E) Research Team, were skeptical of manufacturer performance claims and were looking for guidance on how to specify products. They were also looking for 3rd party validation and evidence that the products performed as claimed by manufacturers. These findings were validated with broader discussions held with other key stakeholders including efficiency program providers, utilities, technology manufacturers, and professional and trade groups.

It was concluded that broader adoption of the High-Efficiency Troffer Lighting Specification and more information about product performance through a central "portal" (the campaign website) would benefit a broader spectrum of users, and that as high-efficiency and controls technology increased in market adoption, the cost of the equipment would decrease as well. A campaign focused initially on troffers was determined to be an effective way to increase use of the specification as well as to assist end-users in overcoming the barriers associated with high-efficiency troffer system designs. Many of the stakeholders who provided input on the viability of the ILC expressed interest in participating. Thus, DOE determined that the timing was right to launch a campaign effort focused on high-efficiency interior lighting and controls systems – starting with a heavy focus on troffers and associated controls.

2.0 Campaign Design and Implementation

This chapter provides an overview of ILC design components and how they were implemented. The ILC, like most technology adoption campaigns, provides technical assistance for early adopters, recognition for exemplary adoption and energy-efficiency performance, and documentation of successes and best practices from both small pilot projects and large procurements. The available resources help provide the foundation for better purchase decisions and additional voluntary technology adoption by others. Feedback from early applications, including product performance and technology or market barriers, is also collected by DOE and shared with industry to help improve inform product development.

Recognition to ILC participants ranges from acknowledgment on the campaign website to formal recognition for exemplary performance at a national event, such as an annual trade or professional conference. For DOE and other program organizers, technology adoption campaigns provide critical channels to collect market and technical data on performance, market barriers, applicability to various building types, and cost effectiveness of emerging technologies (Jiron and Webber 2016).

The ILC serves as a central portal for unbiased information, technical assistance, and best practices on interior lighting technologies, including high-efficiency products, lighting controls, and sensors. The campaign's website serves as a hub for organizations, such as nonprofits, trade and professional groups, manufacturers, and utilities who have common interests in supporting increased adoption of a given technology or practice. Initial campaign planning activities included defining adoption barriers, gauging interest and support from end users and potential participants and identifying organizing partners.

2.1 Identifying Campaign Organizers

Implementation of the ILC started with the formation of an organizing committee. Their role was to help determine campaign goals and performance requirements, establish the schedule, and help recruit and engage participants. They also helped guide other implementation activities including planning and conducting the recognition event, setting up a website, providing technical assistance, collecting and analyzing data, and reporting on the successes achieved through case studies, the ILC Highlights Newsletter, and participants' information channels.

Organizing partners were sought from organizations that had strong credibility with groups the campaign was trying to reach, a strong history of promoting energy efficiency with their members, and the potential to host an ILC recognition event as part of a conference or meeting that draws a national audience. Key partners stepped forward and agreed to be campaign organizers: BOMA, IES, IFMA, GSA, and subsequently NALMCO. Each organizing partner had connections to different audiences and user groups (e.g., BOMA: building owners/managers; IFMA: facility managers; IES and NALMCO: lighting practitioners). Although GSA is neither a trade nor professional group, they are an ideal partner because of their experience in owning and leasing commercial space (i.e., over 376.9 million ft^2 in 9,600 buildings in 2018).

2.2 Recruiting Participants and Supporters

DOE announced the launch of the ILC at the Better Buildings Summit in May 2015. Once the lighting campaign was announced, the organizing partners shifted their focus to encouraging participation and planning the recognition event. Because the recognition event is held annually, participant recruiting is an ongoing activity. Once participants or supporters join the campaign, they are listed on the campaign website, unless they opt out. The ILC recruits participants through a number of channels and approaches, including:

- Better Buildings sector leads
- Better Building L&E Technical Research Team listserv and quarterly meetings
- Energy-efficiency organizations (Northwest Energy Efficiency Alliance, Northeast Energy Efficiency Partnership, Consortium for Energy Efficiency, Midwest Energy Efficiency Alliance), utilities, and manufacturers
- Better Buildings tweets
- DOE press releases about the launch
- An ILC post card and flier at various events
- Webinars
- Articles published in various trade publications.

The ILC includes two types of participation categories listed below, and both groups support the campaign goal to increase the adoption of high-efficiency interior lighting and control systems:

- Participants - building owners/managers
- Supporters - utilities, energy service companies, efficiency groups, manufacturers, manufacturer's representatives, or others.

Some ILC participants had already applied high-efficiency lighting technology in their buildings, whereas others planned to, but had not yet implemented advanced or high-efficiency lighting technologies. Lighting campaign resources and technical assistance provided some site managers with the information needed to take the next step, securing information about best applications or identifying small-scale demonstration projects to inform larger scale or portfolio-level adoption. In order to remain flexible and to encourage broad participation, the "join" requirement for participants in the lighting campaigns (i.e., LEEP and ILC) is a commitment or "pledge" to take some action. Participation in recognition events is a voluntary aspect of campaign involvement and not all participants chose to submit projects and self-nominate for the recognition events.

Supporters represent a spectrum of organizations, including manufacturers, utilities, efficiency groups, and energy service companies who support the goals of the campaign by increasing awareness and promoting participation through their network of customers or members. Because the ILC is voluntary, there are no stringent requirements for inclusion as a supporter. As part of the supporter sign-up process, the ILC requires that supporters agree to the following: "As a supporting partner, my organization will help recruit participants into the Interior Lighting Campaign. We will promote the campaign to our customers or members and communicate the benefits of joining the campaign as a Participant." Although supporters agree to this commitment, the campaign has no way to track or enforce this agreement. However, activity is encouraged through a supporter recognition category added in 2018, for those supporters who have directly influenced the most high-efficiency lighting systems through their programs.

2.3 ILC Performance Requirements and Goals

Minimum ILC performance requirements were based on the goals the ILC identified in the planning stages, and the ILC helped to establish minimum requirements for participation eligibility. The performance requirements ensure that participants are pursuing the use of efficient products that achieve savings well above most energy codes.

The ILC originally set the minimum luminaire efficacy at 85 lumens per watt (lm/W) for troffers. This performance level represented a "best practices" minimum for the technology in 2015 and it aligned with minimum requirements for qualified products established by an important ILC supporter, the DesignLights Consortium® (DLC). Although the DLC included other non-efficiency-related metrics (e.g., color, life, warranty), the ILC avoided prescribing non-efficacy requirements such as those required by the DLC. With an over-arching goal of accelerated adoption of high-efficiency lighting in place from the start, the ILC expanded in its third year to cover additional luminaire types, namely suspended linear, high-bay, and low-bay luminaires. Performance requirements were also increased by over 20% from the 2015 levels to a minimum of 105 lm/W for all luminaires in 2017. An efficacy value of 105 lm/W was selected by Campaign Organizers to account of performance improvements in lighting since 2015 (also aligning with DLC requirements at the time as well) and to continue to recognize top performers.

2.4 Design and Planning of Recognition Event

Like other campaigns, the ILC found that holding an annual event to recognize exemplary participants is an important way to generate excitement about the campaign, recruit new participants, and motivate existing participants to share data about their high-efficiency lighting adoption efforts. Conducting the annual event involves a yearly cycle of activities, as shown in **Error! Not a valid bookmark self-reference.**. The ILC was launched in May 2015 and the first recognition event was held at the BOMA International Conference and Expo, in Washington, D.C., in June 2016. Subsequent recognition events were held at the BOMA International Conference, in Nashville, TN, in June 2017, and at the IES Annual Conference, in Boston, MA, in August 2018. The most recent one was held on August 8, 2019 at the IES Annual Conference in Louisville, KY.

Table 2. ILC Recognition Cycle

Month	Activity
January	Recognition application process announced to current participants, current supporters, the L&E Technical Resource Team listserv, in the ILC HighLIGHTs, and via DOE news release, and social media (tweets).
April	Applications are due to the ILC Organizing Committee.
Late May / Early June	ILC Organizing Committee review submittals.
June-Aug	Exemplary projects announced at recognition event held in conjunction with an organizing partner's national conference.

To ensure that the recognition program captured a wide spectrum of project types, the program was structured with recognition categories that encompassed both retrofit and new construction projects, as well as various project sizes. All the recognition categories are listed in **Error! Reference source not found.**. The recognition also included categories for cumulative values.

Some organizations plan multiple years ahead; the “portfolio-wide” and “largest project” categories recognized participants who have embraced a larger internal plan for their portfolio. These sites may or may not have a single standout site, but it was decided that large aggregate savings should be recognized in addition to a single site with impressive savings when energy savings are a desired goal. By differentiating by types of sites and recognizing both actual energy savings and percent reduction, multiple sites can be recognized while demonstrating to potential participants that varying amounts of savings are possible regardless of project size. While some level of exclusivity is needed to keep the recognition meaningful, ample opportunities for recognition to transform the different markets is needed.

In 2017 a recognition category for supporters was added, “Significant Number of Troffer Systems installed through an Energy Efficiency/Utility Program,” in order to recognize the contributions of ILC supporters with such programs. This category was broadened alongside the basic energy savings categories in 2018 from troffers-only to troffers, high-bay, low-bay, and suspended linear luminaires.

After the 2018 recognition event, the following new innovative categories were added to encourage and capture information about emerging integrated control systems that simultaneously control lighting and provide sensor data useful to control HVAC and/or plug loads, as well as other building systems: “Integrated Controls Plug Loads and Lighting Systems,” “Integrated Controls for HVAC and Lighting Systems,” and “Other Integrated Systems and Lighting.” Electricity use in commercial buildings falls into three categories: HVAC (33%), plugs and process loads (14%), and lighting (17%) (EIA 2016). Although the fraction of energy use for lighting has been decreasing over the past few years, the fraction for plugs and process loads has increased. New occupancy sensors and other control technologies are entering the market that can reduce HVAC and/or plug loads while also reducing lighting loads. With the introduction of these new categories, the ILC hopes to collect data on the use and performance of these new technologies and encourage their adoption.

Table 3. Recognition Categories

Project		Recognition Category		Years Included
	Luminaires Installed	**Greatest Annual Energy Savings for Lighting**		2016 2017 2018* 2019*
Small	<25	Retrofits	New Construction	
Medium	25 ≤ luminaires ≤ 200	Retrofits	New Construction	
Large	>200	Retrofits	New Construction	
	Luminaires Installed	**Highest Percentage of Annual Energy Savings**		2016 2017 2018* 2019*
Small	<25	Retrofits	New Construction	
Medium	25 ≤ luminaires ≤ 200	Retrofits	New Construction	
Large	>200	Retrofits	New Construction	
Special Recognition Categories:				2016 2017 2018 2019
• Best Use of Lighting Controls in a Single Building • Largest Number of Facility Projects • Largest Portfolio-Wide Annual Absolute Energy Savings				
Exemplary Recognition Sector (may be presented to participants in these sectors):				
• Commercial Real Estate and Hospitality • Healthcare		• Retail, Food Service, or Grocery • Federal Government • Municipal and State Government		2016 2017 2018

• Higher Education	2019
Innovative Categories:	2019
• Integrated Controls Plug Loads and Lighting Systems • Integrated Controls for HVAC and Lighting Systems • Other Integrated Systems and Lighting	
Supporter Recognition	2017
• Significant Number of Luminaires Installed through an Energy Efficiency/Utility/Service Program	2018 2019

* Expanded from **ONLY** troffers to include troffers, high-bay, low-bay, and suspended linear luminaires

Recognition categories were developed based on project size to allow different sized projects to participate in the ILC. Significant lighting energy savings (e.g., 1 million kWh) is a great achievement, but most buildings are not large enough to have the necessary fixture count to achieve similar savings. Per the Commercial Building Energy Consumption Survey, about 70% of the number of buildings in the United States are 10,000 ft^2 or less. The luminaires in the ILC cover roughly 80–100 ft^2 of space per luminaire; thus, the small and medium categories are geared towards the bulk of the buildings in the United States. The advantage of this model is that if retail facilities (e.g., bank branch, mobile phone store, convenience store) see savings or are recognized for small projects, the organizations might replicate the efforts. Many retail organizations may be small, but typically prototype designed and large in number, so the aggregate savings can also be significant. Small and medium projects may also be design/build or not utilize expansive design and engineering teams. By recognizing and demonstrating savings in small and medium buildings, these projects may also seek or learn how to replicate the savings.

2.5 Campaign Data Collection, Processing, and Analysis

In order to identify exemplary performance among participants, an energy use analysis is performed at the end of each year's submission period and is based on the following data requested from those participants seeking to be recognized. Once the following data are received and it is determined that the submission meets the minimum performance requirements, the participant is a "submitting participant" for the year in which the data were received:

- Basic site data, such as organization name, address, site name, and/or site number
- Detailed equipment data including pre- and post-retrofit (or new installation) data for operating hours, use of lighting controls, number of light fixtures, light source type, and wattage of light fixtures.

In designing all technology adoption campaigns, there is a balance between requiring usable data and minimizing the burden on participants to acquire and submit the data. To limit the burden on participants, the ILC does not require actual metered data. If a lighting system cannot self-report energy (which few do), metering can be costly (a few thousand dollars for even a small system) and needs to be captured for a few weeks.

Further, not all entities who sign up for campaigns want to or are able to submit the data required for recognition.[1] Forty-seven percent of the participant organizations who signed up for the ILC submitted the larger data set required for recognition. Despite these common data collection challenges, the ILC collected a significant amount of data. To date, the ILC received data on almost 4,000 sites with information about operating hours, numbers of light fixtures, wattage of light fixtures, and lighting controls. Additionally, participants in the ILC have installed or pledged to install or replace more than 3.5 million light fixtures. The ILC has detailed data on 90% of these light fixtures.

To improve data collection and management efforts for the ILC, an interactive web-based tool called the Lighting Project Evaluator (LPE) was offered from 2016–2019. Participants could use the tool to enter their project data and evaluate one or more lighting systems, and the LPE would export the required information for easy submission. Because of the detailed nature of the LPE, the use of the tool was optional (i.e., not required for data submissions) and not required for data submissions, as participants with many projects or those who already had completed the intended work generally preferred to simply share documentation in their own internal format.

Even with data collection tools like the LPE, the focus of the ILC only included a subset of the data. With only specific luminaire types being addressed and performance requirements excluding some of the project work, the ILC determined that an internal analysis method would be implemented to determine savings from controls.

Applying anticipated lighting controls savings is one of the primary challenges with data analysis in the absence of metered data. Because metered data were not required, to manage participant burden, the campaign applied assumptions to estimate the lighting control savings. A meta-analysis of lighting controls was reviewed (Williams et al. 2012). Table 4 provides the best estimate of average energy savings from different lighting controls.

Table 4. Lighting Controls Estimated Energy Savings from Meta-Analysis

Lighting Control Strategy	Estimated Average Savings
Occupancy	24%
Daylighting	28%
Personal Tuning	31%
Institutional Tuning	36%
Multiple Approaches	38%

Although lighting control savings can range by building type, climate, and several other factors, it was decided that the same energy savings percentage by control strategy would be applied across all building types. Further, because there were uncertainties and unknown elements about each of the sites, the ILC-applied lighting control saving values (see Table 4 were less than the meta-analysis lighting control energy savings shown in Table 5. The lighting control strategies factored into the ILC energy analysis and energy savings associated with that control strategy are shown in Table 5.

[1] DOE is also an organizer of the Smart Energy Analytics (SEA) campaign and, in that campaign, not all participants submitted for recognition. It is common for organizations to participate in a Campaign and not submit for recognition.

Table 5. Energy Savings Assumptions Used by the ILC for Individual and Combined Applications of Lighting Controls

Control Type(s)*	Savings Assumptions Applied
Occupancy-Based Control	20%
Dimming Capability	15%
Daylighting	25%
Occupancy-Based + Dimming Capability	30%
Occupancy-Based (or Dimming Capability) + Daylighting	35%
Occupancy-Based + Dimming Capability + Daylighting	35%

*Note: Occupancy-based in this table includes both occupancy and vacancy sensors.

For the purpose of our analysis, both vacancy sensors and occupancy sensors were "occupancy-based" controls. There were also multiple applications for reducing light levels that were all considered to be a "dimming" technique. These approaches range from scheduled light reduction for stocking in retail applications to task-tuning in conference rooms. Some organizations did employ scheduled-based controls where some lighting in the facility was turned off during operating hours. Schedule-based controls were applied directly in the energy analysis by modifying the operating hours for the appropriate type and number of light fixtures.

The ILC offered separate recognition categories for new construction and retrofit applications, and energy code model inputs played a role in recognition analysis. For retrofit recognition, the analysis simply compared the pre- and post-upgrade energy use to determine savings. For new construction, a fixture with an efficacy that could be used to meet the energy code was chosen as the baseline because there was no real baseline product for comparison. The key lighting metric in various energy codes is lighting power density. The ILC does not use lighting power density or calculate the area of the space. The new construction baseline uses the light output of the new fixture divided by the efficacy of a fixture that can meet the energy code to establish the baseline equipment wattage. ILC calculates the input wattage of the baseline new construction fixture by scaling the wattage of the actual fixture installed by the efficacy of the baseline fixture. To simplify and streamline the data analysis challenges inherent in managing large datasets, the ILC developed a database to store the relevant data from each participant's submission in a format for easy export for analysis via Excel calculations.

2.6 Campaign Resources and Technical Assistance

The ILC was built upon a foundation of relevant tools and resources, including independent third-party demonstration results, case studies, financial savings calculators, national laboratory subject matter expertise, and product performance specifications and guidance. These resources are used by participants to evaluate the efficiency savings and performance opportunities for high-efficiency interior lighting and controls technology.

Among the benefits participants gain from joining the campaign are access to DOE and national laboratory expertise and sharing with peers in evaluating and implementing the technology. Resources to support this assistance are limited, but participants have appreciated having access to objective experts as they consider whether to implement a technology and how much energy they might save.

The ILC website https://interiorlightingcampaign.org was designed to serve as a hub for ILC resources and participant information.

The ILC developed case studies documenting the performance and lessons learned from sites that achieved exemplary performance recognition, to serve as examples for others who might be considering the technologies. These case studies also bring national recognition to campaign participants and have been found to be a valuable incentive, especially for organizations with public energy reduction and sustainability goals (e.g., Army Reserve sites). Case studies of ILC participants' projects can be found at https://interiorlightingcampaign.org/resources.

Prior to the ILC, DOE developed the High-Efficiency Troffer Performance Specification (DOE 2015). Participation in the campaign was not dependent upon the use of this specification; however, the specification helped leverage the growing interest in LEDs by helping identify the higher performing products available on the market. The major benefit of the specification was that the performance minimums were defined. The most obvious requirements are those that address the photometric performance of luminaires. A minimum initial lumen output ensures adequate illumination to replace the existing fluorescent stock, while efficacy requirements ensure that the light produced is being delivered in an energy-efficient manner, often through quality luminaire design and component integration. The specification addressed the barrier associated with the lack of understanding of manufacturer performance claims and helped minimize the potential for products that perform inadequately to be used as replacements for the incumbent systems.

The specification served as a common framework for discussions with manufacturers, which led to a better understanding of user needs and issues with current products. It also served as a baseline for addressing more complex performance requirements as the campaign shifted into the fourth year, and the inclusion of the controls-focused innovation categories.

3.0 Results

This chapter summarizes results from the ILC, from its inception in May 2015 through August 2019, including the number of participants, exemplary performance submissions, energy savings, cost data, and other program accomplishments.

3.1 ILC Supporters, Participants, and Submissions

There was a large initial outreach effort to enroll supporters in 2014 – 2015 when the ILC was being established. A large supporter base helps with outreach to possible participants. Figure 1 visually depicts the number of both participants and supporters per year.

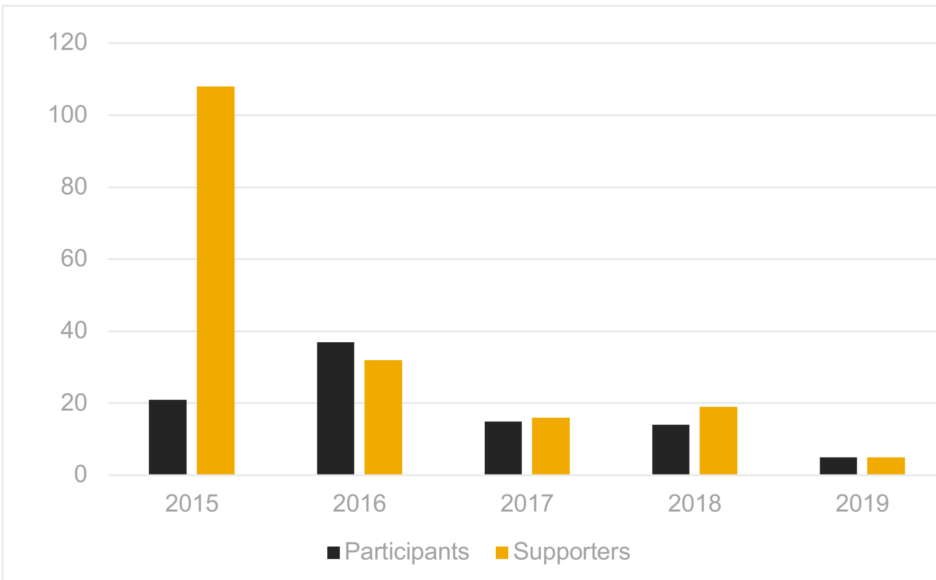


Figure 1. Number of Participants and Supporters per Year

More than 176 organizations who support the goals of the ILC, referred to as ILC supporters, joined to support the campaign as of August 2019. The supporter category includes design teams, industry partners, utilities, energy efficiency organizations, and other similar supporters. Figure 2 depicts the number of organizations that support the ILC. Appendix A provides a detailed list of all the ILC supporters.

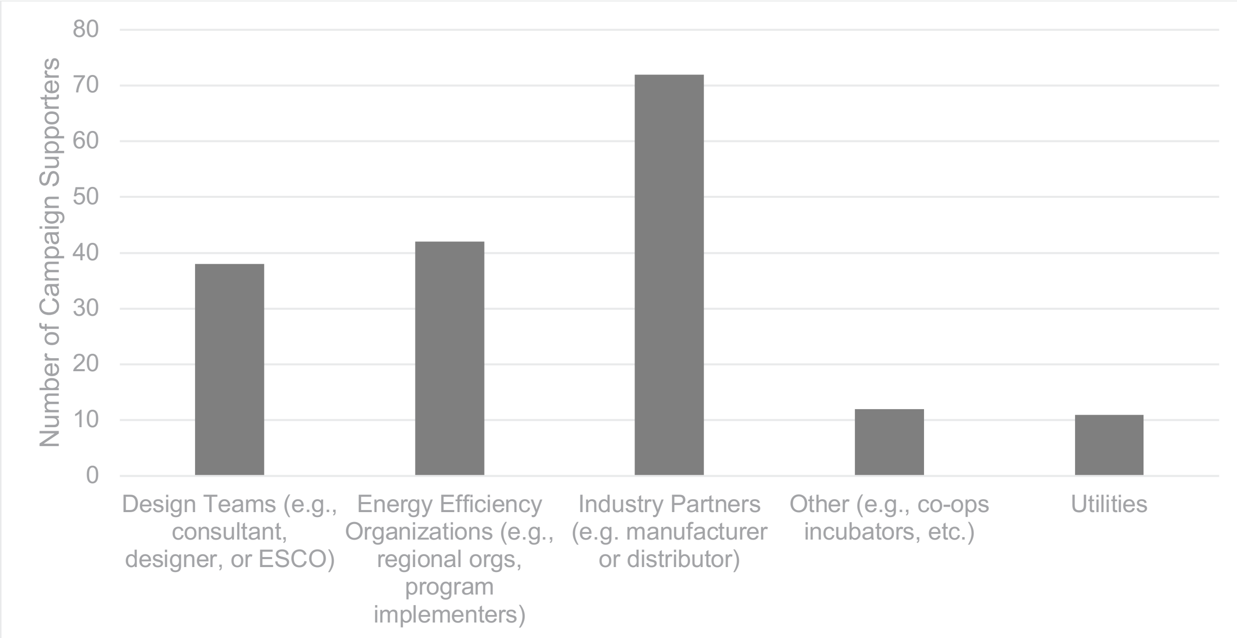


Figure 2. Campaign Supporters by Organization Type

Campaign participants (building owner/managers) include 92 private- and public-sector organizations who have installed, replaced, or upgraded more than 3.5 million fixtures with high-efficiency lighting systems. Participants are mainly in the government, commercial, retail sectors, as seen in Figure 3.

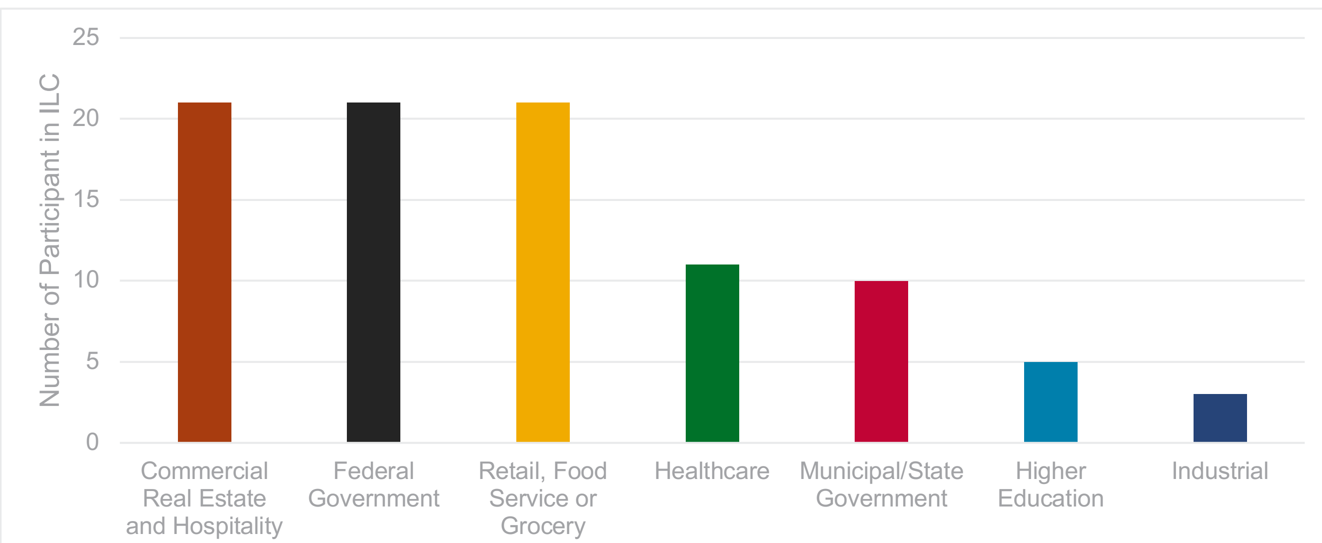


Figure 3. Campaign Participants by Organization Type

ILC participants and supporters are invited each spring to provide details on completed interior lighting system projects that they believe should be considered for exemplary energy savings performance recognition. When participants sign up for the ILC, they are only required to share limited general information including contact information, but also an approximation of fixtures that have been, or will be, installed, replaced, or upgraded. However, if they would like to be considered for exemplary performance recognition, more data are required.

Each year of the campaign, submissions were received from participants in at least four of the seven sector categories. The number of submissions increased from the second to the third and third to the fourth years, but as new innovation categories were incorporated in the fourth year, the historical recognition categories received fewer submissions as the focus shifted to systems integration.

Most submissions for exemplary performance were for projects in the following sectors: federal government, commercial real estate/hospitality or retail, food, grocery sectors (see Figure 4). However, the number of projects per organization differs and the number of submitted projects were dominated by the retail, food, or grocery sector. In total, the three most heavily-represented sectors provided 75% of the ILC's submissions. The heavy representation of the projects included in the retail, food, and grocery sectors is further inflated due to the sheer number of projects the submitting participants provided. Although only representing 22% of the submitting participants, they account for 88% of the luminaires included in the cumulative analysis. In contrast, the commercial real estate/hospitality, federal government, and healthcare participants represented 30%, 23% and 13% of the submittals provided, while their data represented only 2%, 4%, and 6% of the luminaire data, respectively.

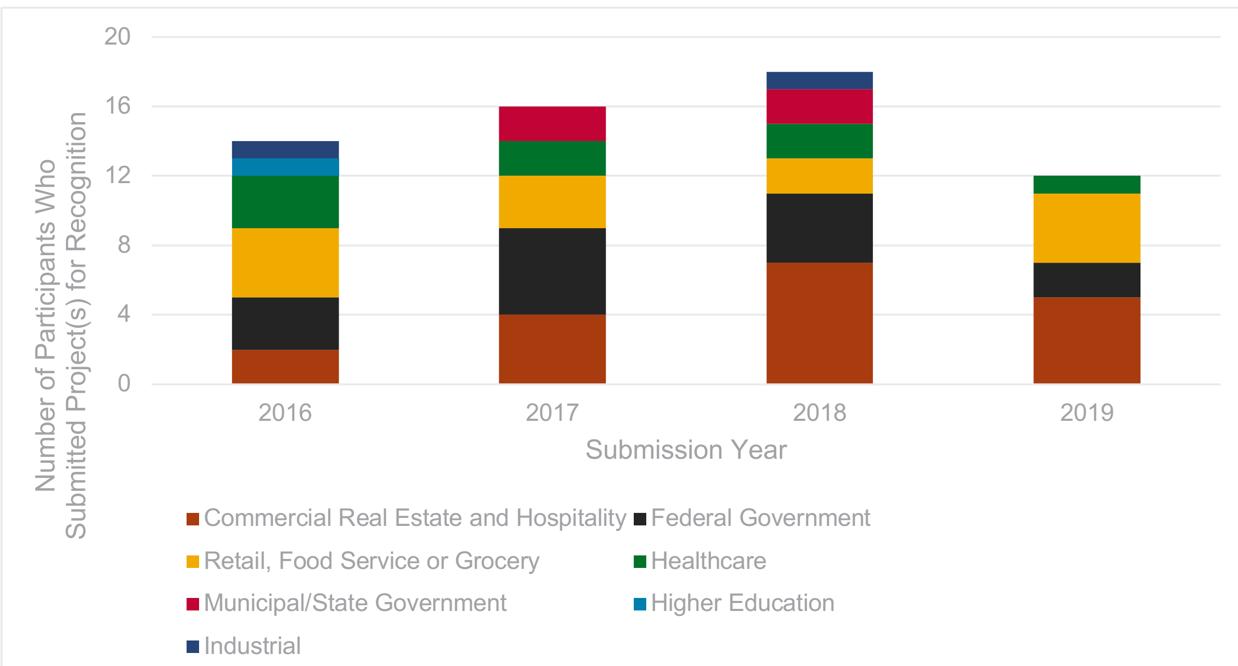


Figure 4. Number of ILC Submissions by Year and by Sector

Projects were categorized as either small, medium, or large. The small projects were those that had fewer than 25 qualifying luminaires. Medium projects were those that installed between 25 and 200 luminaires, and any project with over 200 luminaires was deemed large. Every year the most data were received on large projects, as shown in Figure 5. For the 4-year cumulative total, there were nearly four times as many medium projects as small projects, and nearly 12 times as many large projects as there were medium projects.

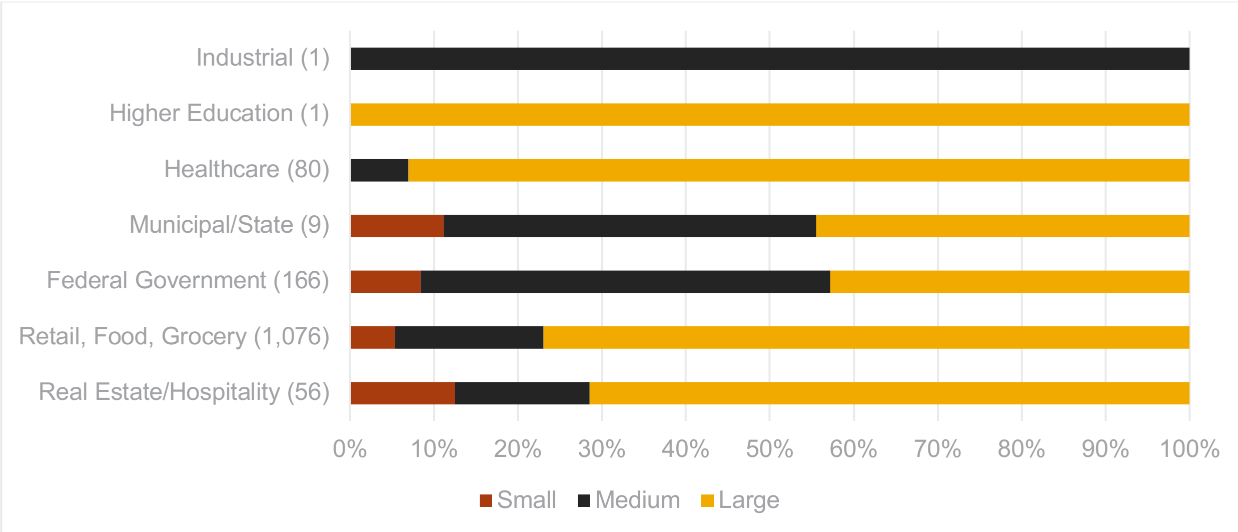


Figure 5. Project Size Representation by Sector

Table 6 lists all the organizations recognized by year.

Table 6. Recognized Participants

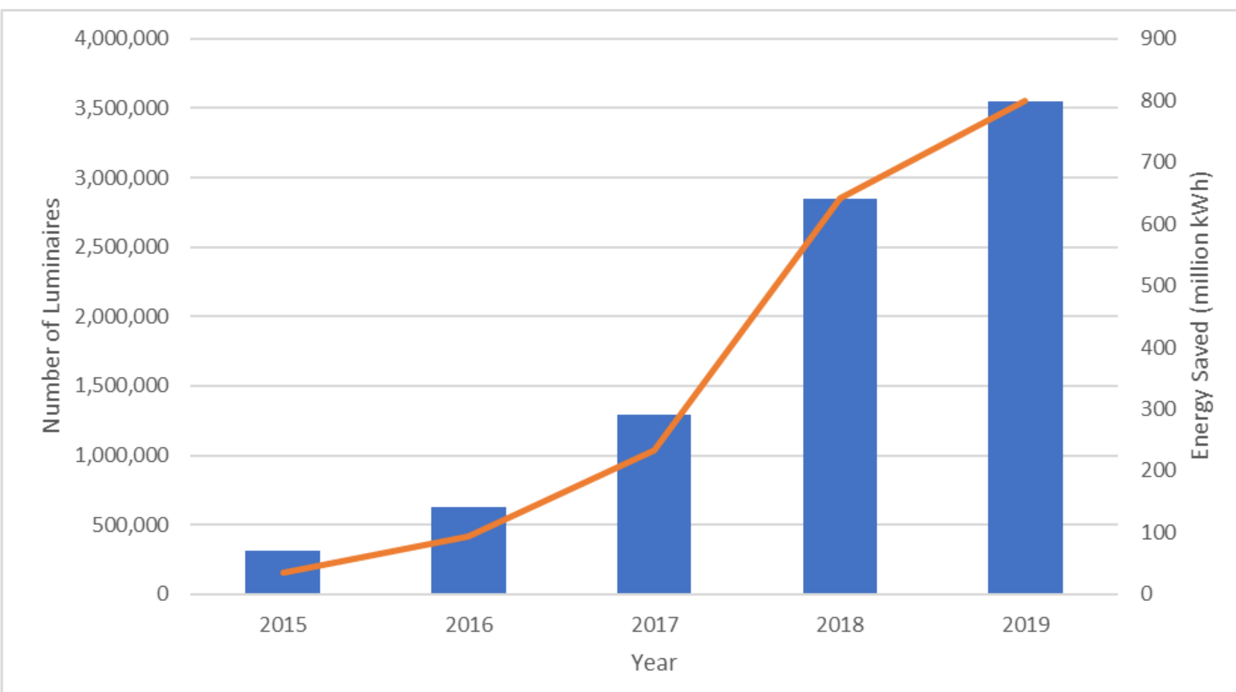
Organization	Year(s) Recognized	Organization	Year(s) Recognized
Alexandria City Public Schools	2018	Sustainable Technologies | Clean Harbors	2016
Avibank Manufacturing, Inc.	2018	Staples	2017
Baylor Scott and White Health c/o CBRE	2016 2017	T-Mobile	2016
Beaumont Health	2018	Target Corporation	2016 2017 2018 2019
BioStar Lighting*	2016	The Hartford Financial Services Group, Inc.	2017 2018
CBRE | McKesson	2019	Thrust IV | Stonebridge	2018
CHRISTUS Health	2016	Tutera Real Estate	2016 2017
City of Spencer	2017	University of Utah Health	2018 2019
CKE Restaurants Holdings, Inc.	2016	U.S. Air Force - Kadena Air Base	2018
Cleveland Clinic	2016 2017	U.S. Air Force - Nellis Air Force Base	2018
Columbia Association	2017 2019	U.S. Army Fort Knox	2019
DiVi Energy*	2017	U. S. Army Reserve – 9th Mission Support Command	2016

Four Seasons Family of Companies	2018	U.S. Army Reserve – 99th Regional Support Command	2016
Jewish Community Center of San Francisco	2018	U.S. Army Reserve – 88th Regional Support Command	2017
Grace Bible Church	2017	U.S. GSA	2016 2018 2019
Life Time Fitness	2017 2018	U.S. Toy Co.	2016
MGM Resorts International	2018 2019	Walgreens	2019
Northern Arizona University	2016	Whole Foods Market	2019
River Trails District 26	2018	Yamaha Motor Corporation	2018 2019

*Received Supporter Recognition

3.2 Energy Savings

After receiving and processing the data received, PNNL applied the average savings numbers to the rest of the participant's pledges so that an assumed level of energy reductions can be estimated across the entire ILC participant base. As stated earlier, data for 90% of the total number of luminaires stemmed from data submitted; therefore, the extrapolation to the full number of luminaires is not a significant extrapolation. Figure 3. Campaign Participants by Organization TypeFigure 6 depicts per year the number of luminaires added to the ILC as well as the cumulative energy saved per year of 799 million kWh from the lighting systems (equipment and controls).



- The bars indicate the cumulative number of luminaires per year. In 2019, the cumulative number exceeded 3.5 million fixtures.

- The line indicates the cumulative annual energy savings estimate of those luminaires. In 2019, the cumulative value was just under 800 million kWh saved annually (actual value was 799 million kWh).

Figure 6. Yearly Number of Luminaires and Cumulative Energy Saved

Although project size was arbitrarily defined by the ILC (small <25 luminaires, medium 25 to 200 luminaires, large >200 luminaires) the energy savings on a per luminaire basis was roughly the same regardless of the quantity of luminaires that were part of the project (see Figure 7). This would be expected because there is no reason that the number of fixtures should significantly affect the energy savings per luminaire. It is worth noting that the greatest range of savings was for the large projects. This is because there were 10 times more large projects than small projects submitted, thus more variation.

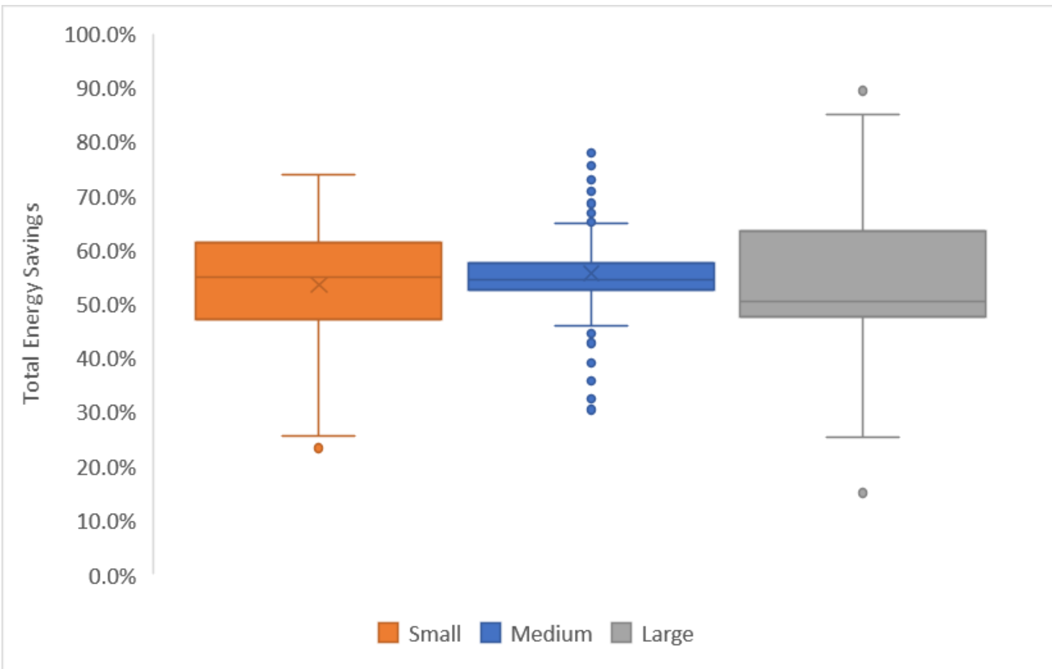


Figure 7. Energy Savings Characterized by Project Size

Alternatively, Figure 8 is a histogram of total energy savings as a portion of the projects submitted. Most of the projects had energy savings of between 45 and 60% of the lighting energy.

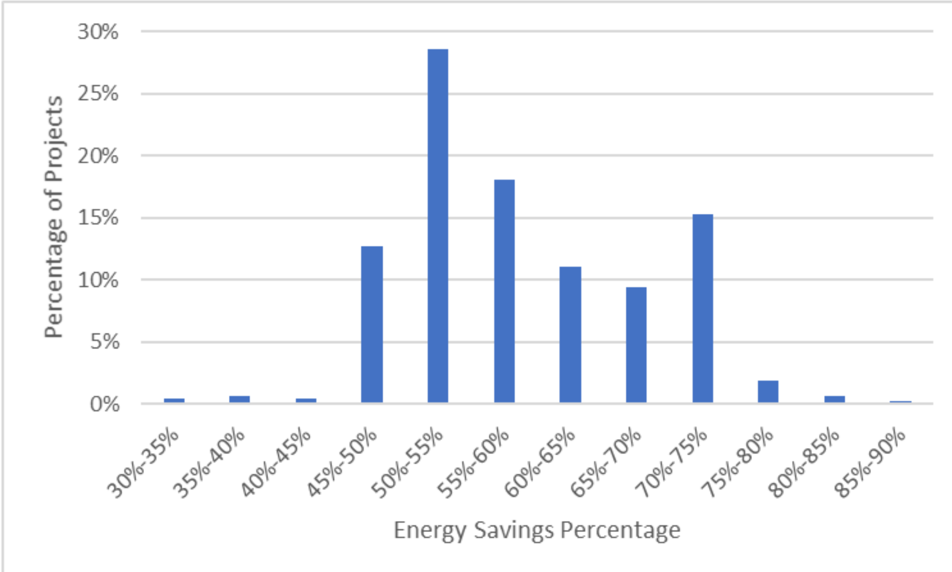


Figure 8. Histogram of Total Energy Savings for Submitted Projects

It is worth noting that greater energy savings were possible for retrofit applications (due to older inefficient technology) than for new construction projects (savings were compared to luminaires used to meet current code). The percentage of data submitted was vastly related to retrofit projects (≈90% retrofit versus 10% new construction). Also, the ILC was technology neutral; however, minimum energy-efficiency requirements (see section 0) were established. The initial value of 85 lm/W allowed LED fixtures and only a very small number of fluorescent fixtures to meet the requirements. The latter requirement of 105 lm/W meant that only LED products could meet the requirements. Post 2018 market data also indicate that LED equipment is the default equipment of choice for very high efficiency systems and systems that required advanced control.

Table 7 provides additional aggregated project savings information by year, including number of buildings submitted, energy use per fixture, estimated percent savings, and estimated controls savings.

Table 7. Energy Use Summary of Submitted Buildings, by Year

ILC Year	Average Savings*	Equipment Savings†	Control Savings if Deployed††	Portion of Buildings using Controls	Energy Use per Fixture** Baseline	New	Equipment Savings
2016	53%	49%	18%	35%	610	300	310
2017	54%	53%	14%	6%	246	110	135
2018	54%	43%	11%	11%	444	187	257
2019	55%	42%	13%	45%	406	186	220

Note:
*Average savings includes savings from high-efficiency equipment and lighting controls if applicable
** Savings may not equal baseline – new because of rounding
† Equipment savings only applies to savings from high-efficiency equipment
†† Control savings if controls are deployed at the site. Equipment savings + Control Savings if Deployed ≠ Average Savings

With projects yielding a wide range of savings, it is worth taking a closer look at some of the outliers and recognize any similarities between the projects. On the lower end of the range, projects saving very little energy were naturally excluded because the equipment installed on some projects did not meet the minimum performance requirements for participation (see section 0). Projects that saved a significant amount of energy, such as those that achieved saving of 70% or more, typically utilized some level of lighting controls. There were, however, several buildings that saved more than 70% without applying any lighting controls. This was from a combination of not only efficient equipment being installed in the upgrades, but also very inefficient incumbent baseline lighting system.

3.3 Lighting Equipment Energy Savings

Figure 9 depicts the typical equipment savings (e.g., replacing the light sources, installation of a retrofit kit, or luminaire replacement) in retrofit applications.

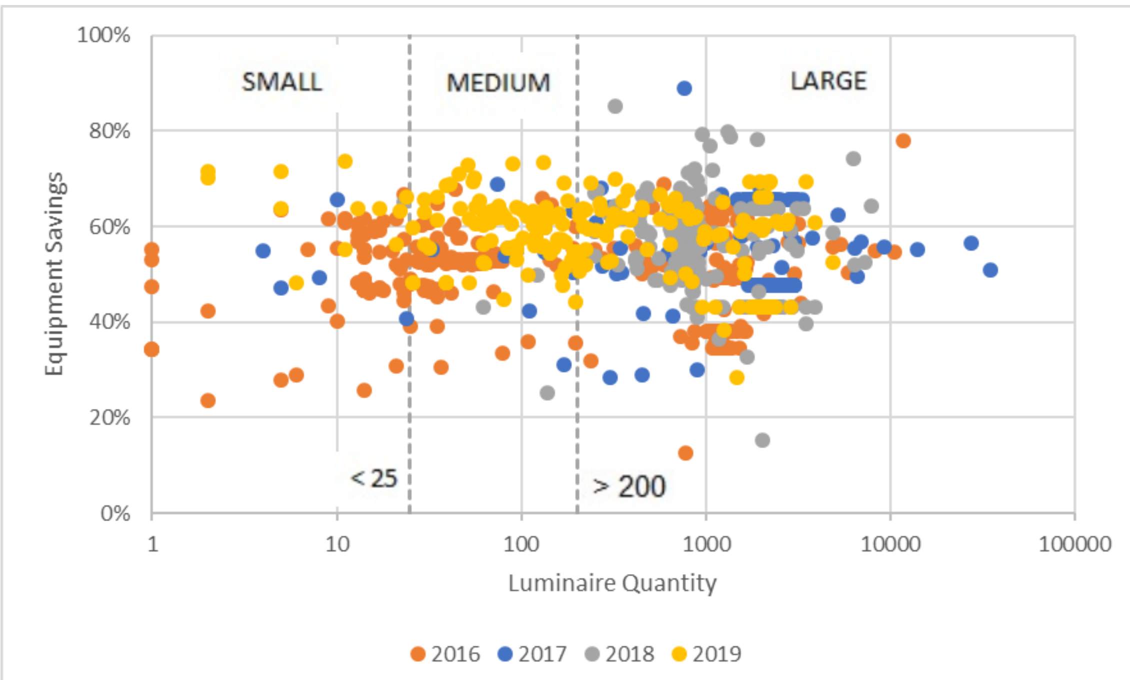


Figure 9. Typical Savings from Equipment Upgrades in Retrofit Applications

Figure 9 show the project size bins separated by gray dashed lines. The campaign defined small (<25 fixtures), medium (25–200 fixtures), and large (200+ fixtures) projects. Regardless of the number of fixtures modified in the retrofit process, the savings were in the mid-50% range. The mean and median savings were 54%. Overall savings were within a similar range for projects submitted 2017–2019. Projects submitted in 2016 were lower than the other years, this is probably because interior LED products both increased in terms of efficiency and availability as the ILC progressed over time.

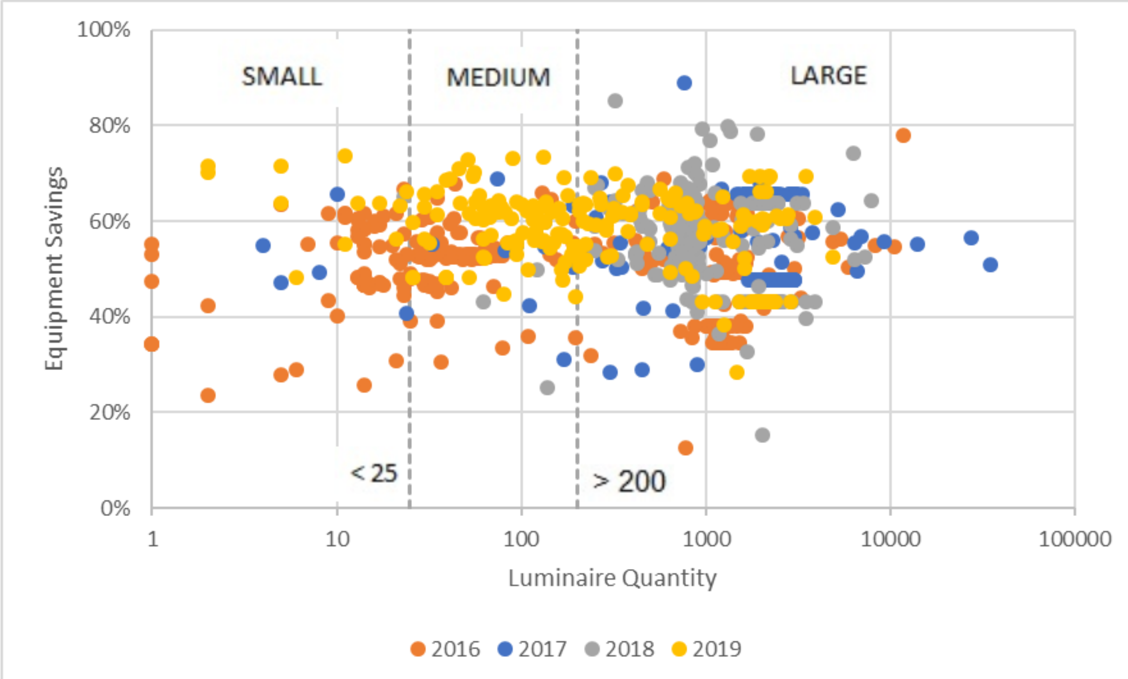
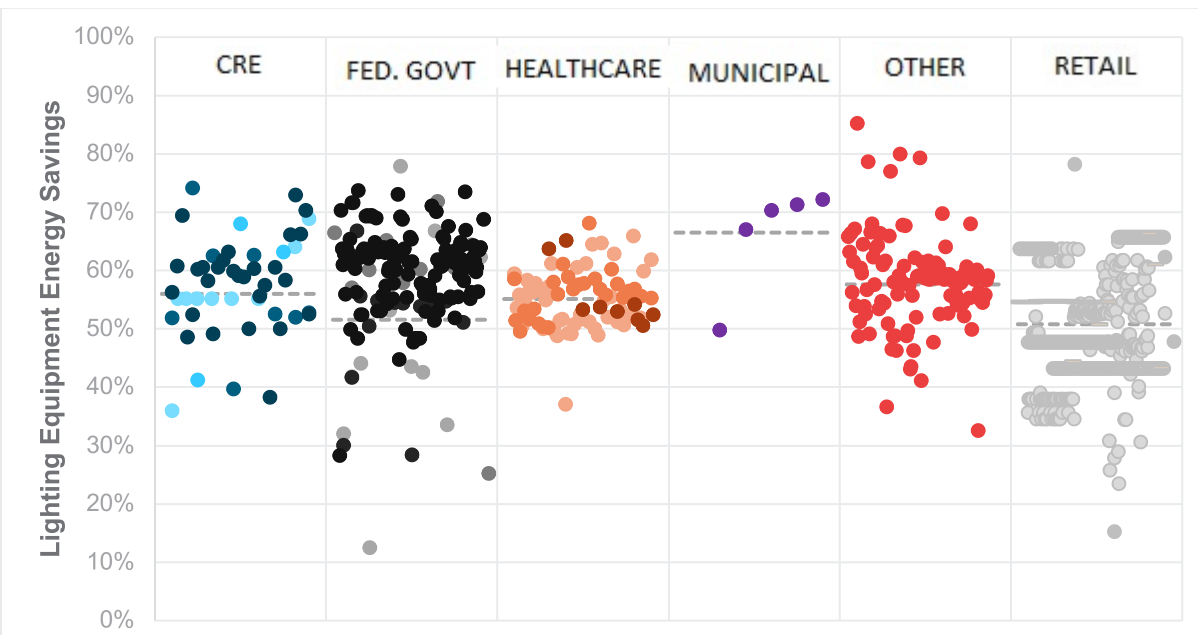


Figure 9Figure 10 depicts the typical equipment savings (e.g., replacing the light sources, installation of a retrofit kit, or luminaire replacement) in retrofit applications comparing the sectors directly.



CRE = Commercial Real Estate. The gray dashed line per sector indicates the mean equipment savings per sector.

Figure 10. Typical Savings from Equipment by Sector in Retrofit Applications

Although the mean equipment savings across all sectors is roughly 54%, as shown in Figure 7 the range of savings can vary significantly from 17%–85%.

The typical equipment savings in new construction applications is shown in Figure 11. The baseline for new construction was a fixture with efficacy that could meet 2016 energy codes. The mean savings was 37% from the lighting equipment, regardless of the project size or luminaire quantity.

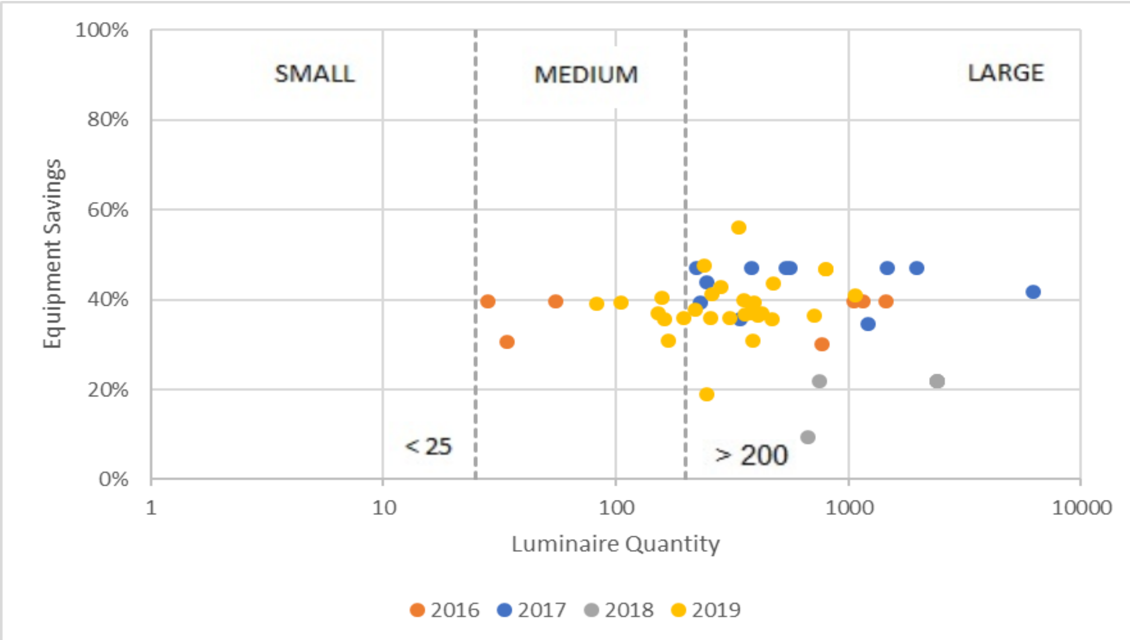


Figure 11. Typical Savings from Equipment Installations in New Construction Applications

3.4 Lighting Controls Savings

Lighting controls were applied most frequently to large projects. Figure 12 depicts the number of submissions by project size that did (or did not) utilize some form of lighting controls.

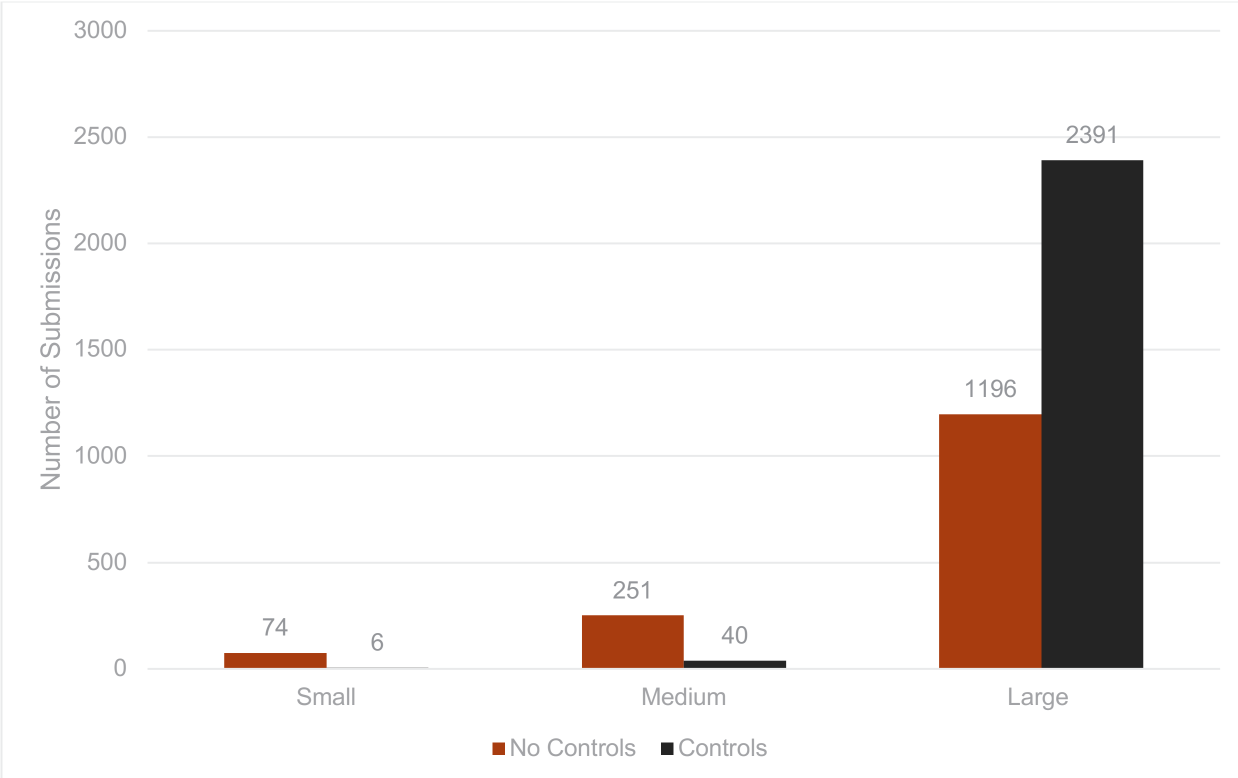
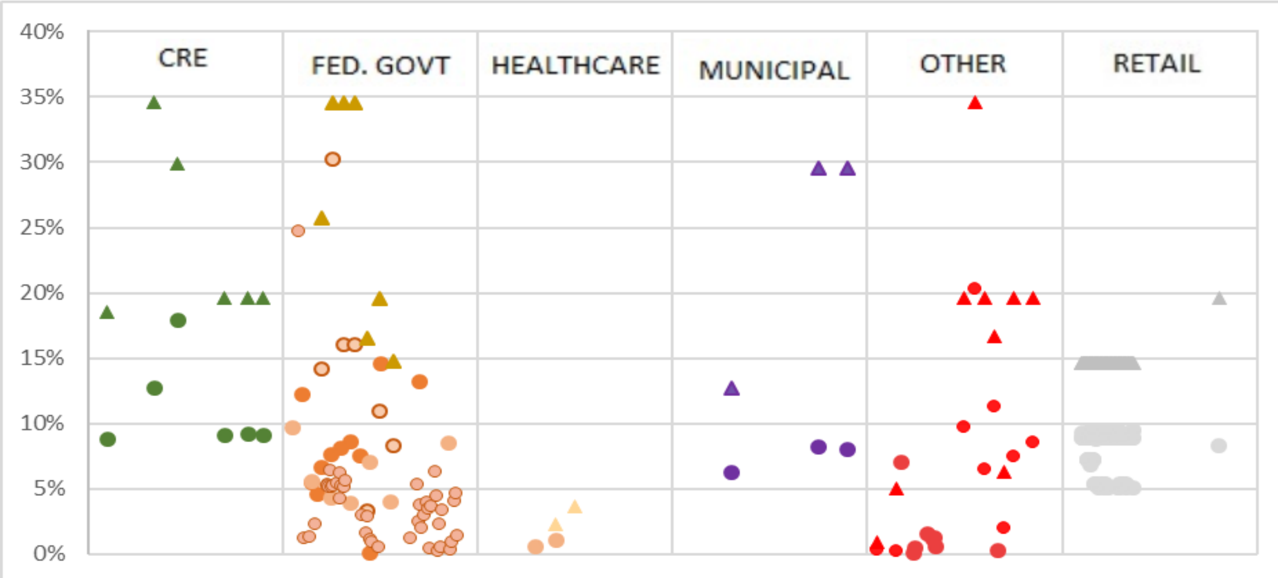


Figure 12. ILC Submissions Utilizing Controls

Only 8% (6 of 80 total) of small projects and 14% (40 of 291 total) of medium projects submitted for ILC recognition consideration had any level of associated controls savings, whereas 67% (2,391 of 3,587) of the large projects utilized one or more of the control strategies (time scheduling, dimming, occupancy-based sensing, or daylight harvesting) considered in the ILC analysis. That said, the 67% value for large projects might be misleading. A large set of the large projects were retail facilities that utilized time scheduling to reduce certain lighting circuits during stocking periods. Lighting controls are often considered active controls like occupancy or daylighting, but time scheduling can be an effective control as well especially in applications like retail where significant use of occupancy sensors can be problematic.

Figure 13 depicts the typical energy savings from the implementation of lighting controls. Fewer projects utilized active lighting controls (i.e., occupancy or daylighting) compared to the upgrading or retrofitting of luminaires. As stated earlier, the sizeable number of large projects utilizing controls was time-based switching that turned off certain lighting in retail facilities. The controls were in addition to the new efficient equipment.



- Round symbols represent the control savings compared to the original baseline. In contrast, the triangular symbols indicate the lighting control savings compared to a new equipment baseline.
- Different shades within the same sector indicate different year recognition.

Figure 13. Lighting Control Energy Savings by Sector

The energy savings shown in Figure 13 are whole project lighting energy savings as a result of the installation of high efficiency lighting equipment and/or lighting controls from either a retrofit or new construction. The portion of lighting project energy saved is not sector specific, but more driven by the portion of lighting equipment utilizing lighting controls. For example, the low values in the healthcare sector stem from that only 16% and 22% of the light fixtures in the two projects utilized lighting controls. In contrast, the greater lighting project energy savings from lighting controls (e.g., 10% – 15%) shown in the Commercial Real Estate and Federal Government directly stems from 80% – 100% of the light fixtures on those projects utilizing some type of lighting control. Further, the circle controls values are affected by the energy savings from the replacement of the light fixture. The greater the wattage reduction between the baseline and new equipment can affect the total controls savings.

Figure 14 visually depicts the data in Figure 13 by comparing the number of fixtures utilizing lighting controls and whole project lighting energy savings. As shown in Figure 14, as the portion of fixtures utilizing lighting controls increases, the whole lighting project energy savings from lighting controls also increases. Similar to Figure 13, the circles in Figure 14 reflect the original fluorescent baseline and the triangles reflect the new equipment (LED) baseline. When comparing to the fluorescent baseline, lighting controls will always represent lower savings than when compared to the new equipment baseline. This is because a large bulk of the energy savings when converting from the fluorescent baseline is in the form of the new equipment. In contrast, when new equipment is the baseline, the savings stem solely from the lighting controls.

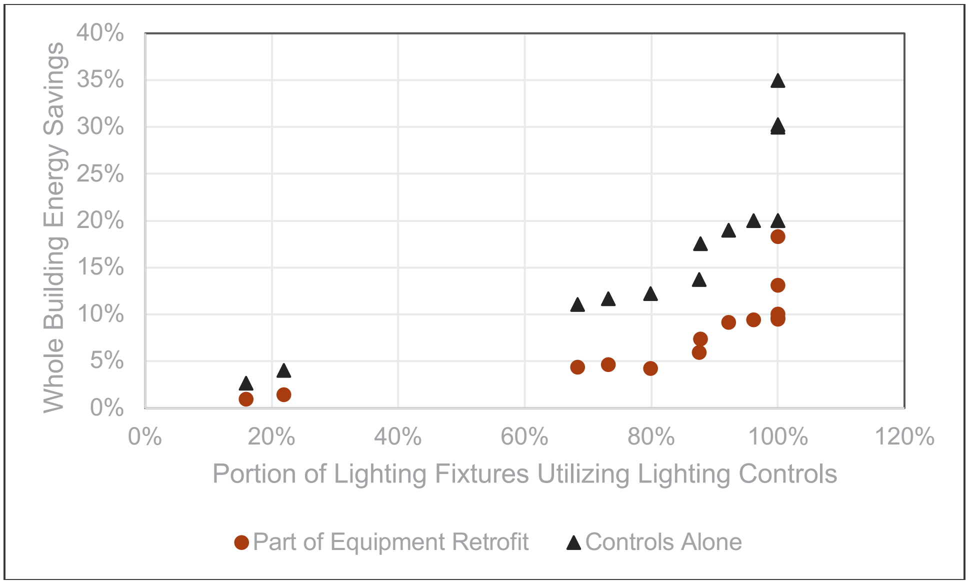


Figure 14. Relationship between portion of light fixtures utilizing controls and whole project lighting energy savings

3.5 Cost Analysis

Energy savings per fixture varied by fixture type. Table 8 presents the average savings by fixture and the possible monetization of those savings.

Table 8. Monetization of Energy Savings

Luminaire	Average Energy Savings (kWh) Per Luminaire Type	Electricity Rate $ / kWh	Annual Savings
Troffer	219	$0.1057	$23.15
Suspended Linear	480	$0.1057	$50.74
High-Bay	1040	$0.1057	$109.93
Low-Bay	505	$0.1057	$53.34

The energy savings per luminaires has a direct relationship on cost effectiveness metrics. Electricity prices vary both regionally and annually. An average price (blended rate) of $0.1057/kWh was used for this analysis. Although the portion of energy saved is significant (typically greater than 50%), the monetized value demonstrates that the first cost (material and labor) has to be limited to achieve desirable cost effectiveness. A common desired simple payback (SPB) period from retailers and commercial real estate organizations is typically 3 years or less. Thus, for a troffer to achieve the desired very low SPB, the total installed first costs (labor and material) could only be around $60. However, this analysis only monetizes the blended electricity rate. If organizations utilized or monetized benefits of utilizing controls to better interface with electric grid benefits or monetize any non-energy benefits available from the lighting system, the first cost of the system would not have to be so low. Features of the lighting system beyond just energy costs need to be monetized.

Although the ILC does not require cost data as part of the recognition application, some participants provided certain cost data. This was typically associated with information provided for ILC case studies of recognized participants published in 2016 and 2017. The SPB varies per site as would be expected. However, the SPB is lowest from large equipment installations, which would be expected in a bulk procurement.

Table 9 compares the total energy savings compared to the SPB achieved by the project.

Table 9. Energy Savings Compared to Simple Payback

Sector Type of Project	Total Energy Savings	SPB (years)	Number of Luminaires
Retail (IoT Sensors)	48%	1.6	1,928
Retail	53%	4.0	57
Commercial Real Estate	55%	2.9	35
Healthcare	55%	4	14,107
Federal Government (IoT Sensors)	57%	*78*	1,507
Healthcare	58%	1.6	3,785
Federal Government	62%	5	424
Healthcare	67%	3.31	2,994
Commercial Real Estate	74%	2.75	60
Federal Government	74%	*15*	40
Federal Government	82%	*10*	11,802

In Table 9, the three projects with payback periods exceeding 10 years are federal sector projects (shown in italics). Two of these projects had deep savings exceeding 70%. Deep energy savings may be possible, but may also require extensive equipment and coordination, thus affecting the payback periods. The federal project that saved 57% (78-year SPB) of the energy incorporated IoT sensors that interface with the HVAC system as well as provide space utilization data. Beyond the IoT sensors, this specific federal site was in a historic building, which affected the lighting design and required more fixtures than normal affecting the cost effectiveness for this project. Monetary benefits from interfacing with the HVAC or space utilization were not factored into the cost analysis and thus the long SPB is an outlier and other features should be monetized into the analysis. Because federal facilities have long lease periods or tend to own their buildings for significant periods of time, longer payback periods can be justified and allowed.

Two projects submitted for recognition utilized advanced IoT sensors—a federal site and a retail site. The federal site saved 57% of the lighting energy with a 78-year SPB. In contrast, the retail site, Target, saved 48% of the lighting energy with a 1.6-year SPB. There are many differences between the two projects that account for the large difference in cost effectiveness. Target was renovating a significant portion of their portfolio, more than 1,000 sites within the retailer's portfolio, and was able to leverage economies of scale because each building within the portfolio was roughly the same as the retailer's prototype. Target was also able to leverage the number of projects to reduce the cost of labor. In contrast, the federal site is a one-off field evaluation project with the primary goal of examining a technology that utilized a new sensor technology, requiring the contractors to learn on the site about the technology. Another major difference between the two projects is the equipment density. The federal site was in a historic building with a unique ceiling construction requiring a specific number of luminaires. As a result, the federal site had 1 luminaire per every 39 ft^2. In contrast, the retail site had a higher ceiling with very few architectural limitations and thus the spacing was 1 luminaire per every 70 ft^2—a value much closer to typical light fixture density.

3.6 Enablers and Barriers

Enablers and barriers identified through the course of technical assistance and data collection, and through feedback from ILC sites that received recognition for exemplary performance are summarized in this section. Findings from DOE's Next Generation Luminaire Systems (NGLS) are also included, as they provide insight as to the struggles installers face when installing advanced lighting systems (Taylor et al., 2018).

Insights into successful campaign design and implementation, including the ILC and other DOE adoption campaigns can be found in a separate report (Myer et al., 2018). Since the onset of the ILC in 2015, some of these barriers have been eased in part through enablers, such as those identified in Table 10, and through technology advances. For example, LED technology performance has improved, and costs have come down significantly.

Table 10. Enablers and Barriers to Successful Adoption of High-Efficiency Lighting Systems

Category	Barriers	Enablers
Specification and product selection	• Identifying acceptable LED replacement luminaires/retrofits • Lack of clarity about luminaire compatibility with controls and/or sensors • Ensuring rebate applicability based on product selection	• High-Efficiency Troffer Specification • Case studies of ILC sites recognized for exemplary performance sites • ILC reports and fact sheets, including: LED Retrofit Kits, TLEDs, and Lighting Controls: an Application Guide; Upgrading Troffer Luminaires to LED; • *Qualified Products Lists* including: the DLC's Solid-State Lighting, DLC's Networked Lighting Controls
Installation and commissioning	• Complexity of advanced lighting control system's architecture and operation • Adequate manuals and documentation that clearly and effectively relays necessary information.	• ILC technical assistance
Cost and utility incentives	• Organizations with sites in numerous utility service areas face issues with identifying available incentives across their portfolio Advanced systems with enhanced controllability are more expensive, limiting their use / specification	• *Incentives Database:* ILC database; third-parties like Briteswitch; DSIRE, etc.

3.7 Lessons Learned - ILC Recognized Participants

Many of the projects that received recognition in 2016 and 2017 provided data and information that were used by DOE to develop case studies documenting performance and lessons learned that not only provide insight for others undertaking lighting upgrade projects, but also provide an indicator of remaining challenges to the more widespread application of high efficiency lighting systems. Table 11 lists the lessons learned shared by those sites.

Table 11. Complied list of lessons learned from 2016/2017 recognized participants

Lessons Learned
Planning
• Spend time in the planning phase. Accurately assess lighting needs by doing site audits. • Be prepared to take the time to specify eligible fixtures and fill out documentation required for incentives. • Create a total project plan to help keep large projects on schedule, but factor in time for testing, obtaining funding, and getting contracts in place.
Product Selection/Procurement
• Complete table-top and onsite testing to identify potential glare or color rendering issues, as well as compatibility with any additional building systems and/or sensors and controls. • Use resources like the DLC qualified product list to find high-quality, high-efficiency commercial lighting solutions. • When selecting a supplier, consider factors such as the warranty, volume discounts, and ability to deliver as needed rather than all at once when storage space is limited.
Maximizing Benefits
• Work with a knowledgeable designer to help improve overall project savings with optimum fixture selection, spacing, and placement. • Look for opportunities to redesign lighting layout and reduce luminaire counts for additional savings. • Combine new lighting with controls to increase energy savings and facilitate demand reduction. • Install daylight harvesting controls in spaces with windows to maximize the use of daylight and energy savings.
Installation
• When evaluating proposals from retrofit lighting installers, consider installation schedules. The vendor's ability to conduct installations at night or on weekends to avoid disruption of production or retail hours may be critical to project success.

Lessons Learned

Financing

- Pursue incentives, often offered by local utilities to help offset the costs of more efficient lighting system.
- Take advantage of utility offerings such as rebates, on-bill payment, and zero-interest loans to improve project feasibility.
- Understand that lamp-only retrofits can be cost effective even without incentives, because LED product quality has been improving while prices have been decreasing, but these cost savings come with big performance drawbacks in terms of controllability and possible future upgradability.

Other Benefits

- In new construction, understand that LED lighting can play a big part in meeting LEED certification goals.
- Look for upgrade opportunities to improve system design and performance in terms of visual needs, usability, and integration with other building systems.

Many of the lessons learned pointed to resources that are available through the ILC such as technical information to use during the planning and product selection stages of the project. Rebates and incentives were frequently utilized but were not always required to make projects cost effective.

3.8 Challenges and Opportunities Related to Advanced Lighting Systems

DOE supports several initiatives targeted at advanced, connected, and integrated lighting systems via research, field validation studies and other efforts. The Next Generation Lighting Systems (NGLS) program in particular provides important insights as it relates to the next generation of high efficiency lighting and control solutions. NGLS evaluates connected lighting systems in real-world installations, in order to identify challenges in installation and operation, reveal needed product improvements, and articulate principles and best practices that will reduce configuration complexity and enable system performance to meet expectations. The following are insights drawn from PNNL's experience with ILC participants, related advanced lighting field validation studies, and a recent NGLS study of 12 connected lighting systems that were marketed as being easy to install and configure. These systems represent a range of control options and luminaire types, including linear pendants, troffers, and retrofit kits (Taylor et al., 2018). Below are observations from these studies:

- **Easier commissioning / configuration of controls.** Manufacturers have more work to do to match systems to applications and then deliver fully on their promise of "easy to use." However, given that most of these systems have been on the market for a short time, and the diversity of approaches taken, early evaluations to date are encouraging. It is also promising that some manufacturers are actively involved in other DOE-supported programs addressing these configuration and commissioning challenges to refine and improve their systems so that promised energy savings can be delivered.

- **Scalable solutions.** Although building owners and managers have a better understanding of LED technology than when the technology was first introduced, many continue to install simple solutions and are not including controls or advanced IoT features. These building owners and operators are missing out on future possible IoT benefits because it is costly to retrofit the fixtures in the future. The large energy and thus monetary savings were realized with the introduction of the LED equipment, and the incremental cost for installing IoT sensors can be cost prohibitive. Some, but not enough, manufacturers are offering scalable solutions that allow for the sensor or components to be deployed at installation and then at a future date to fully deploy the IoT system.
- **Detailed fixture data.** As building owners consider wellness or healthy building systems, they need more data. The spectral power distribution (SPD) is critical in analyzing the lighting for potential wellness aspects; however, acquiring these data can be either very costly in the field or extremely hard to get from the manufacturer in advance. Manufacturers need to provide detailed SPD data and make it easy and standardized for designers and owners to use.
- **Realizing energy savings from controls.** Even "simple" connected lighting systems present significant challenges to successful installation and configuration. These systems are unlikely to deliver promised energy savings without support to address the critical but often overlooked element of all sophisticated technology: the people who install, configure, and use the systems. Utilities that promote connected lighting systems could play a significant role supporting the people involved in implementation of these systems. Development of template specifications for customers interested in simple lighting control systems could be developed to address this issue. These specifications could include user selections for desired functionality to align system complexity with user needs.
- **Documented third-party data on valuation.** Owners understand LED fixtures and retrofits save energy. However, owner and building managers want extremely short 3-year SPB for lighting upgrades. As shown in Table 8, even saving 50% of the lighting energy, the monetized energy saved, is roughly $20 - $50. Manufacturers need verified data and resources that show the value of advanced lighting systems. Data to easily convey to owners the value of the lighting for demand reduction or peak load management are needed without having to do full-scale building or rate tariff analyses. Pilot projects have demonstrated that space utilization or interfacing with customers is possible, via IoT lighting; however, data on the value that can be incorporated to sell these advanced features are not available.
- **Incentives beyond simple widget metrics.** Manufacturers and utilities could collaborative efforts to address documentation issues, making incentives easier to obtain. For instance, utilities could establish minimum documentation requirements for control systems to be eligible for incentives. Since installers identified a strong preference for quick setup guides and online videos, these could be two of the required documents.
- **Incentive-based training.** Utilities could require contractors to complete lighting controls training in order to be eligible for incentives, or they could develop and deliver their own training programs. They could also collaborate with other stakeholders, such as manufacturers and regional energy efficiency organizations, to deliver training. To assist with user education, utilities could also consider a requirement that installers provide a formal handoff and training for the building owner or representative at the end of the job.

It is important to note that the systems evaluated by DOE (e.g., field validations and NGLS) represent new and innovative approaches that have typically been on the market for less than a year. Given the diversity of approaches taken, the results of the evaluations to date are encouraging, since manufacturers are actively involved in the process and are using the feedback from the installations to refine and improve their systems so that promised energy savings can be delivered.

4.0 Conclusions

From 2015–2019, the ILC documented 3,545,185 high-efficiency lighting systems upgraded or newly installed by participants. This number is greater than the ILC's goal of 3.5 million and represents nearly 800 million kWh saved. Energy savings associated with these systems is in excess of $85 million. In addition to 92 participants representing one of more buildings, the ILC also secured the support of over 180 supporters who pledged to support the goals of the ILC and to encourage participation. Table 12 highlights ILC results since its launch in 2015.

Table 12. ILC Highlighted Achievements

	Total
Total Number of Participants	92
Total Number of Supporters	181
Total Number of Luminaires	3,545,185
Total Energy Savings (million kWh)	799
Total Electricity Dollar Savings (million $$)	$85.45

Additional outcomes and achievements include:

- The ILC has received data on almost 4,000 sites with information about operating hours, numbers of light fixtures, wattage of light fixtures, and lighting controls. These data were used not only used for ILC recognition evaluation purposes, but also supported the 2015 Lighting Market Characterization (LMC) published by DOE (DOE 2017). The LMC is a detailed snapshot of the installed lighting equipment and characteristics for a given year (i.e., 2001, 2010, 2015). This detailed ILC data supplied represented a robust data set to help characterize lighting use in the United States.
- The ILC uncovered several barriers to adoption of high-efficiency lighting systems through close interactions with industry partners. These barriers were addressed through a variety of reports, case studies, fact sheets, and webinars. This information informed not only early adopters of these systems, but also product manufacturers as they design next generation lighting and control systems.
- Findings from the ILC, when combined with other high-efficiency lighting, controls, and integrated systems research led by DOE and others, helps inform the next generation of technology development.
- The ILC has established a network of partners, both participants and supporters, that have an established history of working with DOE, which can be leveraged for future work/projects.

4.1 Next Steps

The ILC minimum performance requirements, which were once achievable from only the most advanced products, are now becoming standard in the industry. With these market changes as well as data gathered from the ILC, it is fair to assume that a conversion from a fluorescent system to an LED system should be expected to net at least 40% energy savings, with savings closer to 50% being more typical. Technology is changing quickly, and complications associated with installation and performance are only becoming more pronounced as lighting systems increase in complexity and as there is more interest in integrating lighting with other building components and systems. More clarity on ways in which lighting can best be integrated and all benefits maximized would help building owners that continue to seek the most value out of their lighting upgrades.

Moving forward, DOE plans to re-position the ILC as an “Integrated Lighting Campaign” to serve as a portal, resource center, and data collection hub for new and novel lighting concepts, including those that are integrated with other building systems including plug loads and HVAC that can inform technology development and further accelerate technology uptake, leading to increased energy savings.

5.0 References

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Appendix A

Table A.1. Participants in the ILC as of September 2019

Adams 12 School District
Alexandria City Public Schools
Argonne National Laboratory
AviBank Manufacturing
Baylor Scott and White Health c/o CBRE
Beaumont Health
Bleyhl Farm Service Inc.
Block & Company Inc. Realtors
BriarPatch Co-op
CBRE
Chittenden East School District
CHRISTUS Health
City of Gillette
City of Spencer
CKE Restaurants Holdings, Inc
Clean Harbors
Cleveland Clinic
Columbia Association
Cowork Hive, LLC
Deddens Development
Department of Defense Washington Headquarter Services (WHS)
Deutsche Asset & Wealth Management
DiVi Energy, LLC
Fayette Academy
FDA
Forest City Realty Trust
Fort Knox
Four Seasons Family of Companies
Grace Bible Church
Gundersen Health System
Health University of Utah
JABIL
JCPenney
Jervey Eye Group
Jewish Community Center of San Francisco
Kilroy Realty Corporation
Kohl's Department Stores
Lamey-Wellehan
Las Vegas Sands Corp.
Lawrence Berkeley National Laboratory
Legacy Meridian Park Medical Center
Lewis and Clark National Historical Park
Lexington Co-operative Market
Life Time Fitness
Lush Cosmetics
M Riesco General Contractor
Macy's
May 2016 was deadline for Recognition submittal
Mercy Health
MGM Resorts International
Northern Arizona University
Oregon National Guard
Pacific Northwest National Laboratory
Panasonic - Arrow Electronics
Permaswage
Phoenix Area Indian Health Service
Plaistow Public Library
Portland English Language Academy
River Trails District 26
Sears Holdings Corporation
Stanford University School of Medicine
Staples
Swift Engineering
Target Corporation
Teslights
The Hartford Financial Services Group, Incorporated
The Wendy's Company
Thrust IV
T-Mobile
Tutera Real Estate
U.S. Air Force
U.S. Air Force- 412th Civil Engineer Group
U.S. Air Force- Kadena Air Force Base
U.S. Air Force- Nellis Air Force Base
U.S. Air Force- Vandenberg Air Force Base
U.S. Army Reserve- 63d Regional Support Command
U.S. Army Reserve- 81st Regional Support Command
U.S. Army Reserve- 88th Division (Readiness)
U.S. Army Reserve- 99th Regional Support Command
U.S. Army Reserve- 9th Mission Support Command
U.S. Department of Energy
U.S. Dept. of Veterans Affairs, Perry Point VA Medical Center
U.S. General Services Administration
U.S. Navy Sea Systems Command 05Z32
U.S. Toy Co.
UC Merced
University of California, Berkeley
Valley Natural Foods

Walgreens
Welltower
Whole Foods Market
Wilson Meany Property Managers for The Flood Building
Yamaha Motor Corporation

Table A.2. Supporters of the ILC as of September 2019

1-Stop Enterprises
Access Green, LLC
Acuity Brands Lighting
ADC Energy USA, Inc.
ALB Energy Solutions
Alloy LED
Alphalite, Inc.
ALSET LED
Anixter International
Artificial Sky
ARVA, LLC
Avantti Group
Axis LED Group
Axlen Lights
AZENTIVE
Beimini Sustainable Resources LLC
BioStar Lighting²
BlueRock Energy Services
Border States Electrical
Bramal LED Inc
BRIGHT FOOTPRINT, LLC
BSA LifeStructures
Burlington 2030 District
Cape Light Compact
Capital Tristate
CLEAResult
CMTA Consulting Engineers
Columbia Lighting Inc
ComEd
Comfort Lighting Inc
Concord Light
Constellation New Energy
Correlate
Cree, Inc.
Current, powered by GE
DECO Lighting
Del-Air Mechanical
Deltavation
Deltavation LLC.
DiVi Energy²
DMC Materials, LLC dba Firenze
DuPage County (Cool DuPage)
E Source
Eaton (formerly Cooper Lighting)
Eco Engineering, Inc.
Eco Revolution
EDF Climate Corps
Efficiency Vermont
EMC
EmilyGrene
Emium Lighting
Encentiv Energy
EnerGreen Sites
Energy Conservation Works
Energy Focus Inc
Energy Innovations Group, LLC
Energy Sciences Resource Partners
Energy Solutions
energybank
Engineered Tax Services
Envirobrite/Energy Planning Associates
ERG Lighting
Evergreen Consulting Group
Facilities Resource Group
Facility Innovations Group
Facility Solutions Group, Inc.
Finelite, Inc.
Focus on Energy
Franklin Energy Services
Georgia Power
Gleason Partners LLC
Golisano Institute for Sustainability / RIT
GoodMart, LLC
Gorgeous Lighting Co.,Ltd.
Graybar Electric
Green Facilities Solutions, LLC
Greentek Energy Systems
Groom Energy
H.E. Williams, Inc.
Hawaii Energy
HeSaLight
Hubbell Lighting
iLIGHTECH CANADA
Illumination Resources Inc.
Ilumen Consulting
Innovative Energy Solutions Corp.
Institute for Market Transformation
International Association of Lighting Designers
Jeff Miller & Company, Inc.
Joule Energy
Kaw Southwind Energy, LLC
Kenall Manufacturing
Krypton Lighting LLC
Lampviews Lighting Co., Ltd.
Latino Contractors Association
LED City
LED Energy Solutions
LED Living Technology Inc.
LEDVANCE (formerly OSRAM SYLVANIA)
Leviton Manufacturing, Inc.
LG Electronics
Light / Process / Design
LightEdison
Lights*Energy*Design
Los Angeles Cleantech Incubator
LOUVERS INTERNATIONAL
LUX LED Solutions
M Riesco General Contractor
Maalka Inc.
MaxLite
Metro LED Lighting
Midwest Energy Efficiency Alliance (MEEA)
Mirus Lighting
Molex
National Co+op Grocers

National E Solutions
National Energy Solutions, Inc
National Grid
National Retrofitting Group
NetZero USA for Industry
New Buildings Institute
Northeast Energy Efficiency Partnerships, Inc. (NEEP)
Northwest Energy Efficiency Alliance (NEEA)
OBX Computing Corporation
Ohyama Lights
Okapi Architecture
Orion Energy Systems, Inc.
Orion Lighting Solutions
Pacific Gas & Electric, Co.
Partner Energy
Pearl Street LED Lighting Systems
Penn Lighting Associates
Pepco Energy Services
Philips Lighting
Poli LED & Signs
ProSource Power LLC
PURE LED SOLUTIONS
Quiet Light Solutions, LLC
Regency Lighting
Retail Industry Leaders Association (RILA)
Revelation Energy & Lighting
Rexel USA
RITAL LLC
Robert Bosch LLC
Robinson Sustainable Builders, LLC
Rockwell Financial Group
RTK Energy, LLC
Sacramento Municipal Utility District (SMUD)
Samsung
SEDAC (Smart Energy Design Assistance Center), University of Illinois
Seventhwave
Silver Spark Lighting, Inc.
Sixteen5Hundred
Smart City Infrastructure
Smart Tracked
Southern California Edison
Southwest Energy Efficiency Project (SWEEP)
Southwestern Electric Power Company
Sterling Analytics LLC
Studio T+L, LLC
Summit Systems Inc.
SuperGreen Solutions of Charleston
Sustainable Technologies
Synergy Electrical Sales
Tasi, LLC
Teslights LLC
Thayer Corporation
The DesignLightsConsortium®
The Energy Alliance Group of North America
The Retrofit Companies, Inc.
The University Finance Foundation (TUFF)
Ucontrol Energy LLC
UpGrade Athens County
US Navy
Valley Electrical Contracting Inc.
Vansant & Gusler, Inc.
Virginia Industries for the Blind
Welkin Consultants, LLC
Wilco Electric Inc.
Wyndsor Lighting, LLC.
Yardi Systems

PNNL-29165

Pacific Northwest National Laboratory

902 Battelle Boulevard
P.O. Box 999
Richland, WA 99354
1-888-375-PNNL (7665)

www.pnnl.gov