Connected Lighting Systems Meetings Report

October 12, 2016

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Disclaimer

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Comments

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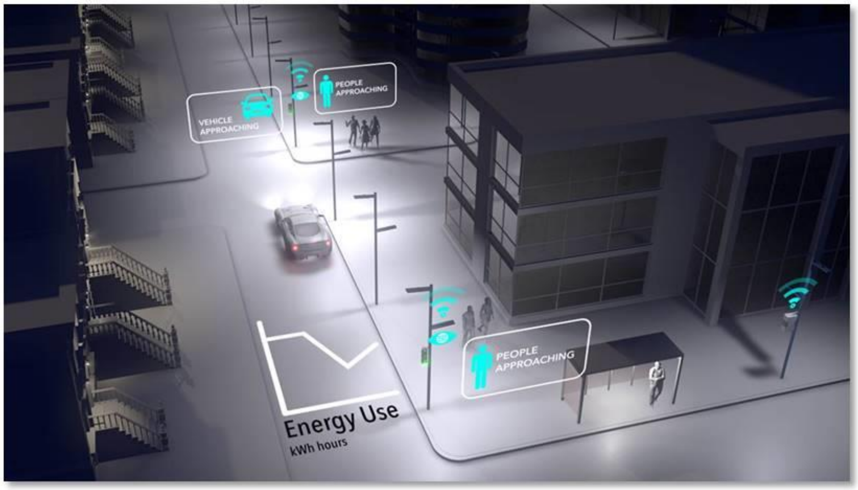
Introduction

The convergence of solid-state lighting (SSL) with the Internet of Things (IoT) is expected to facilitate an unprecedented exchange of data among lighting and other building systems, other devices (e.g., smartphones), and the Internet. The ubiquity of lighting in the built environment provides the opportunity to create a network of nodes for data collection in and near buildings, which can enable not only improved lighting control, but improved space utilization, management of building energy systems and security systems that can make use of shared data, and other features and capabilities yet to be identified.

Traditional lighting controls have seen limited deployment and resulting energy savings, due to their complex configuration, high cost, limited interoperability among devices from competing manufacturers, and the narrow range of people who know how to design, install, commission, and operate them. With such a small fraction of buildings currently using traditional lighting controls, and SSL rapidly replacing conventional incumbents, there is a significant opportunity to increase lighting-energy savings beyond what SSL alone can deliver, by enabling functional, flexible, adaptive lighting, which has the potential to deliver significant energy savings by adjusting the amount of light to real-time needs.

Connected lighting systems can leverage data collected from occupancy or daylight sensors, local controllers, personal devices (e.g., smartphones), or any combination of these, to implement sophisticated adaptive lighting techniques. Connected lighting systems have high potential for overcoming the barriers that have limited market adoption of conventional lighting controls.

SSL is fundamentally controllable, can be designed to be spectrally tunable, and can easily and inexpensively accommodate the integration of sensors, processors, and network interfaces. As such, it's poised to be the key that unlocks the energy savings potential of lighting controls. Intelligent, networked lighting devices with integral sensors could collect and exchange data with each other, implementing a new way to control light by leveraging new data streams, algorithms, and analytics. The value of services made possible by data from



Future connected lighting systems could become a platform for greater energy savings in buildings and cities.

networked SSL systems could partly or fully offset the incremental costs of the sensors, network interfaces, and other additional components, and could extend to such areas as health and wellness, safety and security, and tracking and location.

Connected lighting systems could become data-collection platforms that enable even greater lighting and non-lighting energy savings in buildings and cities, and much more. This ability to collect and exchange useful data, while possibly serving as the backbone of the fast-emerging IoT, has the potential to enable a wide array of services, benefits, and revenue streams that enhance the value of lighting systems and improve building systems that have long operated in isolation.

Right now, however, that potential is still on the table, as technology developers jostle with competing ideas, and assess how much to collaborate and how much to compete. In the best-case scenario, connected SSL will greatly improve lighting energy efficiency, lighting quality, and functionality, but this outcome is by no means assured. Lights could become just a platform for sensors and data collectors, without attention to energy efficiency or lighting quality. The U.S. Department of Energy (DOE) SSL Program's primary interest is in the potential of connected lighting systems to save more energy and provide better lighting quality than would be possible with SSL and traditional controls alone.

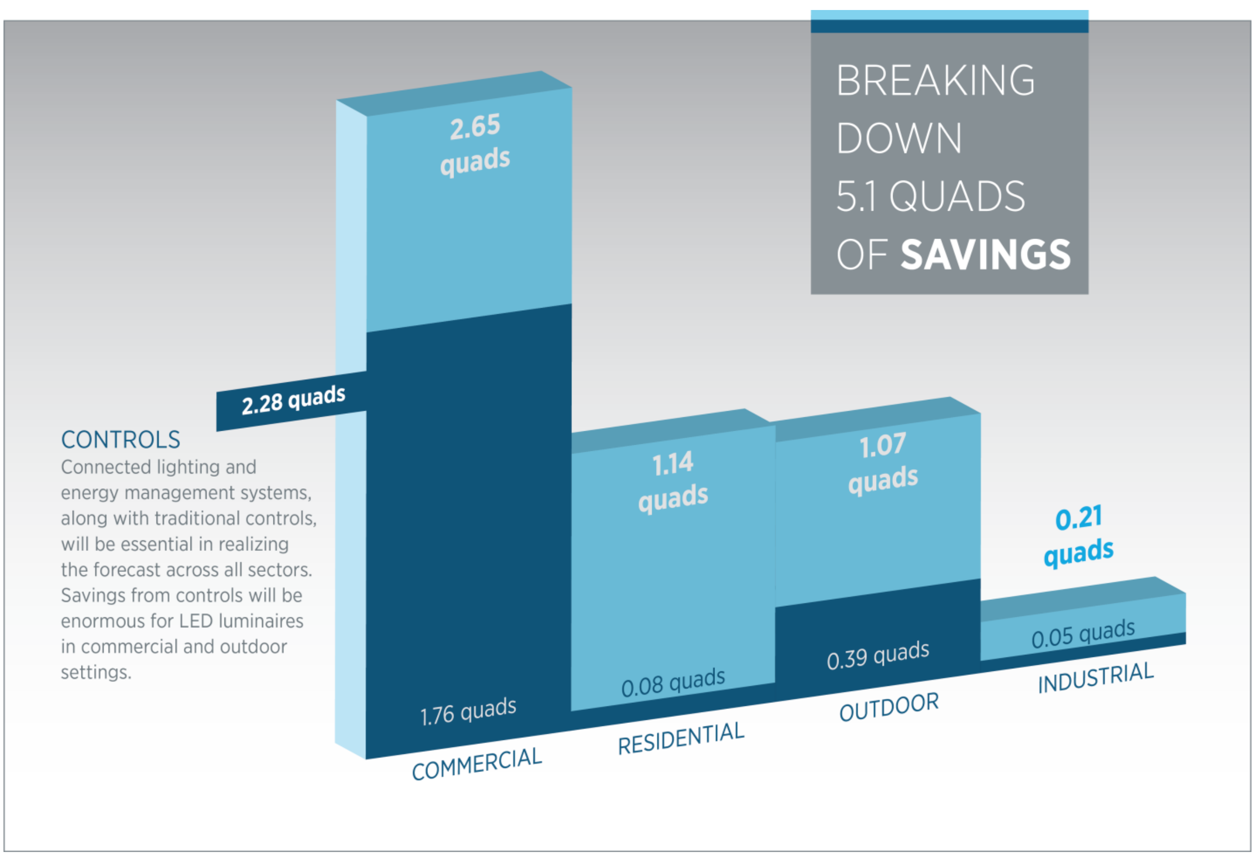
That's why the DOE is working closely with industry to identify and collaboratively address the technology development needs of connected lighting systems. Based on an overwhelming consensus of stakeholder feedback, in 2015 DOE launched a Connected Lighting Systems (CLS) Initiative, which works closely with industry and targets five focus areas:

1. **Energy reporting**: Data-driven energy management can significantly reduce energy consumption, but effective measurement methods are needed to reduce uncertainty.
2. **Interoperability**: System performance is dependent on the ability of devices to work together, and common platforms and protocols are needed to enable the transfer of usable data between lighting devices, other systems, and the cloud.
3. **System configuration complexity**: Systems that are overly complicated and time-consuming to configure have historically delivered less than ideal performance.
4. **Key new features**: High-value CLS features (e.g., resource and process optimization, health and productivity gains, new revenue streams) may offer benefits that match or exceed the energy savings delivered.
5. **Stakeholder collaboration**: Broad-based collaboration among the lighting, semiconductor, computing, and information technologies (IT) industries is essential to realizing the full potential of CLS.

A key component of the DOE CLS initiative involves hosting workshops to gather input from top experts from the lighting, semiconductor, computing, and IT industries, which facilitates collaboration and guides DOE SSL Program planning. DOE provides technical support for various industry standards development organizations working on energy-reporting test methods, as well as industry consortia developing platforms for greater interoperability. The DOE also characterizes the performance of market-available connected lighting systems and provides technical guidance to early CLS adopters, such as the City of Chicago.

Central to the DOE efforts is the development of a connected lighting test bed (CLTB) designed and operated by Pacific Northwest National Laboratory (PNNL). The results of technical feasibility investigations in the CLTB will increase visibility and transparency on what does and does not work, and create tight information feedback loops to inform technology developers of needed improvements related to interoperability, configuration complexity, energy reporting, and key new features.

These efforts are well worth it. If DOE SSL Program goals for LED efficacy are met and accelerated market adoption of connected lighting is achieved, annual savings from LED lighting will reach 5.1 quadrillion Btus (quads) by 2035, worth $50 billion in today's dollars and representing a 75 percent reduction in energy consumption. Of those 5.1 quads in annual energy savings, nearly half (2.28 quads) is made possible by the penetration of connected LED lighting along with traditional controls.



Focus Areas

At the initial connected lighting strategy session held in March 2015, there was a strong consensus among stakeholders that the DOE has a major role to play in the development of connected lighting, and that the DOE's Connected Lighting Systems Initiative should focus on five areas: energy reporting, interoperability, system configuration complexity, new key features, and facilitating stakeholder collaboration.

Connected lighting test bed facility at PNNL.

Central to the DOE CLS efforts is the CLTB, which includes a software integration platform that allows installed lighting devices and systems not natively capable of exchanging data with each other to be able to communicate through a defined middleware interface. Commercially available indoor and outdoor connected lighting systems have been installed in the CLTB, incorporated into the software integration platform, and made available for CLS and other studies.

A cybersecurity characterization capability is being incorporated into the CLTB in collaboration with Underwriters Laboratories (UL) and a variety of technology partners, as part of their effort to develop standard cybersecurity vulnerability test suites. The DOE will share test results with UL, and UL will share hardware and software improvements to the characterization system, as well as general security evaluation expertise, with the DOE.

Energy Reporting

Energy reporting is critical to connected lighting systems, for the simple reason that you cannot effectively manage what you cannot measure. One of the key reasons that electric utilities and energy service companies (ESCOs) have not invested more in lighting controls is uncertainty about the level of energy savings that will be achieved. To reduce that uncertainty, they sometimes resort to manual measurement and verification of lighting energy savings, which can push project costs much higher and even undermine their cost-effectiveness. Data-driven energy management can significantly reduce energy consumption and enable new market opportunities such as pay-for-performance energy efficiency initiatives, energy billing for devices currently under flat-rate tariffs, verified delivery of utility-incented energy transactions (e.g., peak and other demand response), lower-cost, more-accurate energy-savings validation for service-based business models, and self-characterization of available (i.e., marketable) "building energy services."

If connected lighting products have the capability to self-measure and report energy use, they can reduce the cost of energy savings measurement. Utilities could offer incentives to customers based on actual savings instead of estimated savings, and ESCOs could recover payments from customers based on actual savings. Both ESCOs and utilities could offer a more convincing business case to their customers and incur substantially lower costs to collect and analyze energy use data from lighting control projects. The availability of energy use data from luminaires with integrated energy measurement and reporting capability creates opportunities for other energy-management processes. Further, the opportunity to facilitate and develop transactive energy markets with such data could be exploited. A variety of market actors may be interested, including building owners looking to realize the value of available — and perhaps marketable — building energy services.

DOE is currently working with prominent electric utilities to analyze the energy-reporting accuracy of outdoor lighting controllers. Many utilities bill for energy using a flat-rate tariff system and have difficulty vetting the accuracy of commercially available products — a challenge that's exacerbated by the lack of dedicated industry standard and test procedures, and that further impedes utilities and municipalities from adopting more energy-saving connected lighting systems. DOE plans to compare the results from multiple test and measurement setups, and offer recommendations for device manufacturers, test labs, and standards developers.

In tandem with these efforts, DOE provides technical support for the ANSI C136–Standards for Roadway and Area Lighting Equipment committee, with a new focus on draft standards describing both energy reporting accuracy test and measurement procedures and one or more classes of performance. DOE also provides technical support and leadership for the Energy Prediction and Reporting working group in the recently formed ANSI C137–Standards for Lighting Systems committee, which is exploring the energy data accuracy needed for various existing and emerging use cases, including for example, the support of electric utility pay-for-performance incentive programs and the validation of ESCO energy efficiency project objectives. Test and measurement experience is needed to drive the development of standards in the committees listed above and, possibly, other committees poised to have market impact.

Interoperability

System performance is dependent not just on constituent device capabilities, but also on the ability of those devices to work together. Interoperability enables different devices, applications, networks, and systems to work together and exchange data. For users, it reduces the risk of device or manufacturer obsolescence, as well as the risk of having limited hardware, software, data, and service choices. It also improves system performance by facilitating multi-vendor systems, reducing the cost of incremental enhancement, enabling greater data exchange, and encouraging service-based architecture.

Traditionally, there has been little to no interoperability seen in market-available lighting-control devices and systems, as manufacturers have focused on developing and promoting their own proprietary technologies, or their own version of industry standards (e.g., the Lutron EcoSystem® extension of the international DALI standard). Interoperability is a key and much-discussed topic in these early days of the IoT; achieving it requires industry to agree on common platforms and protocols that enable the transfer of usable data between lighting devices, other systems, and the cloud. A number of consortia are working to do that, such as the ZigBee Alliance, oneM2M, and the Open Connectivity Foundation. As with the development of computing and IT technologies, these groups are taking different approaches or addressing different parts of the puzzle. At the moment, there currently remains little interoperability in commercially available lighting.

Stakeholders agreed that potential users of connected lighting need information on the benefits of interoperability and how to specify it. There is also a need for an interoperability test methodology that would enable independent testing and verification. Collaborative opportunities — such as test-bed plug-fests — would help to accelerate CLS developments in this area.

System Configuration Complexity

Historically, systems that are overly complicated and time-consuming to configure have delivered less than ideal performance. This is indeed the case with lighting controls, where the situation is compounded by a lack of standardization. Many contractors find it hard to master such a varied range of complex lighting control systems, so they bid up their prices in order to cover themselves. Moreover, such systems are difficult for users to maintain and optimally utilize. As a result, the potential energy savings just from the correct and consistent use of existing lighting controls is enormous, without taking into consideration the energy that could be saved from wider deployment. Connected lighting systems with increasing degrees of automated configuration — facilitated not only by embedded sensors and intelligence, but also by other features and capabilities that leverage the collected data — have the potential to significantly improve lighting system performance and increase its value. This, in turn, could lead to far more widespread use of lighting control strategies and greater lighting energy savings. Broad deployment of connected lighting systems will require system configuration complexity to be well-matched to owner/occupant capabilities, greatly simplified, or effectively removed.

DOE plans to incorporate a connected lighting systems category into the 2017 Next Generation Luminaires™ (NGL) Competition that involves the subjective evaluation of configuration complexity of connected lighting systems by a panel of impartial judges.

Key New Features

As lighting systems become more connected, it is anticipated that they will offer the ability to, for example, optimize resources and processes, deliver health and productivity gains, and yield new revenue streams. Further, it's likely that these capabilities will offer benefits that match or exceed the value of the energy savings they deliver. The value of services made possible by data from networked SSL systems might partly or fully offset the incremental costs of sensors, network interfaces, and other additional components. Systems made up of connected lighting devices could become data collection platforms that enable even greater lighting and non-lighting energy savings in buildings and cities, and much more.

Connected lighting's ability to collect and exchange useful data and possibly even serve as a backbone of the fast-emerging IoT offers the potential to enable a wide array of services, benefits, and revenue streams that enhance the value of lighting systems and bring that improvement to building systems that have long operated in isolation. In addition to a range of occupancy and daylight sensors, other types of sensors could be installed, including those to measure carbon dioxide, imaging, vibration, sound, and barometric pressure — resulting in such "smart city" features as air quality monitoring, weather warnings, theft detection, guidance to available parking spaces, and transit optimization. SSL is already being used as a platform for indoor positioning in retail and other heavy-traffic buildings, by using visible light communication to provide personalized location-based services for occupants via a mobile app. Retailers use the luminaires to transmit to shoppers location-specific data such as discount coupons or where in the store to find products. Beacons embedded in LED luminaires allow for the monitoring and analysis of building use and traffic, which can lead to operational efficiencies, enhanced safety, and increased revenues in spaces such as airports, shopping malls, logistics centers, universities, and healthcare facilities. Connected lighting is also being considered as a promising new source of broadband communication called Li-Fi, which modulates light to transmit data. And, connected lighting is being combined with spectral tuning in a variety of settings with the goal of improving mood, productivity, and health. DOE is providing technical support and assistance to Chicago's Smart Lighting Project, which is poised to install the country's largest municipal connected lighting system.

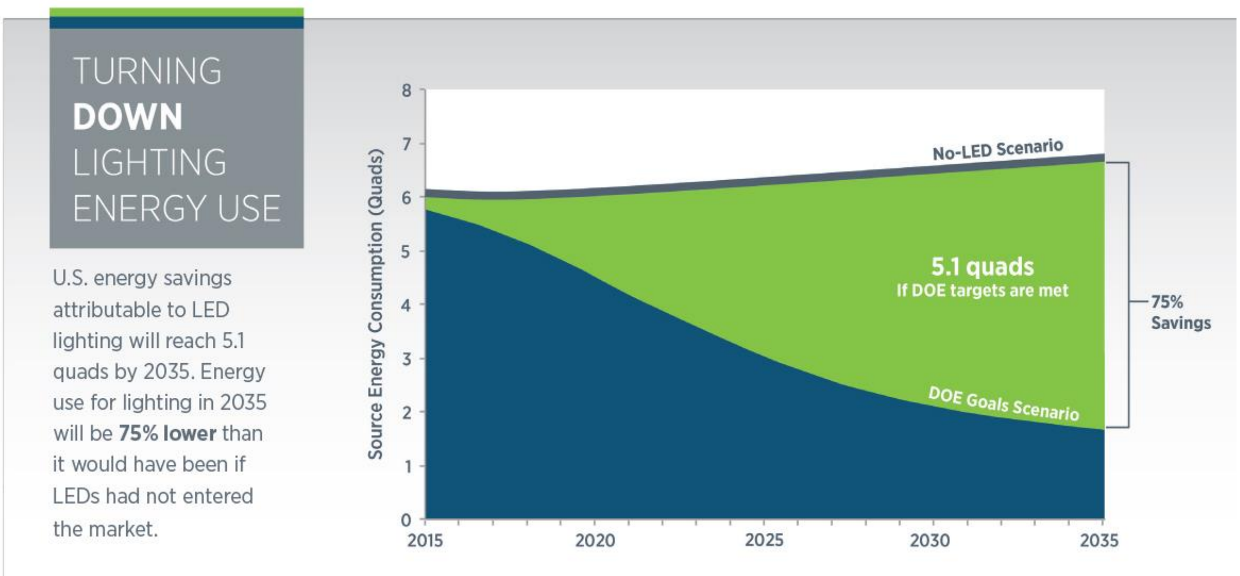
Stakeholder Collaboration

Broad-based collaboration among the lighting, semiconductor, computing, and IT industries is essential to realizing the full potential of CLS, and needs to be facilitated in a variety of ways — including the development of key standards, consortia to promote interoperability, collaborative real-world laboratories (such as the CLTB and Denmark's DOLL program), and ongoing stakeholder meetings.

Stakeholders agreed that communication and collaboration with all major industry players involved in the convergence of lighting and the IoT — including the traditional lighting industry, the networking/IT industry, and the computing industry — should be expanded. Annual workshops should be hosted to share updates more widely. Feedback and contacts from these workshops should be leveraged to encourage connected lighting system test beds, hosted by real-world lighting system owners and operators (such as municipalities, universities, big-box retailers, and parking lot owners and operators) and supported by private industry. Such installations increase the opportunities for stakeholders to see firsthand what's possible and shorten learning cycles for technology developers. Continued strategic technical assistance to select utilities is needed — such as the Northeast Energy Efficiency Partnership/DLC Commercial Advanced Lighting Controls effort that resulted in the April 2016 launch of a specification and qualified products list that are anticipated to see nationwide use.

Conclusion

Much can be gained from the development and adoption of connected lighting. Of the 5.1 quads that are projected to be saved by 2035 if DOE SSL Program goals are met, it's estimated that nearly half will be facilitated by the penetration of connected lighting along with traditional controls, with especially large impacts coming from the commercial and outdoor sectors.



Appendix A: Background

On March 31, 2015, DOE held a strategy session in Golden, Colorado, with a select group of lighting stakeholders to discuss the growing perception that lighting was primed to be a key early pillar of the much talked about IoT, and whether a DOE role was warranted. Attendees included representatives from the lighting design community, manufacturers, electric utilities, energy efficiency organizations, and building facility managers. Also present were representatives from the DOE Building Technologies Office's Emerging Technologies and Commercial Buildings Integration programs, as well as representatives from Pacific Northwest National Laboratory (PNNL) who had been involved in supporting DOE's development of a new interior lighting controls strategy.

Participants provided feedback on the vision for the future of lighting controls, DOE's draft plan, and how that plan might be implemented with help from DOE and other stakeholders. They agreed that LED (light-emitting diode) technology was only the beginning of the coming disruption to the lighting industry, and that lighting was indeed going to become more connected, and thus a more capable and important part of infrastructure in buildings and cities. Ultimately, they encouraged DOE to play an active role in guiding the continued evolution of lighting technology.

This meeting effectively launched DOE's Connected Lighting Systems Initiative. DOE proposed initially focusing on specific areas in an attempt to accelerate the development of connected lighting systems: energy reporting, interoperability, system configuration complexity, and key new features. Stakeholders also encouraged DOE to play a familiar role in promoting stakeholder collaboration, helping to identify common interests, key barriers, and critical decisions while facilitating discussions on potential paths forward.

A number of key themes emerged from the feedback received at this meeting:

- Participants strongly agreed with the vision for a future of advanced lighting systems.
- Both the cost and the value of advanced lighting systems need to be better understood and quantified.
- The plan must be applicable to retrofits.
- Lighting and other building systems need to be able to communicate.
- DOE has a special role as a convener, impartial source of information, and technology accelerator.
- Data need to be transformed into intelligence.
- Participants supported DOE's focus on application-level interoperability and integral energy measurement.
- Building codes can both speed and impede implementation.
- An overarching goal and multi-year plan are needed to guide the industry.
- Other stakeholders can help usher in success.

Appendix B: DOE's Inaugural Connected Lighting Systems Meeting

The meeting in Golden, Colorado, led to DOE's inaugural Connected Lighting Systems Meeting, held November 16, 2015, in Portland, Oregon. The meeting brought together more than 260 lighting technologists, their counterparts from the semiconductor and IT industries, utility representatives, and others to start a cross-cutting dialogue about how best to take advantage of the imminent collision between LED lighting systems and the fast-emerging IoT.

More than 260 participants attended the inaugural Connected Lighting Systems Meeting.

At the Portland meeting, DOE SSL Program Manager James Brodrick recalled that the early SSL market was likened to the "Wild West" because the products did not match the performance of the technologies they were intended to replace, and a lack of standards caused a great deal of confusion compounded by exaggerated performance claims. He noted that the replacement of today's lighting infrastructure with connected lighting systems offers not only immediate, proven energy savings, but also the potential to create a data-collection platform that could yield additional energy savings in buildings and cities. But, Brodrick emphasized, much of that potential is still on the table and faces a number of barriers, including configuration complexity, lack of interoperability between system components, and limited ability to measure and report performance.

Tom Herbst of Cisco Systems gave the meeting's keynote address, which focused on why lighting systems will become more connected. Noting that more and more electrical devices have embedded processors, he defined the IoT as consisting of intelligent network-connected devices that one isn't accustomed to being connected to networks. Herbst pointed out that lighting is ubiquitous both inside and outside of buildings and can accommodate many different types of sensors, including imaging sensors that pass information — not just raw images or video — to building owners. He said we probably will not know what the most interesting applications will be until we build an infrastructure that has less friction to

Tom Herbst of Cisco Systems delivered the keynote address.

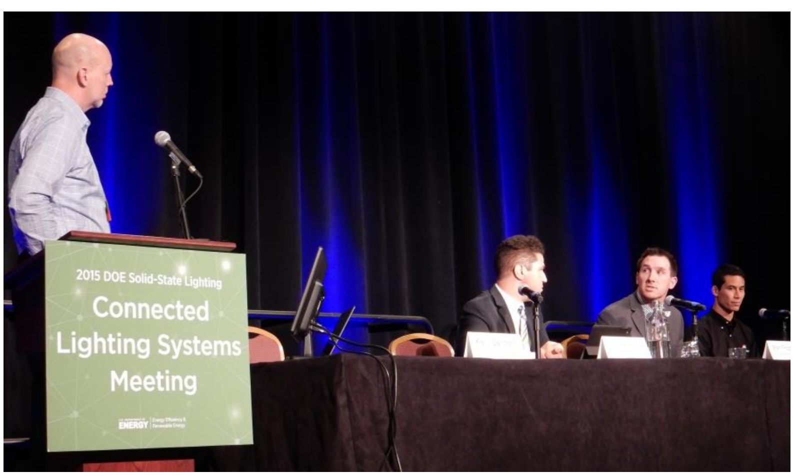
change, noting that "removing the impediments to innovation is one of the biggest reasons for doing the IoT."

Gabe Arnold of the DesignLights Consortium™ (DLC) spoke about the need for lighting systems to evolve. He observed that although lighting controls have been on the market for decades, they have met with limited success, primarily due to a lack of knowledge in how to design, install, commission, and operate them. Arnold described a future where intelligence, communication, sensors, and even energy measurement will be incorporated into every luminaire in a standardized, interoperable, and interchangeable way. He imagined that such self-commissioning products would be purchased the way we currently buy cars — i.e., as a base model that can include optional/advanced features and packages for an extra cost.

Michael Poplawski of PNNL reviewed the focus areas for DOE and the Connected Lighting Systems Meeting: energy reporting, interoperability, system configuration complexity, key new features, and facilitating stakeholder collaboration. He noted that SSL technology inherently facilitates the integration of intelligence, network interfaces, and sensors into lighting devices, and that enabling intelligent lighting systems with data can result in reduced energy consumption, improved lighting performance, and, potentially, myriad other capabilities and benefits. But Poplawski cautioned that the collected data may enable other revenue streams that compete with lighting and energy performance. However, observing that "you can't effectively manage what you can't measure," he suggested that energy data should not be viewed as of interest solely to DOE.

Why and How Lighting Systems Should Report Their Own Energy Consumption

Kelly Sanders, representing the Northwest Energy Efficiency Alliance, moderated a panel on enabling lighting systems to report their own energy consumption. He noted that SSL is becoming cheaper and more adoptable, while microelectronic devices in general are getting smarter all the time. Sanders listed reasons why utilities should be interested in lighting system energy data. The main reason, he explained, is that basing incentive programs on energy data has the potential to result in deeper and more persistent energy savings. It could also enable optimization of lighting systems and space utilization, and improve the relationship between utilities and customers, while allowing utilities to simplify and streamline their energy efficiency programs.



A panel considered in-depth the idea of enabling lighting systems to report their own energy consumption.

Panelist Michael Poplawski suggested that historical lighting control deployment strategies have been overly focused on devices that are tightly coupled to installed luminaires, with not enough consideration given to system issues and intangibles such as owner organizational maturity and difficult-to-predict performance and energy savings. After reiterating the opportunity offered by energy data to implement data-driven, performance-management processes that hold the promise of increased and more persistent energy savings, he explored a variety of other uses of energy data. While DOE is very interested in the opportunity to facilitate and develop transactive energy markets, Poplawski noted that energy data can create opportunities for a variety of market actors, including utilities and their energy efficiency programs, energy service companies (ESCOs) and others employing service-based business models, and building owners looking to realize the value of available — and, in the future, perhaps marketable — building energy services.

Brent Protzman of Lutron discussed the "applied" accuracy needs of energy metering. He defined applied accuracy as the average accuracy a user can expect to achieve on the desired measurement, which includes common load types, typical input values, and aggregation across time and measurements. Protzman emphasized that different end uses of energy data have different accuracy needs; load type matters when evaluating the accuracy of energy meters; a single accuracy rating is typically indicative of nominal performance in operation rather than minimum performance; energy can be estimated mathematically fairly accurately when done right; and new standards are needed to validate the performance claims of the new class of energy meters and energy reporting devices and systems.

Jefferay Lawton of Microchip talked about how power and energy reporting can be implemented in connected lighting devices and systems. He discussed and compared centralized vs. distributed measurement, software estimation vs. direct measurement approaches, and various system implementations for direct measurement. Lawton also gave a number of examples of how power or energy measurement provided novel features and benefits. For instance, monitoring has been used in commercial ovens to allow them to adjust their power as equipment ages and conditions change, and in coffee makers to provide the manufacturer with a profile of how the machine is being used.

Where and When Do We Need Interoperability?

A panel discussion on interoperability was moderated by Poplawski, who defined interoperability as the ability of two or more devices, applications, networks, or systems to work together and to reliably and securely exchange and readily use data with a common shared meaning. Distinguishing interoperability from compatibility and interchangeability, he noted that it can be talked about and defined at a number of different levels, most coarsely differentiating between the end-use application and the discernment of information from data, the transport of data, and the physical creation and preparation of data for transport. Poplawski introduced a group of panelists representing industry consortia working to facilitate the development of interoperable devices and systems in various ways.

Roy Harvey of OSRAM SYLVANIA spoke on behalf of the ZigBee Alliance, which was founded in 2002, before there was much (if any) talk about the IoT — making it one of the longest-running groups focused on serving the IoT. He noted that lighting was the largest category of ZigBee-certified products in the past year, and that ZigBee Light Link was chosen by the Connected Lighting Alliance as the preferred common open standard for residential connected lighting applications. Harvey highlighted the fact that ZigBee 3.0, which is currently in development, will unify the existing, and sometimes competing, ZigBee application standards.

A panel featured representatives from organizations working on different aspects of interoperability.

Ivan Judson of Microsoft discussed the AllSeen Alliance, formed in late 2013 as a Linux Foundation collaborative project and based on the AllJoyn software created at Qualcomm. Noting that AllJoyn is in some ways similar to other IoT efforts, such as Brillo/Thread, Open Interconnect Consortium (OIC)/IoTivity, and HomeKit, he highlighted that it is open-source, currently available, and already shipping in products. Judson pointed out that when developing specifications for an emerging technology, activities by different consortia that may initially seem to be competing can actually result in solutions that meet different sets of needs.

Remy Marcotorchino of Sierra Wireless talked about oneM2M, focused on developing a common machine-to-machine service layer that sits just below the device or machine application layer and bridges systems that use different platforms or serve different vertical industries (such as lighting, energy, security, fleet, and environment) while allowing each system to use its own semantic. These bridges provide access to common IoT functions and applications, while letting them focus on their own application logic. "We're not trying to reinvent the wheel," Marcotorchino said. "We're trying to leverage what's available, from a standards standpoint."

David McCall of Intel discussed the OIC, starting off by noting that the IoT "isn't just the things, it's the entire network." He differentiated the scope of the OIC — developing specifications and certification tools — from a sister organization, IoTivity, which is sponsored and funded by the OIC and serves as a forum and repository for the development of open-source implementations of OIC specifications. McCall further expounded on the strategic decision to separate the two groups, describing their unique intellectual property-rights policies.

Reducing Lighting System Configuration Complexity

Christine Wu of the U.S. General Services Administration (GSA) moderated a panel discussion on lighting system configuration complexity and how important it is to be well matched with user capabilities and experience. She pointed out that reducing that complexity will speed market adoption, and briefly reviewed the Green Proving Ground program, which was established to help GSA meet its energy goals and is evaluating connected lighting in some GSA buildings.

Dagnachew Birru of Philips Lighting focused on self-configuration of connected lighting systems. He noted that to a large degree, self-configuration is about auto-commissioning or simplified commissioning, and explained how advanced analytics can be applied to connected lighting systems so that they become as easy to use as smartphones, which hide their complexity behind a simple interface. Birru reviewed several Philips products that offer simplified self-configuration — including CityTouch and SpaceWise.

Tom Griffiths of AMS-Taos was part of a panel that discussed lighting system configuration complexity and how it can be reduced

Tom Griffiths of AMS-Taos reviewed the role chip-scale integrated sensors combined with local intelligence can play in reducing the configuration complexity of smart lighting. "If the whole commissioning process becomes a painful thing, we've achieved nothing," he said, adding that self-configuration requires knowledge of the space, which sensors can supply. Griffith emphasized that integrating sensors into luminaires — essentially turning them into sensing hubs — both simplifies the incorporation of knowledge-generating sensors into a space and increases the value of the luminaires and lighting system that houses them. "Making lighting intelligent only solves part of the problem," he noted.

Kishore Manghnani of Orama focused on the role next-generation IoT networks can play in reducing configuration complexity. Reinforcing the oft-repeated reality that networked lighting controls have seen low penetration to date, he laid the blame at expensive and time-consuming commissioning, proprietary and expensive control electronics, and the limitations of existing smart IoT lighting capabilities, all of which make for long paybacks. Manghnani said making the commissioning software-centric rather than hardware-centric can have a significant impact, adding that "the technology is there to make it happen." He stated that lighting controls can reach 60 to 70 percent penetration in the next five years if configuration complexity is reduced this way, but that will not happen without open standards.

Connected Lighting Systems that Are Already Changing the Game

Marc Ledbetter of PNNL moderated a panel that looked at some recent examples of installed connected lighting systems that are demonstrating improved lighting energy performance and other benefits. Kaynam Hedayat of Digital Lumens described several connected lighting projects that both resulted in increased energy savings and provided other benefits. For example, at Ace Hardware, adding daylight and occupancy sensors and grouping the lights into coarse and fine zones yielded a 93 percent reduction in energy consumption that not only achieved but surpassed the initially predicted 75 percent savings used to justify the project. At Atlas Packaging, the connected lighting system not only reduced energy consumption but also provided occupancy data that enabled path tracking through the warehouse, which led to optimized inventory placement and reduced warehouse traffic.

Panelists share a laugh as they engage with the audience while discussing installed connected lighting systems.

Dan Cocosa of Google recounted the path that led to his company deploying connected lighting throughout multiple campuses. He noted that unlike the unsophisticated lighting control systems of the past, which were mostly only effective in implementing simple "occupied = on, unoccupied = off" energy management strategies, today's systems are increasingly more versatile and effective. Cocosa characterized lighting as "low-hanging fruit" as far as energy savings are concerned, especially because California's new Title 24 requirements mandate controlling at least 50 percent of the plug load. He noted that at Google's properties, dimming the lights down to 20 percent during vacancy is a starting point. Cocosa said his company plans to use occupancy sensors and heat mapping to optimize building-space utilization, to determine what entrances and exits people use the most, and to automatically control lights and HVAC in conference rooms.

Brodrick concluded the meeting by thanking the attendees and speakers for their input and participation, and inviting them to stay for DOE's 10th annual Solid-State Lighting Technology Development Workshop beginning the next day.

Tour of 911 Federal Building

Portland's 911 Federal Building was the destination for a guided bus tour that took place the evening of November 16. The tour provided a first-hand look at an LED connected lighting system that replaced T8 fluorescent lighting in sections of the eight-story building as part of the General Services Administration's Green Proving Ground program. Tour participants observed in action the Philips SpaceWise system, consisting of 2x2 LED troffers with integral controls and sensors that can share data wirelessly with neighboring luminaires, thereby allowing them to switch, raise, or lower their light output in response to occupancy and daylight — and, in the process, improve their operational efficiency. Participants also had a chance to observe the incumbent T8 fluorescent system on a separate floor, for comparison.

The presentations and materials from this workshop are available at http://energy.gov/eere/ssl/2015-doe-connected-lighting-systems-presentations-and-materials.

Appendix C: DOE's Connected Lighting Workshop

About 170 participants attended the second Connected Lighting Systems Workshop.

DOE held a Connected Lighting Systems Workshop on June 7–8, 2016, in Santa Clara, California, which brought together about 170 lighting technologists, their counterparts from the semiconductor and IT industries, and others to build on the November 2015 meeting and continue a cross-cutting dialogue about how best to prepare for and take advantage of the imminent collision between LED lighting systems and the IoT.

Connected Lighting Fundamentals

The workshop was preceded by a morning of background education sessions, the first of which focused on communications fundamentals. Panelist Michal Koenig of Qualcomm Technologies gave an overview of the wide variety of wireless technologies that are increasingly being integrated into lighting devices and systems. He differentiated between connectivity technologies — which provide localized connections between assets, sensors, and humans — and interconnect technologies, which connect assets to the cloud. Koenig noted that a new era of connectivity technology use is being driven by the growing availability and use of edge processing, which reduces the need to bring data to the cloud when analytics can be done locally.

Himanshu Mehra of Cisco Systems talked about the emergence of Power over Ethernet (PoE) as an option for indoor connected lighting. He noted that the transition to PoE has been going on for a while, just as PoE has been evolving to accommodate an increasing amount of power and today can handle up to 60 watts — enough to power an indoor lighting fixture. Mehra reviewed the benefits of PoE for lighting, including speed (easier installation, simplified operation), efficiency (low-voltage, DC-based), and scalability, as well as the elimination of DC current conversion, lower maintenance and upkeep costs (because no electrician is needed), and higher occupant controllability. He described a product Cisco recently launched to facilitate smart buildings.

Shane Dewing of Intel focused on the challenges arising as a result of the growing IoT, which is leading to an explosion in the amount of data and number of control points. He noted that in order to realize its promise, IoT technology solutions need to work across varying form factors, operating systems, platforms, manufacturers, service providers, and vertical markets — and also need to scale from smart devices to the cloud. Dewing then discussed how industry consortia are rising up to meet this challenge, focusing on the efforts of the Open Connectivity Foundation (OCF), which grew out of the former Open Interconnect Consortium and is striving to make it easy for developers to deal with the complexity of IoT communications. He explained that the OCF is focused on providing common data models that developers can use to interface with all IoT devices and data. These data models, coupled with a resource model, are intended to deliver as much interoperability as possible in the short term, while providing a path toward future consolidation. Dewing also reviewed the OCF licensing agreement, certification plans, and cybersecurity strategy and described the important role of the OCF's sister organization, IoTivity, which develops reference implementations of the OCF specification.

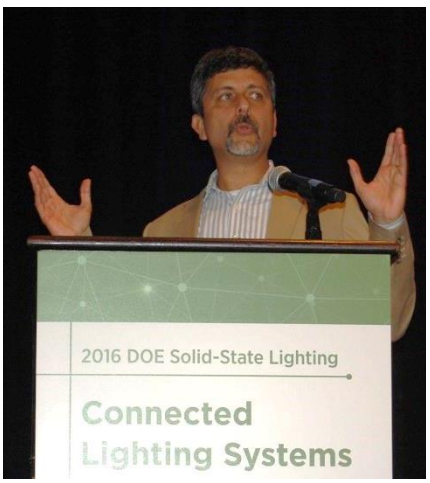
A pre-workshop session on communications fundamentals featured speakers from Intel, Qualcomm, and Cisco.

The second pre-workshop session explored cybersecurity fundamentals. Prasad Jogalekar of Ericsson reviewed major cybersecurity challenges in the world today, giving real-life examples. He described the recent evolution of the security paradigm — where compromising systems has gone from a challenge and perhaps a badge of honor to a business that profits from ransom requests. Prasad then proceeded to discuss the IoT from a cybersecurity perspective, including the risks inherent in bringing so many new devices online quickly, and what the industry could and should be doing now to intelligently manage those risks in a way that balances security and performance, ease of use, interoperability, and business impact. Jogalekar noted that IoT penetration in various verticals increases the potential attack surface, and that compromised IoT devices can fall in a traditional firewall's blind spot. He likened the IoT market at its current stage to the Wi-Fi market in pre-WEP (Wired Equivalent Privacy) days, and said standardized security built into devices from the ground up (as opposed to strapped on later) will be essential for the wide, successful adoption of IoT devices.

Ken Modeste of Underwriters Laboratories (UL) focused on cyber-assurance needs, what is currently available in the marketplace, and what is missing. At present, he said, there is no single cybersecurity framework that addresses the needs of many. Rather, there are multiple frameworks, written primarily for IT (and not lighting or other IoT) applications, each with its invested constituency, and most broadly written without a clear path to compliance. Modeste suggested that the industry needs a compliance scheme that includes a cybersecurity rating system to manage expectations and addresses not only products and software, but also process. He emphasized that security risks should be managed and assessed according to what are often application-specific objectives. Modeste walked attendees through an example of how one might work through a risk assessment for lighting systems, and concluded with a proposed assurance-level scheme that would leverage a new UL effort focused on product or system cybersecurity testing.

Opening Remarks

DOE SSL Program Manager James Brodrick began the workshop by reiterating its motivation: a belief that enabling intelligent connected lighting devices with data can result in greater lighting energy savings in buildings and cities, and an acknowledgement that the data collected by lighting systems could make possible other features and revenue streams that accelerate adoption. Brodrick explained that in its role as vendor-neutral facilitator and convener, DOE aims to accelerate the development of connected lighting systems by creating tight information feedback loops to inform manufacturers and developers of needed improvements, and increasing market visibility and transparency on what works — all while promoting collaboration among the various stakeholders.



Tanuj Mohan of Enlighted delivered the workshop's opening remarks.

The workshop's opening remarks were given by Tanuj Mohan of Enlighted, who noted that the IoT is not new — we've had an industrial IoT for decades. At present, Mohan said, large buildings produce a billion times less data than jet engines produce and use to optimize their performance. The opportunity that lies in front of us requires us to first understand how those same jet-engine design approaches and analytics could be used to optimize buildings using environmental, operation, and behavioral data. Mohan reiterated what many in the lighting industry have come to believe but others have thus far been slower to realize: that lighting is an ideal place to install the sensors that comprise the IoT's "nerves." He noted that while lighting provides embedded sensors with complete coverage and access to power, sensors can provide lighting with enough intelligence that the efficiency a connected system brings to a building might pay for the entire data collection system. But Mohan warned that the realization of lighting as the IoT data collection platform currently is — and, if the lighting industry does not change its ways, will continue to be — hampered by a profusion of new vendors and standards, varying levels of compatibility and interoperability, and an inability of the lighting industry to handle the pace of change that is emblematic of the IT and computing worlds it is colliding with. He closed with a call for advanced sensors with upgradeable software; security built in rather than bolted on; a wholesale focus on busting existing silos; and a paradigm shift where intelligent embedded sensor and analytic systems take the place of test beds, mockups, and long, expensive customer and occupant surveys and research.

Leading-edge Connected Lighting Installations

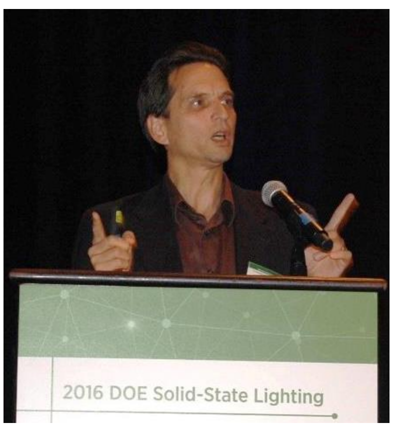
The first day of the workshop closed with two panel sessions addressing what we can learn from innovative connected lighting installations that impact the business case by demonstrating improved lighting performance and other benefits. Cody Crawford, a facilities manager at Vulcan, led off the first panel, on indoor installations. He shared his experiences with a connected lighting system intended to provide human-centric benefits, in which 1,400 incumbent fixtures were replaced with color-tunable LED lighting that can produce white light with correlated color temperatures ranging from 6500K to 2700K, accompanied by 400 occupancy sensors and 100 daylight sensors in 129,000 square feet of occupied office space. Crawford recounted how the new system is currently on target to reduce total energy consumption by 15 percent, and observed that implementation costs were lower than for any other system considered, with the City of Seattle providing a 10 percent rebate. He noted that while user satisfaction has been very good thus far, Vulcan is only beginning to explore the system's potential and intends to increase its focus on the quality of the work environment and the impact on the end user. "Employees make up 75 to 80 percent of your operating costs, so if you increase their productivity even one percent, that goes a long way," Crawford said.

Facilities manager Kenny Seeton of California State University, Dominguez Hills recounted his early-adopter experience with a connected lighting system, which has been overwhelmingly positive. Among the lessons learned, he said, are how easy it can be to gain control of the HVAC system (heating, ventilation, and air conditioning) at a much more granular level than before, and how easy it is to make occupants happy by talking to them in person and being able to set light levels according to their preferences — as opposed to "how the electrician thought they should be," as one faculty member put it. Seeton emphasized the importance of involving the IT department from the beginning of the project, and expressed excitement about what he anticipates that the future holds — noting that once a full connected lighting network and sensor platform are installed, he sees the possibilities as being mostly limited by his imagination.

George Denise of Oracle led off the second panel, on outdoor installations. He reviewed his company's dedication to energy efficiency and then dove into Oracle's recent experience with the installation of connected lighting in one of its buildings as well as in the adjoining parking lot and garage. Denise noted that initially, only four floors of the building were installed with controls, but they were so successful that they were then installed throughout the entire building. The result, he said, was an 81 percent reduction in lighting electricity use. In the garage and parking lot, a key to the high occupant acceptance of the connected lighting system and implementation of occupancy-based lighting control was the ability to program the lights to ramp up and down slowly, rather than to suddenly turn on and off — resulting in a fluid motion of the lighting as it precedes and follows vehicles, an effect Oracle hopes to extend to the building's interior as well. The combination of occupancy sensing and daylight harvesting reduced lighting electricity consumption by 89 percent.

Richard Webster, who manages street lighting for the Suffolk County Council in the United Kingdom, described his county's five-year experience with connected street lighting. He discussed the path taken and lessons learned along the way that led to the installation of 60,000 control nodes, 47 base stations, and one central management system, hosted by the vendor. Webster observed that, to date, there have been less than 0.1 percent node failures and no significant service or operational issues. Most of the issues experienced, in fact, were due to operational shortcuts made by county staff navigating the learning curve. Webster noted that the system capabilities have already become integral to how his county operates, in a number of ways. Integration with the asset management system has led to the end of night scouting, fewer outage hours, zero day burners, and the ability to exceed key performance indicator (KPI) goals for lighting. Integration with the utility meter administrator, together with a new tariff process, has facilitated the ability to monetize adaptive lighting schemes, including a recently approved part-night policy. A traffic-adaptive pilot project is in the works. Webster concluded by noting that, largely on the basis of his county's experience, most of the other jurisdictions in his area have either already installed connected street lighting or are actively considering it.

Test Beds



Rafael Reyes of Prospect Silicon Valley discussed how test beds can accelerate CLS development.

Rafael Reyes of Prospect Silicon Valley and Michael Poplawski of PNNL examined how test beds can accelerate CLS development, looking at it from a few different perspectives. Reyes discussed how his organization has been supporting technology innovation and adoption in a number of ways — from investor connections to demonstrations to pilots — and working towards test beds capable of supporting a variety of recurring project types. He strikingly illustrated the need for test beds that can accelerate the ascent of technology learning curves for manufacturers and building and municipal project planners, by noting that in the time it took San Francisco to build one bridge, the industry saw three generations of battery technology, five generations of automobiles, and 10 generations of mobile devices hit the market. Reyes discussed a number of ways in which technology developers and adopters need to figure out how to share the risks and rewards when navigating any type of learning curve, focusing on the challenges that are unique to cities. He emphasized the need for a structured process that is independent of procurement, defines and limits scope, is structured for learning by third parties, is transparent, has a sustainable funding mechanism, and is clearly seen as relevant to the hosting agency's ongoing needs and long-term plans.

Poplawski considered the broad question of how to accelerate the development and adoption of connected lighting, offering up some lessons learned thus far in its still-formative phase. He characterized a spectrum of activities commonly embarked upon, if not required, prior to the deployment of new technology — ranging from the vetting or identifying of qualified vendors, to characterizing technology features or capabilities, to demonstrating real-world use cases in real-world environments, to conducting pilots focused on learning what you do not realize you need to know. Poplawski then described several existing test beds, including PNNL's Lab Homes, Lawrence Berkeley National Laboratory's FlexLab, Denmark's DOLL, and a new DOE connected lighting test bed — noting where in the aforementioned pre-deployment spectrum each test bed was targeting or effectively operating. He closed with set of questions for the audience, including a call for feedback on what lighting applications could most benefit from a dedicated, cooperative, real-world test bed.

Integrating Connected Lighting into the IoT

Day 2 of the workshop kicked off with a panel on how connected lighting systems should be integrated into the IoT. Panelist Brian Chemel of Digital Lumens observed that lighting is poised to play a pivotal IoT role in buildings but cautioned that this is far from a done deal, and that industry has much to do in order to make it happen. He warned against making the kinds of mistakes that could undermine lighting's chances to play a major role in the IoT — such as underestimating one or more industry players, focusing on technical specs instead of on end-user value, and downplaying the importance of interoperability. Nevertheless, Chemel's overall tone was very optimistic, given SSL's inherent compatibility with intelligence, sensing, and networking, and the fact that, as he put it, lighting currently is the only IoT platform that actually pays for itself. He noted that for a long time, lighting has been a "bubble," isolated from other fields, but connected lighting is changing that in a big way.

Day 2 kicked off with speakers from Intel and Digital Lumens, who explored how to integrate connected lighting systems into the IoT

Sameer Sharma of Intel said we have already reached the inflection point where the IoT is economically viable, driven by the falling costs of sensors, bandwidth, and processing. He explained how connected lighting will be enabled by increased demand for smart cities, the advent of 5G technology, and the continued development and adoption of key standards. Imagining a future world with 7 trillion high-functioning connected things will require, Sharma said, not one but a multitude of integrated air interfaces, the ability to optimize signaling traffic in real time, sufficient security for managing risks — and, in many cases, device-to-device (rather than device-to-cloud) communication. He shared a forecast that 50 billion devices will be connected by 2020 but emphasized that to unlock the open-platform approach essential to realizing this forecast, a number of keys are needed — including consensus collaboration, public-private partnerships, operational models, and open horizontal test beds. Sharma said the convergence of lighting and the IoT will produce benefits in the areas of health and wellness (e.g., sleep management and the treatment of seasonal disorders), safety and security (e.g., egress lighting), tracking and location services (e.g., in retail stores), and process optimization (e.g., productivity management and resource tracking).

How Energy Reporting Can Accelerate Deployment

John Scott of Colliers International led off a panel focusing on business opportunities enabled by the ability of connected lighting systems to report their own energy consumption, noting that lighting has historically been the most commonly discussed, understood, and utilized tool for energy efficiency, and also one of the most stress-free and cost-effective to implement due to a typically short payback period. He observed that lighting technology is emerging at an accelerating rate, and cautioned that standards and codes must follow process. Codes that lag technology can be difficult to interpret and apply, potentially hindering the deployment of higher-performing system technologies such as connected lighting. Scott recounted how some lighting efficiency projects in the past were compromised due to lack of performance measurement, and described how lighting systems that report their own energy usage make better business sense because they reduce risk, hassle, and project costs.

Russ Abber of EmilyGrene discussed the myriad challenges commonly faced when trying to get customers to deploy technology that is newer, has higher upfront cost, and/or offers less-certain energy savings than other options that are more proven but likely lower-performing. He echoed Scott's sentiments that most customers are very risk-averse, fear that promised savings from lighting retrofits will not materialize, and wait for code requirements to push higher-performing product specifications. Abber explained that risk reduction is critical to the buying decision, but lamented that historical means for predicting or verifying energy savings suffered significant uncertainties. Comparing electric bills before and after a lighting retrofit is a very inexact process, as weather variations, plug-load additions, and/or the unanticipated installation of new equipment can lead to wrong conclusions. Simple lighting loggers are relatively easy to deploy but only capture hours-of-use and rely on assumption about power draw. Like Scott, Abber believes that connected lighting systems that can report their own energy consumption are seen as having reduced risk, and he noted that in his early experiences with them, the willingness to accept higher upfront cost has been rewarded with paybacks similar to those of basic LED retrofits.

Jeff Harris of the Alliance to Save Energy focused on the importance of energy reporting data to future codes and standards. He observed that while lighting product-level efficiency has made huge advances, with more to come, future gains in some cases may be incremental and more costly. Harris said that ultimately, whole-building efficiency is what matters to most people. He remarked that energy savings achieved by systems of devices working together could be two to 10 times greater than the savings realized by efficient (but otherwise unaware or uncoordinated) devices. Harris said lighting energy reporting can help in the development of codes and standards by verifying actual performance and savings, providing new metrics for delivered lighting services and making possible new business models.

The Importance of Application-level Interoperability

Russ Sharer of Fulham led off the third panel of the day, which focused on why application-level interoperability holds the key to broad CLS deployment. He said standards and specifications that do not deliver application-level interoperability often become self-limiting and do not deliver upon their full potential. Sharer noted that interoperability makes things easier to understand, install, and troubleshoot, allowing for more trained installers and making for a faster return on investment and more user choice. Citing Metcalfe's Law that the value of a network is proportional to the square of the number of users, he stated that the development of interoperable networks may require a greater investment of time and money up front, but as the network and the number of users grow, development and deployment costs become incrementally cheaper. Sharer said that interoperability makes multivendor installations possible, thereby allowing users to choose the products that are best for them.

Speakers from Cisco, Fulham, and Silver Spring Networks addressed how application-level interoperability holds the key to broad CLS deployment.

Sean Tippett of Silver Spring Networks noted that proprietary or closed solutions indicate an immature market. He predicted that as the connected lighting market evolves, we will see new device form factors enabled by interoperability. Tippett pointed out that interoperability starts with specifications but does not stop there, and that vendors need to stress-test those specifications through real-world use. He cited lighting as the "killer app" for an IoT that demands interoperability to realize its potential, because it provides an IoT platform that makes economic sense, allowing for the deployment of other IoT applications that by themselves might be difficult to justify financially. Tippett advised customers to specify interoperability requirements in tender and to be open to partial solutions, and advised vendors to be willing to innovate as well as standardize, build solutions that can evolve over time, and listen to their customers.

Tom Herbst of Cisco Systems reviewed many of the standards bodies and industry consortia that have facilitated interoperability in computing and mobile networks that we now take for granted — many of which have started to focus on the IoT and connected lighting — and offered thoughts on the strengths and limitations of each. These included the Institute of Electrical and Electronics Engineers, the Internet Engineering Task Force, the Wi-Fi Alliance, the WiSUN Alliance, the ZigBee Alliance, the Thread Alliance, the Open Mobile Alliance, the TALQ Consortium, the Fairhair Alliance, and the Open Connectivity Forum. Noting that most of these bodies have not historically addressed the application level, he preached patience, observing that everything does not come together immediately, but rather emerges over time as best approaches become evident and build momentum in the marketplace. “It’s okay to innovate,” Herbst said. “Just because we want interoperability doesn’t mean everything we do has to be totally in lockstep with everyone else.”

Technologies that Can Reduce Configuration Complexity

Gary Trott of Cree reminded attendees “the best technology is the one that actually gets used.”

Configuration complexity has long been viewed as a barrier to the broad deployment and success of lighting control, and many have observed that connected lighting will have to bring technology that reduces that complexity in order to be successful. Panelist Gary Trott of Cree started off his presentation by reminding the audience that “the best technology is the one that actually gets used.” For that reason, he said, it is critically important that the user experience not be designed by engineers, but rather by those who are attuned to what users want and need. “The technologies don’t matter if you don’t get the user experience right,” he said. Adding that typically, lighting control solutions have been entirely separate from the corporate IT network, Trott stressed the importance of thinking about everyone who will touch the technology, from contractor to end user — and noted the advantage of approaches that are common (e.g., facilitated by interoperability standards and specifications) or that borrow from familiar and well-established solutions (e.g., leveraging security know-how from IT systems).

Neil Joseph of Stack Labs talked about how technology that makes spaces responsive effectively reduces configuration complexity by facilitating the ability to adapt to changing conditions. He stated that connectivity should improve the user experience, simplify setup, and increase efficiency — as evidenced by the pervasiveness of computing and mobile-device technologies — but that today’s building controls systems are complex, expensive, and hard to install. Slow improvement, Joseph said, is not good enough; rather, what’s needed to create responsive lighting is an investment in embedded sensors — which, he believes, hold the key to easy (if not auto-) commissioning of entire rooms, zones, and even floors. Manufacturers should work together to develop simple, common ways to embed sensors that can be leveraged by multiple methods of control, and should spend more time investigating other technologies (e.g., the existing infrastructure, visible light communication, machine learning, ultrasonic) that can assist with commissioning.

Charlie Huizenga of Acuity Brands picked up where Joseph left off and talked further about how sensors are key to reducing the configuration complexity of lighting systems. He explained how sensor integration is one of four major paradigm shifts that, in his view, are crucial to the success of connected lighting. Huizenga characterized the first necessary shift — moving from hardware-based control to software-based control — as still somewhat of a new frontier for the lighting industry. Distributed intelligence, he said, brings advantages (lowest latency, most scalable, no single point of failure) that far outweigh the single disadvantage of increased computing cost at the node. Huizenga noted that the integration of sensors and controls (or intelligence) at the fixture ultimately lowers hardware, assembly, design, and installation costs while optimizing performance and increasing reliability. He stressed the importance of sensors that can help a fixture determine its location in space as key to reducing configuration time and cost, and called for more research and development on reducing the cost of sensors and supporting signal-processing techniques. Huizenga called the IoT the fourth paradigm shift, saying that sensors are ultimately at the heart of the IoT and that lighting systems with sensors integrated into each fixture can deliver the rich data that will unlock many IoT use cases.

Architecting the IoT to Deliver on Its Potential

The final workshop panel shed some light on IoT architecture proposals from two different industry stakeholders. Panelist Ron Victor of IoTium talked about what he called managed software-defined networks, and illustrated how they work through two use-case scenarios. He drew an effective analogy with Skype, noting that it became immensely popular because it is just software and is so simple that anyone can use it without having to think about whether their hardware technology infrastructure is Mac or PC, Wi-Fi or Ethernet, etc. Victor said that's exactly what's needed for lighting and IoT systems, and it can be done today. He said the hardware interface does not matter, as long as the data can be extracted.

An evening reception was one of several networking opportunities.

Keith Day of Telensa explained why he believes economics currently dictate IoT technology decisions, citing connected streetlights as an example. He observed that in order to economically deploy connected streetlights today, the network needs to be low-bandwidth, low-duty-cycle, or both; to be medium to high latency; to be in an unlicensed spectrum; and to employ a long-range star or short-range mesh topology. This, in turn, dictates the types of IoT applications that can best be supported by such lighting networks, which Day suggested could range from indicating parking occupancy and traffic patterns to monitoring air quality and noise levels. On the other hand, he offered that — at least today — other IoT networks will likely have to support video surveillance, parking cameras, traffic controls, and municipal Wi-Fi.

The presentations and materials from this workshop are available at http://energy.gov/eere/ssl/2016-connected-lighting-systems-workshop-presentations-and-materials.