The Third Annual Connected Lighting Systems Workshop

Meeting Presentations and Materials

Lighting technologists, their counterparts from the semi-conductor and IT industries, and others gathered in Santa Clara, CA, June 7–8, 2017, to participate in DOE's third Connected Lighting Systems (CLS) Workshop and continue a crosscutting dialogue about how best to prepare for and take advantage of the evolving collision between LED lighting systems and the Internet of Things (IoT).

Opening Remarks

DOE Solid-State Lighting (SSL) Program Manager James Brodrick began the workshop by noting that while SSL is a disruptive force that's been transforming the lighting industry, connected lighting is a "second lighting revolution" that SSL — because of its ease of integration with microelectronics such as network interfaces and sensors — has helped make possible. This second lighting revolution, he said, appears to be coming even faster than the SSL revolution and is promising even greater disruption. Brodrick observed that DOE is very interested in connected lighting because of its potential to greatly increase energy savings in addition to bringing improved lighting quality and other valuable capabilities. He reviewed many of the key barriers to connected lighting, including a lack of interoper-ability, a lack of suitable test and measurement methodology for energy reporting accuracy, and exaggerated or oversimplified claims. Brodrick then turned over the podium to a series of speakers who addressed the impact connected lighting is having on their corner of the lighting industry.

Participants from the lighting, semiconductor, and IT industries attended the third Connected Lighting Systems Workshop.

Big Changes for Industry

Robert Hick of Leviton discussed how lighting manufacturers are changing to meet the connected lighting revolution. Noting that it will take a huge effort to keep up with the pace of this technology, he said we need to predict what standards will be needed for interoperability and when they'll be needed, for example, and move as quickly as possible so that we don't repeat the mistakes of the past. Hick observed that the lighting industry, once stable and well-organized, has already been seriously disrupted, with lines between the different sectors blurred. He pointed out that although the lighting industry, in comparison with many other building technologies, is at the forefront of the IoT, one of the biggest problems is that there continues to be no best practice for integrating lighting with building-automation systems. Noting that more changes are coming whether one wants them or not, Hick advised manufacturers to find the new opportunities in the SSL and connected lighting market disrup-tions and to leverage them, and offered a number of specific recommendations to deal with the disruption.

Chris Brown of Wiedenbach Brown discussed the role distributors might play in connected lighting.

Chris Brown of Wiedenbach Brown focused on the role distributors might play in the connected-lighting future. He said connected lighting offers great opportunities, but most distributors aren't ready, or even preparing to advantage of them — adding that some "are out of business already; they just don't know it yet." Brown voiced concern that distributors may be facing disintermediation, and urged them to innovate and evolve their businesses to survive and thrive in the new world of SSL and connected lighting. Noting that "lighting isn't just about light anymore," he wondered whether lighting will become a subset of the tech industry when the tech and lighting industries align, and pointed to the "tech gorilla" companies that have already entered the lighting field — such as Microsoft, Google, Intel, Cisco, Apple, and Amazon. Brown said lighting as a service potentially takes distribution out of the equation, and declared "the future of lighting is here, and we'd all better embrace it or, in the words of Willie Nelson, 'turn out the lights, the party's over.'"

Mark Lien of the Illuminating Engineering Society of North America (IES) reviewed the various efforts of industry associations that are trying to provide guidance for the advent of connected lighting and thereby pave the way to change. He recounted the results of informal interviews he conducted with representatives from the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE); the California Energy Commission (CEC); the International Commission on Illumination (CIE); the Institute of Electrical and Electronics Engineers (IEEE); IES; the National Electrical Manufacturers Association (NEMA); the National Institute of Standards and Technology (NIST); and the U.S. Green Building Council. Lien said the technology is moving so fast that it's hard to anticipate what will be needed in the future, but it's possible to assemble specialized teams and have them at the ready to address specific topics as they arise. He noted that 1.1 billion people in the world still lack access to electricity, and raised the question of how we can bring energy to all of them. Lien urged the audience to get involved in the industry and in the creation of standards.

The Cybersecurity Question

Michael Ring of Star Lab spoke about ensuring that cybersecurity issues don't limit connected lighting's potential.

Michael Ring of Star Lab spoke about how to ensure that cybersecurity issues don't limit the potential of connected lighting. He pointed out that lighting and all connected systems are vulnerable to a wide range of attacks, and that attackers are everywhere and can compromise not only connectivity but also such things as firmware, by exploiting default passwords and settings, poorly written code, open ports, operating-system flaws, and improperly implemented encryption. "Right now, hackers are planning multiple attacks against systems similar to yours," Ring told the audience. He said such tactics as perimeter security, "shot-gunning" security, managing all security aspects yourself, and adding security after the fact don't work. What does work, Ring explained, includes such things as taking a systems engineering approach, establishing chains of trust, locking down the operating system, and not forgetting to take care of the basics.

The End User Perspective

Michael Poplawski of Pacific Northwest National Laboratory (PNNL) moderated a panel discussion that considered whether today's connected lighting systems are serving the needs of end users. Filling in for panelist Charles Koekemoer of Regency Lighting, who was unable to attend, Poplawski continued the

discussion about the lack of interoperability currently in the market, the threat of proprietary system "turf wars," and why they constitute a barrier to the development and deployment of connected lighting. He noted the "one-size-fits-all" marketing of most connected lighting systems currently in the market, and hypothesized that sector-specific solutions might be needed to deliver enough value to really drive adoption. Well-suited sector-specific solutions might not only, for example, increase operational efficiency, but also impact marketing strategies. Poplawski espoused a belief that end users need to be more proactive in discerning and describing their needs to technology developers, and suggested that competitors in some industry sectors have enough common needs to justify working together to identify and crystallize them in ways that can be acted upon — such as specifications, standards requests, and position statements, as well as demonstration projects that qualify or quantify value and establish metrics.

Speakers from PNNL, Oregon Health & Science University, and the Ron Bernstein Consulting Group considered whether connected lighting systems are serving the needs of end users.

Lisa Newman of Oregon Health & Science University recounted her organization's experience with a design process for a new building that brought together the various "siloed" organizations within her hospital system to determine their common needs and how they might be met by targeted design choices. DOE invited her in the hopes that her experience in identifying and defining user needs in a complex organization might shed light on how such a process might help to identify similar high-value user needs that might be met by well-targeted connected lighting systems. As Newman noted, such needs, as well as how they might best be met, are not necessarily obvious to outsiders, or even to the often-siloed insiders in a given institution. However, processes that bring together the diverse stakeholders within an institution and identify common practices and issues, and that debate solutions from all perspectives, have high potential to identify important needs or opportunities for improvement. Newman noted that many of the solutions identified flew in the face of commonly held beliefs about what would, or would not, be most effective. Further, her presentation made it clear that users often need help in unlocking and articulating their needs, which can get tangled up by their assumptions about

what can and cannot be done — and that we've barely scratched the surface of understanding the needs that might be met by connected lighting.

Ron Bernstein of the Ron Bernstein Consulting Group discussed integrated systems from an end user's perspective. He recounted some of his experience designing open building systems created using the products and systems from multiple vendors, and how, in the end, they offer greater flexibility, easier management, higher levels of scalability, and lower life-cycle costs. Bernstein said fully open systems will result in greater choices in vendors and suppliers, lower energy costs, lower installation and life-cycle costs, greater system scalability, better access to information, and other advantages. "We've got to find a way to develop standards and industry best practices to support the design and development of more open, interoperable systems, so we're not doing the same thing over and over again," he said. Bernstein stated that end users should pursue higher levels of integration, a common infrastructure, and IP-based system-to-system connectivity with interoperability at all levels, reduced system complexity, and clearly identified roles and responsibilities.

Separate from the panel discussion, Evan Petridis of Enlighted provided a brief introduction to the IoT Ready Alliance, noting that although LED fixtures are ideal for incorporating sensors, there's no standard way for a sensor to plug into a luminaire, and this hasn't been addressed by any of the other standardization efforts. He explained that the IoT Ready Alliance aims to come up with a sensor interface that will allow any luminaire to accept any sensor. "The goal is to make upgrading sensors in the field as easy as changing a lightbulb," Petridis said, and also to "future-proof" the lighting system so that as the technology changes, people can change or upgrade, and perhaps go to competing solutions, without having to do a complete lighting retrofit.

Day 1 concluded with a networking reception sponsored by the Next Generation Lighting Industry Alliance (NGLIA). Mark Hand of Acuity Brands explained that NGLIA is an organization of lighting manufacturers working collaboratively to accelerate SSL advances through government–industry partnership, and invited the audience to get involved.

Intra- and Inter-Luminaire Communication Protocols

To kick off Day 2 of the workshop, Clement Gaidon of PNNL moderated a panel discussion on whether the connected lighting market is ready to converge on common intra-luminaire communication protocols. Panelist Kevin Fitzmaurice of Georgia Power focused on outdoor lighting, outlining user needs from his utility perspective. The first priority, he said, is to select a digital addressable protocol. Fitzmaurice urged letting go of 0–10V and standardizing on a two-way communication protocol such as DALI (digital addressable lighting interface — which is what Georgia Power is currently pursuing for its deployment and pilot

projects) for connecting external networked lighting controllers with LED streetlights, noting DALI's maturity and proven track record. This, he pointed out, necessitates both digital addressable drivers (DALI drivers are commercially available) and digital addressable sensors (he wasn't aware of any DALI-enabled sensors available for outdoor lighting). Fitzmaurice also said it's important to define common AC and DC operating voltage ranges, as well as interfaces and connectors, and create and publish related standards. He concluded that the connected

Panelists from Georgia Power, Fulham, and Philips LED Electronics addressed intra-luminaire communication protocols.

lighting market is definitely ready to converge on common intra-luminaire communication protocols, and that it's time to select and standardize them so that manufacturers can build products to meet user needs.

Peter Duine of Philips LED Electronics agreed that DALI is a good starting point for connectivity inside the fixture, notwithstanding the challenges that still exist in using DALI for broader networked room control. "Lighting is going digital; it will happen anyway, so it makes sense to connect," he said, adding that "because it's digital, it's easy to add communication protocols." Duine said that although wired connectivity makes the most sense in the fixture, he believes that wireless is the future outside the fixture, thereby necessitating multiple protocols for full network communication. Following up on Fitzmaurice's discussion, Duine noted that while the U.S. has always worked with a seven-pin ANSI interface for outdoor luminaires, there's now a four-pin proposal that might be best suited for sensors, so we need sensor companies to deliver devices that can communicate DALI over this four-pin interface.

Russ Sharer of Fulham started his talk by reviewing the various devices that comprise a luminaire, and how they need to be integrated together. Stating that "the time for standards is now," he challenged the thinking that we need multiple technologies inside the luminaire. Sharer then considered how to build a luminaire today in such a way as to give end users the most functionality and security possible. "All of us want to solve the problem of lighting control," he said. But if lighting controls are too hard to use, then they're not used, so it's important to figure out how to make them simpler, so that we can make them more effective. "If we can treat all the devices in a lighting system the same from a communications standpoint, it makes luminaire and system design more flexible and, by definition,

more interoperable," Sharer said. He then briefly discussed how the emerging Bluetooth mesh technology might be suitable for both intra- and inter-luminaire communication, or otherwise connecting all devices in a lighting system, regardless of where they're physically integrated or installed.

Gaidon moderated a second panel, similar to the previous one but focusing on inter-luminaire communication protocols. Duine, once again a panelist, focused on indoor lighting, noting that while the myriad non-lighting and non-energy benefits of connected lighting are still in the early stages of being fleshed out, the benefits for indoor commercial lighting control are well understood. He suggested that, rather than explore what protocol might be best suited for use cases whose value is still not well understood, the industry should focus on delivering known adaptive lighting strategies (e.g., occupancy control, task tuning) by overcoming longstanding challenges (e.g., high complexity and total cost of implementation). Duine said it's probably too early to claim an ideal wireless standard for inter-luminaire connectivity, as many competing options are still significantly evolving. The current best path forward, he stated, is to start with Zigbee, "but we probably need something else."

Speakers from Philips LED Electronics, Cortet by CEL, and Silvair focused on inter-luminaire communication protocols.

Erik Davidson of Cortet by CEL observed that wireless mesh networking is ready for prime-time deployment, meshing architecture can sufficiently scale and is well-designed to sleep to save energy, and standard application layers are emerging. He noted that while Cortet currently focuses on Zigbee, it promotes and leverages application programming interfaces whenever possible. However, although we're ready for convergence from a technological point of view, Davidson said, we're not ready for it from a political standpoint, as witnessed by the intense protocol fights that are occurring. He pointed out that many implementations, while based on standards, are still effectively proprietary. "We've spent a lot of time overcomplicating this problem," Davidson said. "We just have to move forward." Doing so, he stated, requires five things: being standard, planning to expand, focusing on function, letting business drive, and finding partners.

Simon Slupik of Silvair asserted that the industry needs a standard that brings true cross-vendor interoperability, and he said his company believes that Bluetooth will usher in a new era for lighting by delivering it, and is proposing to use it not

just for lighting control, but for everything lighting system-related. Slupik observed that the space between light fixtures is shrinking, and that there are now more devices per luminaire. He reviewed the strengths and weaknesses of leading connectivity standards, and explained that none of the technologies addressed Silvair's view of industry requirements, so it dug deeper and ended up opting for the emerging Bluetooth mesh, whose advantages he reviewed, and for which Silvair has become a significant contributor. Slupik invited attendees to join the Bluetooth SIG (special interest group) to "help us make this thing better."

Specifying for Cybersecurity

PNNL's Karsten Kelly moderated a panel that focused on how owners and operators can specify connected lighting systems that meet their cybersecurity needs. Panelist Aaron Temin of the Mitre Corporation discussed cybersecurity tools for connected lighting. He described the National Cybersecurity Federally Funded Research and Development Center, which Mitre began running 2½ years ago to support the National Cybersecurity Center of Excellence at the National Institute of Standards and Technology. Temin reviewed emerging IoT device cybersecurity challenges, including device constraints, lack of market incentives to integrate cybersecurity features, lack of a cybersecurity culture, lack of standards, missing cybersecurity functions, and poor practices. Emphasizing the importance of risk management, Temin noted that there are no really good cybersecurity measures and metrics yet, and advised making use of frameworks for looking at vulnerabilities and weaknesses.

Kevin Powell of the U.S. General Services Administration (GSA) reviewed the main cybersecurity challenges that he's experienced as director of the Green Proving Ground program, such as how industry typically builds products with cybersecurity as an afterthought, that the IT security compliance timeline can be at odds with construction's previously defined critical path, that vendors may not have the resourcing required for responsiveness to the IT security process, and that evolving technology and security risks mean evolving requirements for IT security compliance. Powell called for vendors to "bake in" cybersecurity by following NIST 800-53 Rev 4 "Recommended

Panelists from the Mitre Corporation, the General Services Administration, and Xilinx discussed specifying connected lighting systems that meet cybersecurity needs.

Security Controls for Federal Information Systems and Organizations" and NIST Special Publication 800-82 Revision 2 "Guide to Industrial Control Systems (ICS) Security," adhering to NIST FIPS 140-2 Encryption modules and TLS 1.2 or higher encryption, and allowing sufficient time to submit required information and remediate vulnerabilities identified by IT Security compliance testing that will take place prior to installation, when setting project expectations.

Dan Isaacs of Xilinx talked about a security test bed created by Underwriters Laboratories (UL) under the auspices of the Industrial Internet Consortium. He noted that the test bed has an open, configurable cybersecurity platform, with coverage including endpoint, gateway, and other networked components, and that it supports key characteristics of industrial Internet reference architecture (IIRA) and industrial Internet security framework (IISF), and is used to demonstrate the system operational security processes, provide evaluation of the participants' claims, and enable identification of vulnerabilities and remediation options. The goal, Isaacs said, is to evaluate technologies that can support cybersecurity testing of, and validate cybersecurity claims for, connecting lighting and other IoT technologies. He explained that initial testing is in progress. "There's no one silver bullet that's going to address the security problem," Isaacs said. "It has to be a multilayered approach."

Integrating with Non-Lighting Systems

Poplawski moderated a panel that focused on how connected lighting systems are currently being integrated with non-lighting

Speakers from Arup and Integrated Building Solutions explored how connected lighting systems are being integrated with non-lighting systems.

systems in the real world. Panelist David Wilts of Arup started his discussion by considering what it takes to leverage lighting control systems to their potential. He said that if you want to design different systems to be integrated together, it takes more work, foresight, and perhaps experimentation, but the end result transforms the user experience, which is something the design and construction industry typically fails to understand. Wilts emphasized the importance of understanding what the operations model is for the client in question, and then designing the system accordingly. "We need to get away from what is often referred to in the industry as 'design intent,' which pushes too much, if not all, of the responsibility onto the contractors," he said. "You can't integrate or build a smart building without clear, concise directions for the contractors." Wilts observed that clients are increasingly marketing their facilities as a differentiator, and that converged building systems reduce risk, optimize savings and revenue,

increase asset value, promote wellness among workers, and help with recruitment. "It's not just lighting and IT," he said. "There are a lot of data that are important and can be integrated together."

Jon Sargeant of Integrated Building Solutions dug into the technical implantation of some real-world projects in his discussion of connected lighting systems and their integration in "smart" buildings. He noted that building owners are increasingly demanding connectivity between the systems that are being designed into their facilities, thereby requiring them to speak in a common language, and that the current standard protocol in commercial buildings is BACNet, with LonWorks a less widely used alternative. But Sargeant said BACNet is not the panacea that was hoped for, and connecting the systems together is only the first step in a relatively long journey toward a usefully integrated facility. He observed that some lighting control system vendors that don't support an open standard protocol instead offer a software application programming interface (API), which is less desirable from an integration standpoint because, among other reasons, it adds additional complexity to the integration process, which adds expense. Both approaches leave potentially fragile points of failure in the system and require significant, typically underestimated, time and experimentation to make things work as desired, which is ultimately a cost barrier for many projects. A more modern, well-adopted, and standardized data model would have a significant impact on the data integration process, Sargeant said.

What About Enery Data?

The workshop's final panel was moderated by PNNL's Jason Tuenge and considered the present and future of energy data for connected lighting systems. Panelist Gabe Arnold of the DesignLights Consortium® enumerated a wide range of things lighting energy data can be used for — from eliminating capital cost barriers; to enabling and expanding business models; to saving millions of energy-efficiency incentive dollars in measurement and verification costs; to improving customer experience; to creating a financial mechanism for continual performance improvements and, if necessary, system upgrades; to quadrupling project close rates; to creating guaranteed long-

Panelists from the DesignLights Consortium and Cisco talked about energy data for connected lighting systems.

term revenue streams. He emphasized the potential of the lighting-as-a-service business model, noting that energy data are a key enabler for it, and outlining the benefits, such as higher equipment sales and project close rates, new and guaranteed long-term revenue streams, a financial mechanism and

motivation for continual tech upgrades, reduced risk of ownership, and no capital costs for the users. Arnold said "lumens as a service" can unlock a $63 billion opportunity in the commercial building sector. He reviewed recent developments within the Green Button Alliance, which is an industry-led effort to provide electricity customers with easy access to their energy-usage data in a consumer-friendly format, which might play a beneficial role in accelerating the use of connected lighting system energy data.

Akshay Yadav of Cisco focused on the ability of Power over Ethernet (PoE) technology to provide energy data. He reviewed the evolution of PoE and discussed the underlying network architecture supporting energy data in buildings. "Today, when you construct a new building, you don't need five or six types of cable," Yadav said. "Ethernet can handle most of it." Yadav said Cisco has focused a lot on digitization of building data, and the company felt that PoE was its segue into entering the commercial building lighting arena. "The IoT is not just about power; it's about the communication," he said, noting that PoE is not just for new installs; Cisco has completely retrofitted three or four buildings in this way so far. Yadav reviewed the benefits of PoE lighting and building systems, including analytics for better efficiency and security; ease of deployment, monitoring, and scale; and modern experiences through IP convergence.

Brodrick concluded the workshop by thanking participants for their input and participation. He noted that the next DOE SSL workshop — the 12th annual SSL Technology Development Workshop — will be held in Portland, OR, November 8–9, and encouraged attendees to stay apprised of all DOE SSL program activities by visiting www.ssl.energy.gov. ∎

U.S. DEPARTMENT OF ENERGY | *Office of* **ENERGY EFFICIENCY & RENEWABLE ENERGY**

For more information, visit: energy.gov/eere/ssl