LEDs MAGAZINE®
TECHNOLOGY AND APPLICATIONS OF LIGHT EMITTING DIODES

SEPTEMBER 2023

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Playful pixels

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COVER STORY Brad Koerner's design philosophy of "every light is a pixel and every pixel is a light" is demonstrated at the intersection of architectural lighting and digital signage in immersive experiences (see page 11). [Image courtesy of Koerner Design. Original rendering enhanced with the aid of Midjourney generative AI software.]

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CARRIE MEADOWS

New ‘kids’ on the block

The next couple months represent my favorite time of year. The weather is usually wonderful, and the back-to-school energy hangs in the air, even for those of us far removed from school.

I remember some first days of school well, complete with the obligatory, informal portraits my mother hurriedly took before the bus arrived. I’m sure some of you have them, too. Every year brought the promise of expanded knowledge and new social experiences — what we’d call “networking” today.

I grew up in a small community and attended public school from kindergarten through twelfth grade so I was never a “new kid” in school. Still, I’ve had my share of first-day anticipation. I experience it even now when I attend industry events, and when our team launched the first LightSPEC West event last fall. I imagine many people who have launched an event have had a similar feeling — like attending the first day of school in a new location, full of promise and unknowns, such as how will it all go, who we will meet, and so on. There are a few such “new kids” to acknowledge on the lighting and controls industry event calendar.

At press time, representatives of the Lighting Research Center at Rensselaer Polytechnic Institute and the optical society SPIE are welcoming attendees to San Diego for a new addition to the SPIE Optics+Photonics conference: a 3D Printing for Lighting event to be held Aug. 22–23. Back when we first covered the 3D printing announcement, I inwardly bemoaned my inability to attend and hear the compelling research on the agenda. I look forward to hearing from the organizers how it all went.

The fall calendar has two more newcomers, both focused on lighting controls technology. On Sept. 26–27, the DesignLights Consortium will host “Unlocking the Potential of Networked Lighting Controls” in Detroit. The panels and discussions aim to engage DLC members, utility program personnel, and decarbonization advocates in overcoming barriers to implementing networked lighting controls to the benefit of building owners, managers, and occupants. And our old friends at the Illuminating Engineering Society New York City section (IESNYC) and Designers Lighting Forum of New York (DLFNY) — known for organizing the annual LEDucation conference and exhibition — will debut NYControlled in the Big Apple on Nov. 14. The one-day event will feature tech talks and networking opportunities on the exhibit floor at the Metropolitan Pavilion NYC.

And finally, our editorial team itself has a newcomer: Hayden Beeson has joined *LEDs Magazine* and *Architectural SSL* as associate editor. Hayden hails from Tulsa, Okla., and has worked as a freelancer and in editorial operations at industrial-machine lubrication media and training provider Noria Corp. On behalf of our LED and solid-state lighting community, welcome!

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Tunable white light and its benefits become more accessible

In an excerpt from *Architectural SSL*, GREGORY KAY of PureEdge Lighting summarizes advanced, customizable illumination solutions that improve building occupant experience.

The pandemic has changed how we think about offices, remote working, and employee workplace needs. While many office positions have allowed for remote work since 2020, many workers are being asked to return on-site today.

To entice employees back to the office, building owners and company facility managers have implemented strategies to improve indoor air quality and overall interior environments. Lighting is also critical as it affects productivity, health, and wellbeing.

In 2017, the American Society of Interior Designers in partnership with Cornell University, Delos, and the Innovative Workplace Institute researched the impact of workplace design on behavior and performance; the impact of spatial design on organizational goals; and the impact of design on human, organizational, and environmental sustainability. The study found that 68% of employees were dissatisfied with the lighting in their offices. In other words, there's ample room for improvement.

Today, tunable white lights are a reliable technology that can support alertness and productivity in an environment by helping workers maintain their natural circadian rhythm.

A 2013 study of human-centric lighting in five government office buildings by Rensselaer Polytechnic Institute's Lighting Research Center (LRC) found that employees working under human-centric tunable lighting had better sleep and lower levels of depression and stress than those who did not. Additional studies have shown the impact of light's spectral content and intensity on circadian rhythm. For example, too much blue light at night can undermine sleep.

In 2016, property company CBRE Netherlands along with the University of Twente and Vrije Universiteit Amsterdam installed time-controlled, Kelvin-changing lighting at CBRE's Amsterdam offices. High illuminance levels and cool, indirect white light were used in the morning and early afternoon; warmer, lower levels were used at midday and in the late afternoon. Approximately 120 employees were surveyed over a seven-month period via questionnaires, biological data, and interviews. Employees working under the new light settings experienced notable benefits:

Image courtesy of PureEdge Lighting

- Productivity increase of 18%.
- Work accuracy improvement of 12%.
- Happiness increase of 76%.
- 71% felt they had more energy.
- 50% of employees felt healthier.

At the study's completion, the office returned to its original lighting conditions. One of the first things the participants requested? Resuming the new lighting settings.

FULL VERSION AT:
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First look at the Virtual Sun for enhanced interior illumination

Access to daylight and views have been cited by many studies as important to human wellbeing as indoor air quality, and programs such as the International Well Building Institute's WELL Building standard certify buildings that prioritize such concepts for occupants. But what if you can't actually see sunlight and outdoor scenes because you're in a basement-level gym, an interior hospital room, or a windowless office space?

In 2013, Jonathan Clark and Sean Flynn co-founded the U.S.- and U.K.-based Innerscene with the goal of developing wall-mountable 3D displays realistic enough to be substituted for physical windows. LED technology engineered into Innerscene's Virtual Sun artificial skylight mimics the experience of real sunlight for spaces without views.

Courtesy of Innerscene

A row of Virtual Sun artificial skylight units

Virtual Sun casts electric light of varying color temperature onto objects and creates shadows; and when occupants look up, they appear to see the sun surrounded by a boundless blue sky. This illusion is achieved with a 2D image slice created by an array of collimated images and projected onto a Fresnel prism sheet, which produces an effect similar to virtual reality goggles or a 3D TV, but without the need for glasses.

As users move past or under Virtual Sun, the sun appears fixed in the sky. This effect is enhanced when multiple units are placed side-by-side: It doesn't appear that each window contains its own sun, but rather that all the windows are showing the same sun.

Beyond aesthetics, Virtual Sun can provide other benefits that come from skylights and access to the sun, such as circadian rhythm regulation, or entrainment. Innerscene designed the circadian rhythm cycle mode to automatically vary the brightness and correlated color temperature (CCT) over the course of a day to mimic the lighting outside. Installers can also program the skylight with a current location so that sunrise and sunset changes coincide with real-time natural daylight. When operated in circadian rhythm mode, Virtual Sun's warmest CCT measures 3000K and the coolest, 18,000K. With a reported color rendering index (CRI) value greater than 90, the unit can match the sky's color with a high level of accuracy. Unless you notice that the shadows around you aren't moving as the day goes on, you might just believe that you are experiencing the sun overhead. ◂

"First look at the Virtual Sun for enhanced interior illumination" originally appeared on Architectural SSL, an Endeavor Business Media partner site.

MORE: ledsmagazine.com/14297934

Fluence offers rebate assistance to horticultural SSL customers

Many people will procrastinate on filling out paperwork, sometimes to the point of avoiding it altogether even if that means missing out on financial opportunities. Now, horticultural lighting vendor Fluence has drawn attention to a free service that it provides to help out with such form-filling phobia.

The Austin, Texas–based LED specialist said that it has garnered over $26 million for its customers since 2017 by navigating what can be the bewildering processes of applying for rebates and incentives that many utilities offer for purchasing energy efficiency gear.

LED lighting, of course, generally fits the "energy efficiency" tag. So growers who chose to buy it could often qualify for utility cash-back programs. But securing the rewards can be "nuanced and time-consuming," noted Fluence rebate analyst Jason Battles. A grower might indeed apply, but "will often not secure the maximum rebate/incentive possible," he said.

Upfront costs can be prohibitive, but rebate programs can sometimes cover up to 100% of equipment costs, a Fluence spokesperson told *LEDs Magazine*.

Cannabis and other farm operators have slowed their purchases considerably over the last year, sending the horti-

Photo 79094980 © Rawpixelimages | Dreamstime.com

cultural lighting industry into a slump as noted by Fluence parent Signify.

Fluence's rebate update is the latest in a series of marketing and educational moves by the business and other LED lighting vendors in an effort to reverse the horticultural lighting slowdown. ◄

MORE: ledsmagazine.com/14298096

UCSB 'windowless' dorm design dies

The University of California is reviewing new dormitory designs after officials scrapped plans to build a 4,500-student dorm on the Santa Barbara (UCSB) campus. The abandonment of the original design comes in response to criticism regarding the population density and lack of windows in sleeping areas.

First revealed in 2021 and billed as a design that encouraged socialization outside of the dorm room, the proposed layout appeared to many as an attempt to maximize students and profit without regard to the general wellbeing of the occupants. Several university students and faculty argued that access to windows and daylight is necessary for mental and emotional health, a sentiment echoed in the resignation letter of UCSB architectural consultant Dennis McFadden, who stepped down from the university's design review committee in protest.

In his letter, McFadden described the planned building as a "social and psychological experiment with an unknown impact on the lives and personal developments of the undergraduates the University serves." McFadden included internal resident isolation on his list of concerns, noting that "an ample body of documented evidence shows that interior environments with access to natural light, air, and views to nature improve both the physical and mental wellbeing of the occupants."

Every floor of the building — save the top floor — was designed to adhere to what a UCSB spokesperson described as "a traditional 'House System' that is used by many universities across the country to create a community-within-a-community." Each floor featured eight houses, with each house containing eight suites, and each suite consisting of two bathrooms, a community area with a kitchenette, and eight single-occupancy (windowless) bedrooms. Windows were located in the common areas of each house: a "convivial" kitchen, laundry room, game room, and great room. The 11th and top floor of the building featured a landscaped, naturally ventilated courtyard nearly an acre in size and covered by a canopy.

The windowless living areas were ostensibly designed to encourage student interaction, as has been argued by Charles Munger, a billionaire and longtime UCSB donor who was to provide the primary funding for the project. But in a 2021 Q&A, UCSB staff revealed the reason for placing bedrooms in the center of the structure, without external windows, writing, "This approach allows for more student bedrooms and amenities on the site."

Munger has offered to donate $200 million toward the project with the stipulation that his design specifications be followed. When asked about the lack of windows, he argued that virtual windows installed in every bedroom would prevent any psychological distress and maintain the circadian rhythm cycles of residents.

Prior to its complete abandonment, the Munger design was altered, reducing the number of floors in response to population density concerns. According to a petition opposing the design, the building would be the largest university dormitory in the world — a title currently held by the U.S. Naval Academy's Bancroft Hall, which houses 4,400 midshipmen, according to the Naval Academy Business Services Division.

UCSB has since released a request for qualifications asking for bids and designs from architects to build a dorm to the latest specifications: 3,500 new beds, 1,000 fewer than the original Munger project. Moreover, according to a report from the *Santa Barbara Independent*, Munger has stepped away from the project.

This is not the first student housing project that Munger has been involved with. The vice chairman of the conglomerate holding company Berkshire Hathaway designed and funded a similar dormitory, the Munger Graduate Residences, at the University of Michigan (U-M). The dorm, completed in 2015, is advertised as "transdisciplinary living" designed to house graduate students from various fields. The university's website describes the dorm as "an environment that asks you to grow." To access sunlight, residents must travel to a windowed common area.

While on one hand dismissing the idea that windows are necessary, U-M has also attempted to combat the apparent psychological effects of living in such a facility by partnering the residency hall with the university's psychology department to provide seasonal affective disorder

Image courtesy of UCSB

lights. Such lights are designed to deliver mood-boosting effects from high-brightness, full-spectrum light boxes used at prescribed times of day during periods with shorter daylight cycles.

While the battle over windows in Santa Barbara may be finished, the push for windowless living spaces will likely continue. In March, New York mayor Eric Adams received criticism when he proposed eliminating the requirement that spaces designated as bedrooms should have windows. ◄

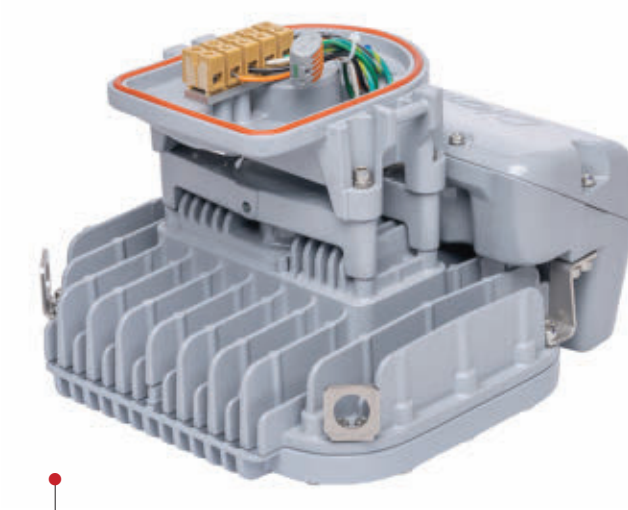
MORE: ledsmagazine.com/14298211

PRODUCT | spotlight

INDUSTRIAL & SPECIALTY SSL

LEDs have made their way into specialty and industrial use cases due to their high brightness, long lifetime, and color quality features. In some applications, luminaires are required to deliver high performance under harsh conditions, with exposure to cleaning solutions, ocean spray, high or low outdoor temperatures, shock and vibration, and attempted tampering all presenting potential challenges. A selection of specialty luminaires and drivers for demanding environments follows.

COMPILED BY HAYDEN BEESON



Battery Backup Area Light, Dialight

The new area light model provides an auxiliary battery backup solution that delivers illumination for a minimum of 90 minutes in accordance with National Fire Protection Association (NFPA) 101 guidance on emergency lighting. Vibration tested to IEC 60068-2-6, the 20-pound fixture is designed to withstand harsh industrial environments, with both non-hazardous and hazardous location models available. The area light is certified to UL1598/A, UL924, and UL844 to meet marine, emergency, and hazardous application requirements.

DIALIGHT.COM

Mercmaster LED Low-profile Luminaires, Appleton

Mercmaster LED industrial-grade luminaires feature an installed profile of six inches, ideal for low-ceiling applications. With outputs of up to 5500 lumens and four field-replaceable globe alternatives (clear glass, clear polycarbonate, diffused polycarbonate, and prismatic glass refractor), the low-profile fixtures can withstand harsh industrial conditions, wet and marine environments, and corrosive atmospheres. An emergency battery backup version offers 90- or 180-minute operation modes and a functional self-diagnostic test for code compliance.

APPLETON.EMERSON.COM

Two-hour Emergency Driver Solutions, IOTA

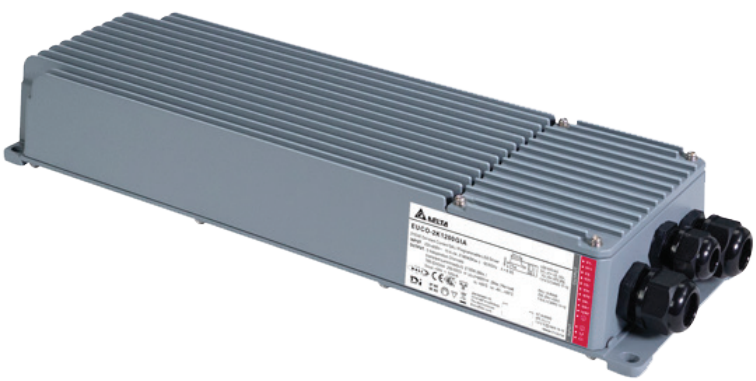
ILB2H and ILBHI 2H Series emergency drivers boast an extended 2-hour runtime capability, exceeding the standard 90 minutes of emergency operation outlined in the Life Safety Code. The drivers deliver constant, non-diminishing emergency illumination and are UL924 listed for factory and field installation. Installation is simplified with the intelligent AC activated battery circuitry, and the units automatically perform self-tests and self-diagnostics.

IOTAENGINEERING.COM

EUCO-2.1kW LED drivers, Delta

The latest EUCO Arena Sport Series devices feature DALI 2/D4i and DMX/RDM control versions and are designed to optimize the sports lighting experience for on-site and TV audiences. The DALI model is certified to the D4i standard, an extension of the DALI-2 lighting protocol, to meet demands for IoT connectivity. The drivers consist of three programmable independent output channels with a max output power of 700W/channel and can achieve a low peak-to-peak current ripple (<1%). They can handle a wide range of operating temperatures (–40°C to +50°C) and are IP66 rated.

DELTAPSU.COM



Lifeshield Architectural Downlighting, Current

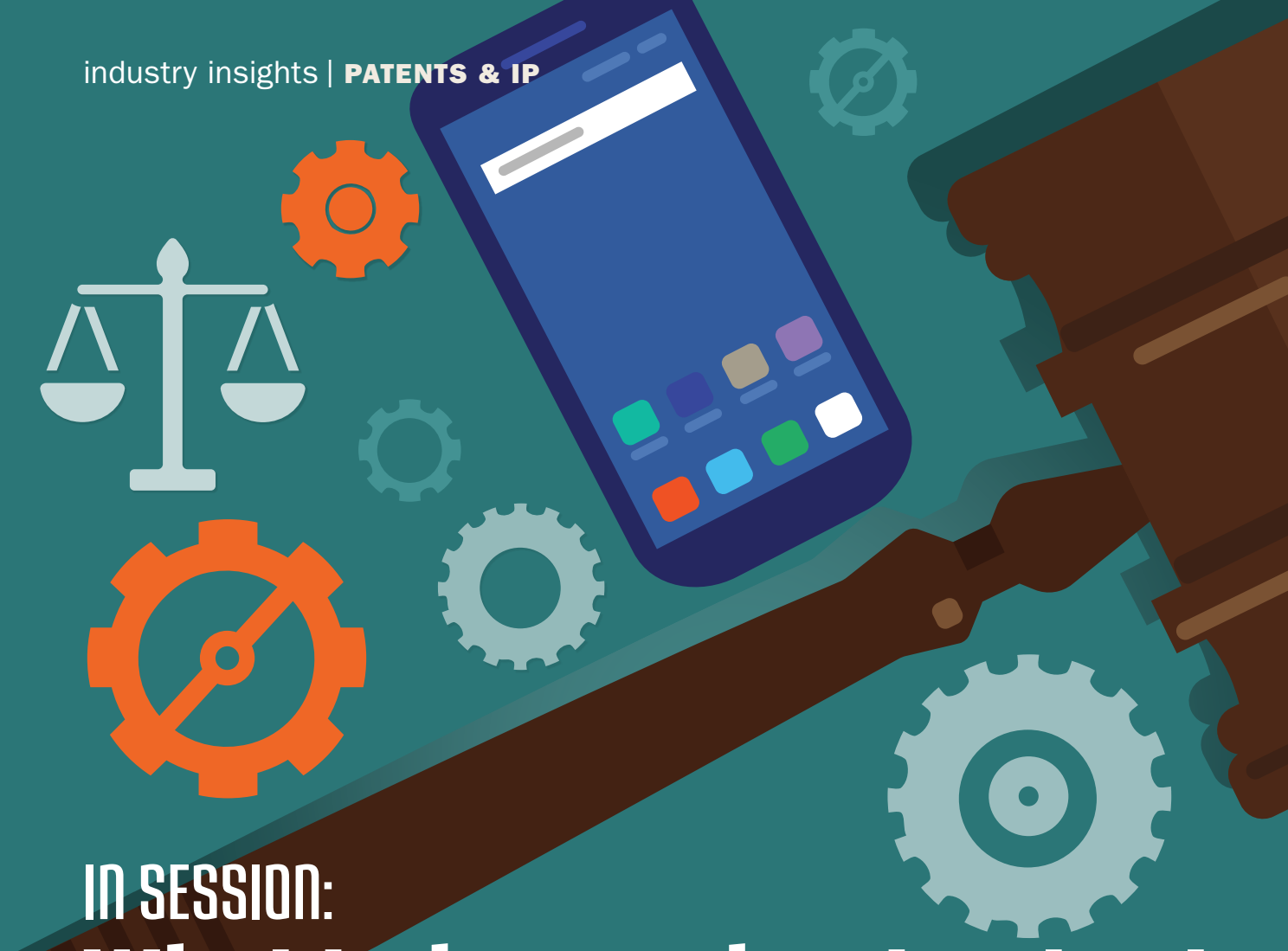
Designed for healthcare, behavioral, institutional, and cleanroom settings, Lifeshield downlights feature low-glare, quiet-ceiling designs that deliver a 50-degree visual cutoff to source and true color rendition. The fixtures are ISO3 cleanroom rated for sterile environments and meet other electrical, ingress protection, and safety standards, including CSA, Wet Environment, IC, CCEA, UL924, IP66, IP69K, IK10, MIL461G, and IEC. The luminaires are available in 4- and 6-inch round and square aperture models with beam distributions ranging from very narrow to extra wide.

CURRENTLIGHTING.COM

TritonPro and Harris Exterior LED Product Lines, Orion Energy Systems

The Harris and TritonPro product lines are aimed at construction and retrofit markets. The Harris Area Light Lumen Select, a high-performance outdoor LED fixture, illuminates large outdoor areas. The TritonPro line features four products in linear, linear high-bay, and troffer form factors to serve high ceiling, commercial, institutional, and retail environments, with reduced footprint and improved robustness across indoor and outdoor settings.

ORIONLIGHTING.COM



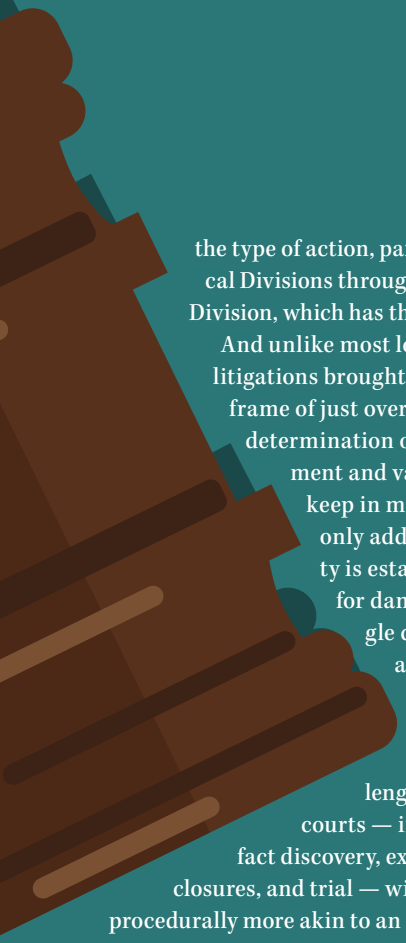
IN SESSION: What to know about patent litigations in the UPC

IP litigators **JONATHAN AUERBACH** and **DAVID RADULESCU** help lighting companies navigate process changes under the European Union's new Unified Patent Court system.

The Unified Patent Court (UPC) is poised to upend the European patent landscape with its launch on June 1, 2023. Rather than litigating in every jurisdiction where there is potential infringement, a patent owner can now bring one suit in a centralized court that will handle all issues with respect to liability in a streamlined timeframe. This article focuses on the practicalities of the new court and what LED lighting companies doing business in Europe need to know going forward.

On the litigation (contentious) side, the UPC will allow companies to bring a single infringement action that covers infringing acts in any of the member states. In the UPC, patent owners can assert both Unitary Patents — a patent issued via the new streamlined and central prosecution process — and the traditional European patents, rather than filing separate actions across multiple countries in Europe. Depending on

JONATHAN AUERBACH *is a patent litigator and* DAVID C. RADULESCU *is founder and partner at Radulescu LLP, a New York–based patent litigation firm that represents many technology innovators.*



the type of action, parties will file their cases in Local Divisions throughout Europe or in the Central Division, which has three branches.

And unlike most local European jurisdictions, litigations brought in the UPC will have a timeframe of just over one year from filing to reach a determination of liability, including infringement and validity. Although that is fast, keep in mind that this first proceeding only addresses liability. Once liability is established, a second proceeding for damages is then initiated. A single court in Luxembourg hears all appeals, which are expected to take a year.

LED lighting companies used to the multiple and lengthy phases of litigation in U.S. courts — including claim construction, fact discovery, expert discovery, pretrial disclosures, and trial — will find the UPC proceedings procedurally more akin to an *inter partes* review proceeding before the U.S. Patent Trial and Appeals Board. In those proceedings, parties litigate the validity of patents via a series of briefs and expert declarations, with little to no traditional discovery, and a decision on the merits is due within a statutory timeframe of one year from institution of the proceeding.

How does a UPC infringement action start?

To initiate an infringement action, the patent owner files a Statement of claim. The Statement includes facts, evidence, and legal argument demonstrating infringement. This evidence can include written witness statements and expert declarations.

An alleged infringer then has three months to file a Statement of defense, which similarly contains facts, evidence, and legal argument demonstrating non-infringement. At that time, the alleged infringer can also file a counterclaim for revocation, declaring that the asserted patent is invalid.

The patent owner then files a reply in support of its original Statement relating to infringement, a Statement of defense with respect to the invalidity claim (if filed), and may also move to amend the patent claims. Each party completes its briefing, with each allowed two papers per issue. The patent owner gets an initial Statement and reply relating to infringement, while the accused infringer gets a Statement of defense and a sur-reply relating to non-infringement.

Discovery — Who needs it?

Conspicuously missing from the aforementioned process is the several-years-long fact discovery period typical of a district court litigation in the U.S. There are no automatic disclosures; any discovery that a party seeks from the other side must be specifically requested and its production subsequently ordered by the judge. Given the fast pace of these proceedings, parties will likely need to rely on evidence already within their control.

Fast track to a one-day trial

Following the written procedure phase, the proceeding then enters an interim procedure phase. An interim conference, akin to a pretrial conference in the U.S., may be held. During the interim procedure, both parties crystallize the issues in dispute, the judge rules upon orders regarding discovery and orders further scheduling for the rest of the proceeding, then all participants discuss the possibility of settlement. The interim procedure lasts three months, then the oral procedure follows.

During the oral procedure, an oral hearing is held and expected to be completed in a single day. The parties present their oral arguments and any witness testimony. Following the hearing, the court is expected to issue a decision on the merits within six weeks. If the patent owner prevails, it then has one year from the final decision on the merits — including all appeals — to bring a separate proceeding to determine damages. Unlike in the U.S., where each party bears its own costs for the litigation, the successful party during the UPC liability phase may bring a cost proceeding to recover its litigation costs from the losing party.

Invalidating a patent at the UPC

Rather than wait to be sued, an LED lighting company expecting an infringement suit can first file a stand-alone revocation action challenging the validity of a questionable patent. Unlike the infringement action, which is heard by one of the local divisions, revocation actions are heard by the Central Division headquartered in Paris, with sections in Munich and Milan — the latter replacing London following Brexit.

The division of proceedings is based on the patent classification or art unit of the challenged patent. The World Intellectual Property Organization (WIPO) classification organizes patents into different technology areas. LED lighting companies should note that the Munich section will hear revocation actions involving lighting-related patents, classified as F21, under the WIPO system.

A patent owner may bring counterclaims for infringement in a revocation proceeding. As the UPC cases proceed, LED lighting companies should consider whether it is more beneficial to wait for an infringement suit — brought where the infringement occurs or where the alleged infringer is located — or preemptively file a revocation action that will be heard by judges in Munich.

Fees, fees, fees

Both infringement and revocation actions require payment of an initial set fee; current fees are €11,000 for filing an infringement action and €20,000 for filing a revocation action. A value-based fee must also be paid for actions involving infringement, based on the value of the case and determined

by the court during the interim procedure. It ranges from €0 for a case valued at less than €500,000 up to €325,000 for a case valued at more than €50,000,000.

Protective letters: A sneak-attack injunction

With respect to the UPC, perhaps the most important activities for LED lighting companies to understand right now are provisional measures and protective letters. A patent owner may apply for provisional measures with the UPC, requesting an injunction, the seizure of allegedly infringing goods, or a freeze of assets held in bank accounts. Critically, the UPC has the power to grant this relief *ex parte* — without the alleged infringer having the opportunity to be heard — in cases where delay might cause irreparable harm to the patent owner or where there is a chance that evidence may be destroyed.

To counterbalance the risk of provisional measures being imposed *ex parte*, an alleged infringer can file a protective letter, which can serve as a preemptive Statement of defense. The letter contains arguments from the alleged infringer regarding why it should not be subjected to provisional measures; it is the equivalent of opposing a motion for a preliminary injunction in the U.S. but filed before the triggering motion is filed, and it contains facts, evidence, and law. A €200 fee is required to file the letter — considerably lower than the fees for infringement and revocation actions.

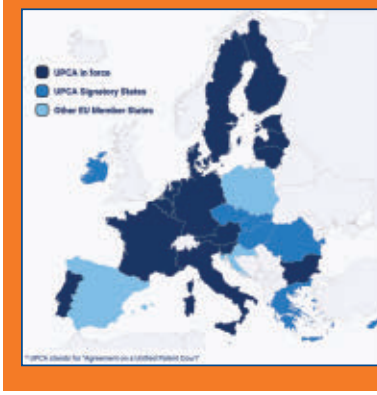
Once filed, the protective letter is *not* served on the patent owner nor is it made publicly available. Rather, the letter is sent to the patent owner only in the event that a request for provisional measures is subsequently filed. At that time, it is also sent to the appointed judge or panel hearing the request for provisional measures. A protective letter is only kept on file for six months; if no request for provisional measures is filed within that timeframe, the letter is removed from the UPC registry unless the alleged infringer pays a €100 fee to extend its expiration, with further extensions available upon additional payment.

The purpose of the protective letter is to protect the alleged infringer from the judge or panel issuing protective measures without that party getting a chance to be heard. In the case where a party has filed a protective letter and a patent owner subsequently files a request for provisional measures, the judge or panel will have arguments from *both* sides before issuing any remedy.

Notably, as of June 26, 2023, the UPC had received 236 protective letters, compared to only 4 applications for provisional measures. Thus, parties are taking the imposition of protective measures seriously even though the number of requests for provisional remedies has been relatively low so far. Additionally, in that first month of the UPC, 3 Revocation actions and 14 infringement actions were filed.

As noted by the UPC Administrative Committee, these numbers are likely to change dynamically as the months go by, and LED lighting companies should be monitoring the volume of new filings. In this way, they can be prepared for what is expected to be a popular avenue for enforcement and/or defense of patent rights across the E.U. market, and assess whether it makes sense to turn to the UPC or whether to continue litigating their patents in the local jurisdictions.

Unified Patent Court
Einheitliches Patentgericht
Juridiction unifiée du brevet



Unified Patent Court: A single patent court for Member States of the European Union. It was set up to decide on the infringement and validity of both Unitary Patents and classic European Patents. The UPC is a Court common to currently 17 E.U. Member States for which the Agreement on a Unified Patent Court (UPCA) has entered into force on June 1, 2023.

UPC

Source: https://www.unified-patent-court.org/en

Koerner Design

EDITED BY CARRIE MEADOWS

Koerner Design founder Brad Koerner has spent more than two decades in the architectural lighting and construction industries, spanning roles in global matrix organizations, design consultancies, and startups. Since obtaining his master's degree in architecture from Harvard Graduate School of Design, Koerner has designed architectural lighting projects in addition to developing new LED lighting products and market categories that have earned in excess of $350 million. Based in Amsterdam, Koerner has spent plenty of time traveling around the world seeking inspiration and sharing his experiences and ideas at industry events, in addition to writing on future trends in lighting design and immersive digital experiences

Firm mission, in layperson terms: I help lighting and A/V companies dramatically improve their innovation processes. I enjoy focusing on the intersection of architectural lighting and digital media systems, and helping clients develop innovative product lines to create new experiences in the built environment.

What the firm is known for: I invest heavily in understanding the state-of-the-art in a broad range of topics in order to distil future trends. I think many people in the industry know me for my thought leadership over the years, either through my blog and other contributed writings, or from the many conferences at which I've spoken, on topics ranging from embedded lighting to sustainable lighting to immersive digital experiences.

What people don't know about me: When I was young, I dreamed of being a Disney Imagineer and building immersive attractions and experiences. That led me to study architecture along with theatrical lighting, which led to my two-decades-long career in architectural lighting and creating innovative lighting systems. Innovation always fuses the best of multiple worlds.

First commission: After leaving the Corporate Ventures group at Philips Lighting, for my first commission I helped DigiValet, a fast-growing tech startup with an innovative app-based hospitality experience control

Brad Koerner has spent two decades bringing together architectural lighting and creative digital experiences.
All images courtesy of Koerner Design.

system, explore how to integrate branded lighting moments into its product offering.

Favorite product/project by your company and why: Helping Sean Darras and his team develop and launch Lightly, a new lighting brand focused on sustainable, bio-based, specification grade LED fixtures. I have advocated for bringing genuine sustainability to architectural lighting for over a decade, including developing a couple of beautiful sustainable products at previous companies that never made it to market. So to see the Lightly team having a wildly successful market launch with the reps in North America is rewarding and validating. They are making genuine steps toward cleaning up the toxicity and carbon emissions from the LED lighting category.

Luminous patterns developed for the former Philips Lighting showcase a broad range of embedded lighting possibilities, from warm and inviting lounge spaces (top) to streamlined retail displays (bottom).

Summarize your firm culture: I help clients dream big but execute practically. I understand how scarce resources are for all of our clients. Together, we explore exciting new concepts, but I aid them in realistically defining their ambition and setting precise goals through practical project scoping exercises.

What are you currently working on? I'm always looking for the next project or role helping leaders drive innovation at their firms!

A lighting trend to leave behind: Needlessly complex lighting controls based on antiquated technology standards.

A tool or product you want to invent: Where to begin? I'm deeply creative and constantly produce ideas for new product lines. I have so many product concepts waiting to find good homes.

As one example, I want to reinvent ceiling systems in commercial construction, fusing circadian lighting with acoustics and biomaterials to

Koerner has shaped development of solutions-oriented product lines such as Cima Cove, an indirect luminaire in a panel form factor, available with customizable materials, finishes, and color temperature options to meet project needs in new buildings and retrofits.

Top: For Koerner, decorative lighting presents an opportunity to fuse technology and allure. These enclosed luminaires mimic the simplicity and soft glow of tea lights while conveying a modern, sculptural glamour. Bottom: Koerner Design's philosophy of "every light is a pixel and every pixel is a light" is represented by the intersection of lighting and digital signage into immersive experiences. Original rendering enhanced with the aid of Midjourney generative AI software.

create gorgeous new aesthetics. The product concept is supported by several interesting technology trends, such as parametric design, digital manufacturing, novel biomaterials, and DC power.

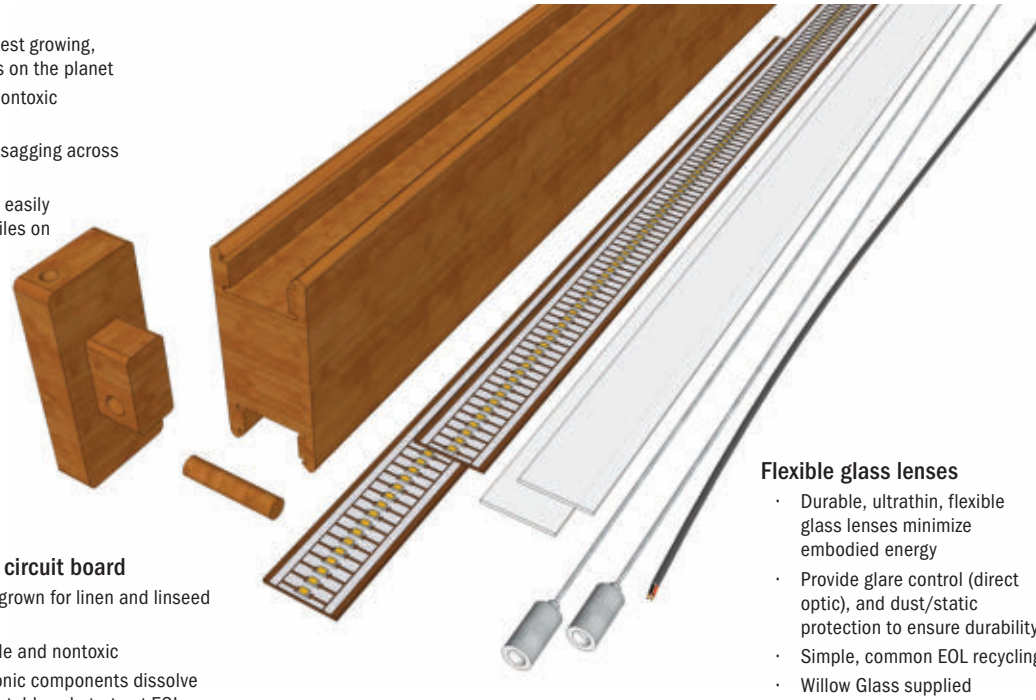
Don't get me started on all the ideas I have for decorative lighting, embedded lighting, workstation lighting, immersive digital experiences…

Advice to anyone interested in entering the lighting industry: Take a very broad view of what you define as "lighting" to ensure you are future-proofing your skills base and building your professional network in the market category you really enjoy.

Make sure to spend the time and money on attending a broad range of tradeshows and conferences to expose yourself to the various market segments of lighting. If you are in North America, these include LightFair for architectural lighting, LDI for theatrical lighting, InfoComm for digital signage and AV systems, or shows like Dallas Market Center for decorative lighting. If you are in Europe, the equivalents are Light+Building for architectural lighting, PLASA or Prolight+Sound for theatrical, Integrated Systems Europe for digital signage/AV, and Salone Del Mobile for decorative.

Laminated bamboo body

- Bamboo is one of the fastest growing, most renewable resources on the planet
- Fully biodegradable and nontoxic adhesives and finishes
- Dimensionally stable, nonsagging across lengths up to 12 feet
- Standard 2×4-foot profile easily channeled to precise profiles on 5-axis moulder
- Elements supplied by Lamboo Technologies



Flax-based printed circuit board

- Flax is commonly grown for linen and linseed oil production
- Fully biodegradable and nontoxic
- Traces and electronic components dissolve away from compostable substrate at EOL
- Soluboard supplied by Jiva Materials

Nontoxic cabling

- Small gauge, low-voltage DC wire minimizes copper consumption
- Free of halogen, chlorine, bromine, and fluorine
- EcoAcePlus supplied by Furukawa Electric

Flexible glass lenses

- Durable, ultrathin, flexible glass lenses minimize embodied energy
- Provide glare control (direct optic), and dust/static protection to ensure durability
- Simple, common EOL recycling
- Willow Glass supplied by Corning

If you are still in school, use the available academic discounts to attend conference tracks whenever you can. Or better yet, submit presentation proposals! Those conference sessions are the most relaxed place to network with industry leaders.

Technology, (third-party) product, and/or designer you admire: The digital signage industry is experiencing a period of innovation and growth with technologies such as direct-view LED screens and live rendering. I believe that every light is a pixel and every pixel is a light: The fusion of what we consider "architectural lighting" and "digital signage" is already underway; architects and lighting designers need to rapidly retool their thinking and skillsets.

Favorite lighting/engineering rule of thumb, standard, or equation: If you're starting a new entrepreneurial venture, whatever you think it will cost, double it. Then double it again, and you might be in the right ballpark.

Summarize your firm's environmental, sustainability, and governance (ESG) initiatives: For over a decade now, I've been a vocal industry advocate for adopting a radical, simplified concept of sustainability in LED fixture design. The U.S. Department of Energy Solid-State Lighting team has been highly receptive: I've been invited to present at several DOE R&D Workshops to advocate for funding for sustainable product research. In 2019, I independently won the grand prize in the DOE R&D competition for a sustainable office luminaire design with my "bamboo pendant" concept — which was popular among industry colleagues and helped lead to the launch of Lightly.

Visit Koerner Design online

Koerner's drive to achieve beauty, simplicity, and sustainability led to the DOE R&D grand prize-winning bamboo pendant design, which helped to drive the launch of bio-based luminaire developer Lightly.

LIGHTING AND ENERGY AUDIT INCREASES RETROFIT PROJECT SUCCESS

GINA GRIFFITHS RODDA explains the importance of defining energy-code compliance requirements for existing buildings, and how lighting audits can ensure that retrofit projects check every box.

Indoor lighting is one of the single largest consumers of electricity in commercial buildings, representing nearly one-third of electricity use. The California Energy Code strives to minimize lighting energy use, without compromising quality of light or task work by limiting allowed lighting power (watts) installed in buildings, specifying basic equipment efficiency, and requiring lighting controls. California offers several energy-code compliance options for lighting projects. Some options require submittal of a reflective ceiling plan and audit at the time of permit application. Before beginning work on a lighting retrofit project, audit the space and note existing conditions. Knowledge of the existing lighting conditions can help designers, specifiers, and installers select the best compliance path in addition to demonstrating to the local building department how the existing lighting power density levels and controls compare to the proposed design.

The first thing to understand is that if an indoor, outdoor, or sign lighting project increases the energy use of the retrofitted system, the project is considered an "alteration" and must comply with the energy code. If the project does not increase the energy use of the existing system, the project is considered a "repair" and does not trigger the energy code requirements. Tables 1 and 2 on page 17 show the types of projects that may or may not trigger the energy code.

Energy code requirements

Indoor and outdoor lighting alteration projects can pursue three different pathways, based on project scope, that provide alternative means of showing compliance to the wattage allowance *and* what mandatory controls will be required. When assembling a lighting alteration package for a client, it is

GINA GRIFFITHS RODDA, *a certified energy analyst (CEA) and LEED accredited professional (AP) is principal and owner of consultancy firm Gabel Energy, and contributes her expertise to Energy Code Ace as a subject matter expert, providing support and training on Title 24, Part 6.*

TABLE 1. Indoor lighting system project tasks and energy code scope.

Project scope of altered indoor lighting systems: New construction and alterations must show compliance with the energy code. Repairs that do not increase energy use will not be required to show compliance.	**Compliance scope per energy code**	
	Will require compliance to the energy code for applicable lighting features	Will not require compliance to the energy code
Increasing the connected lighting load in a space	New construction	
Replacing/rewiring ≥10% of luminaires in a space	Alteration	
Replacing or rewiring >50 luminaires a year in a ≤5,000-square-foot building, or ≤5,000-square-foot tenant space in a multitenant building	Alteration	
Moving ≥10% of luminaires in a space (even if putting them back)	Alteration	
Redesigning reflected ceiling plan in a space and not increasing lighting load	Alteration	
Adding luminaires while replacing/rewiring others, in which the connected lighting load in the space is not increased	Alteration	
Rewiring lighting circuits; relocating, modifying, or replacing lighting wiring	Alteration	
Replacing lamp and driver for ≥10% of luminaires in a space	Alteration	
Adding or altering lighting controls (removing existing controllability not allowed)		Repair
Moving walls but not making changes to the luminaires in a space		Repair: New area control may apply
Moving luminaires to facilitate asbestos abatement		Repair
Removing luminaires in a space		Repair
Replacing a lamp, lens, or driver while not increasing energy use		Repair

TABLE 2. Outdoor lighting system project tasks and energy code scope.

Project scope of altered outdoor lighting systems: New construction and alterations must show compliance with the energy code. Repairs that do not increase energy use will not be required to show compliance.	**Compliance scope per energy code**	
	Will require compliance to the energy code for applicable lighting features	Will not require compliance to the energy code
Increasing the connected lighting load of the outdoor lighting system	New construction	
Replacing 10%–49% and five or more luminaires	Alteration: Wattage requirements will not apply; controls will apply; BUG may apply	
Replacing ≥50% and five or more luminaires Adding luminaires while retrofitting existing luminaires so that the total site lighting load is not increased	Alteration: Wattage and control requirements will apply; BUG may apply	
Modifying or retrofitting luminaires but existing pole to remain		Repair
Replacing <10% and no more than four luminaires		Repair: BUG requirements may apply
Removing luminaires		Repair
Replacing a lamp, lens, or driver while not increasing energy use		Repair
Adding or altering lighting controls (removing existing controllability not allowed)		Repair

important to be aware of how the wattage of the proposed luminaire may affect required lighting controls (see Table 3).

For indoor lighting options, one-to-one alterations per §141.0(b)2I either replace whole luminaires one for one — in which the only electrical modification involves disconnecting the existing luminaire and reconnecting the replacement luminaire — or the luminaire components alone are modified without replacing the entire fixture. This method is limited to buildings and tenant spaces (in multitenant buildings) greater than or equal to 5,000 square feet that can show more than 40% permanent energy reduction compared to the pre-altered wattage. Energy code is not triggered when fewer than 50 luminaires per floor or tenant space are altered per year. Not all mandatory indoor lighting controls are required with this method, and existing control functionality cannot be removed, but it can be replaced.

Luminaire alterations per §141.0(b)2I cover adding luminaires, removing and reinstalling luminaires, or combined replacement of lamps and ballasts or drivers. Luminaire alterations do not include repairs, such as replacing lamps only, ballasts or drivers only, diffusers, shades, or luminaire covers. This method is limited to projects removing and reinstalling 10% or more of the existing luminaires, replacing and/or removing 10% or more of luminaires in an enclosed space, and redesigning the lighting system. The alteration excludes enclosed spaces with only one luminaire.

Any prescriptive compliance method can be used (Complete Building, Area Category, or Tailored Approach). The Area Category Method (§140.6) supported in this article is most often used to determine the maximum wattage allowance per space type. If the project can show that the total altered lighting power is less than or equal to 80% of the indoor lighting power allowance in §140.6, then not all mandatory indoor lighting controls are required. Again,

Alterations that increase the lighting load must comply with new construction requirements.

TABLE 3. 2022 Mandatory indoor lighting controls for alterations §141.0(b)2I.

Requirements based on lighting alteration compliance method used		One-to-one component method	Luminaire alteration method Excluding spaces with ≤1 luminaire	
		Total wattage reduced ≥40% Limited to 5,000 square feet	Using ≤80% of allowed LPD	Using >80% of allowed LPD
Manual area controls (on/off): §130.1(a)		Yes	Yes	Yes
		Separate switching for "general" and "other" not required for shared circuits		
Multilevel control: §130.1(b)		No	No	Yes *Only for modified luminaires*
Auto shut-off control: §130.1(c)1-8 Excluding healthcare facilities	Whole building shut-off (timeclock, timeswitch, or all luminaires control locally with sensors): §130.1(c)1-4	Yes	Yes	Yes
		Separate controls for "general" versus "other" not required for shared circuits		
	Partial-on or vacancy sensors (when multilevel required) or occupancy sensor (when multilevel not required): §130.1(c)5	Yes	Yes	Yes
	Full or partial-off sensors: §130.1(c)6 Partial-off sensors: §130.1(c)7	Yes *130.1(c)6D for Offices >250 square feet not required*	Yes *130.1(c)6D for Offices >250 square feet not required*	Yes
	Hotel/motel room auto shut-off: §130.1(c)8	Yes	Yes	Yes
Primary and secondary automatic daylighting control: §130.1(d)		No	No	Yes
Demand responsive controls: §110.12(c)		No	No	Yes

TABLE 4. 2022 Outdoor lighting controls and wattage requirements for alterations.

§141.0(b)2L	Modify or retrofit luminaires*	Replaced luminaires		
		<10% or ≤4	10%–49% and ≥5	≥50% and ≥5
Prescriptive wattage allowance required §140.7	No	No	No	Yes, unless replacement uses ≤40% of existing wattage
Shielding/BUG §130.2(b)	No	Yes, if luminaire ≥6,200 lumens Exception for alteration(s): Replacement of existing pole luminaires meeting all of the following: • Where the existing luminaire does not meet the luminaire BUG requirements in Section 130.2(b); and • Spacing between existing poles is greater than six times the mounting height of the existing luminaires; and • Where no additional poles are being added to the site; and • Where new wiring to the luminaires is not being installed; and provided that the connected lighting power wattage is not increased.		
Daylight available §130.2(c)1	No	No	Yes	
Automatic scheduling §130.2(c)2	No	No	Yes, when either of these is true: • Parking or sales lot luminaire ≤24 feet above ground and is >40W; or • Parking or sales lot luminaire >24 feet, or any other luminaire type, is >40W, and *does not* include a motion sensor.	
Motion sensing §130.2(c)3	No	No	Yes, when either of these is true: • Parking or sales lot luminaire ≤24 feet above ground and is >40W; or • Parking or sales lot luminaire >24 feet, or any other luminaire type at any height, is >40W, and *does not* include automatic scheduling (luminaire lighting power to be reduced with motion sensor ≥40%).	

existing control functionality cannot be removed, but it can be replaced. Alterations that increase the indoor lighting load of the space will be required to show compliance with new construction lighting requirements.

For outdoor lighting options, when modifying or retrofitting an existing luminaire per Chapter 6.6 of the *Nonresidential Compliance Manual*, no energy code requirements are triggered.

Under §141.0(b)2Lii and iii, depending on how many luminaires are being replaced, wattage, shielding, BUG, and/or controls may be required (see Table 4). Wattage compliance can be achieved by permanently reducing wattage by at least 40%, or using prescriptive requirements of §140.7 as required for new construction projects. As with indoor lighting, alterations that increase the outdoor lighting load will be required to comply with new construction lighting requirements.

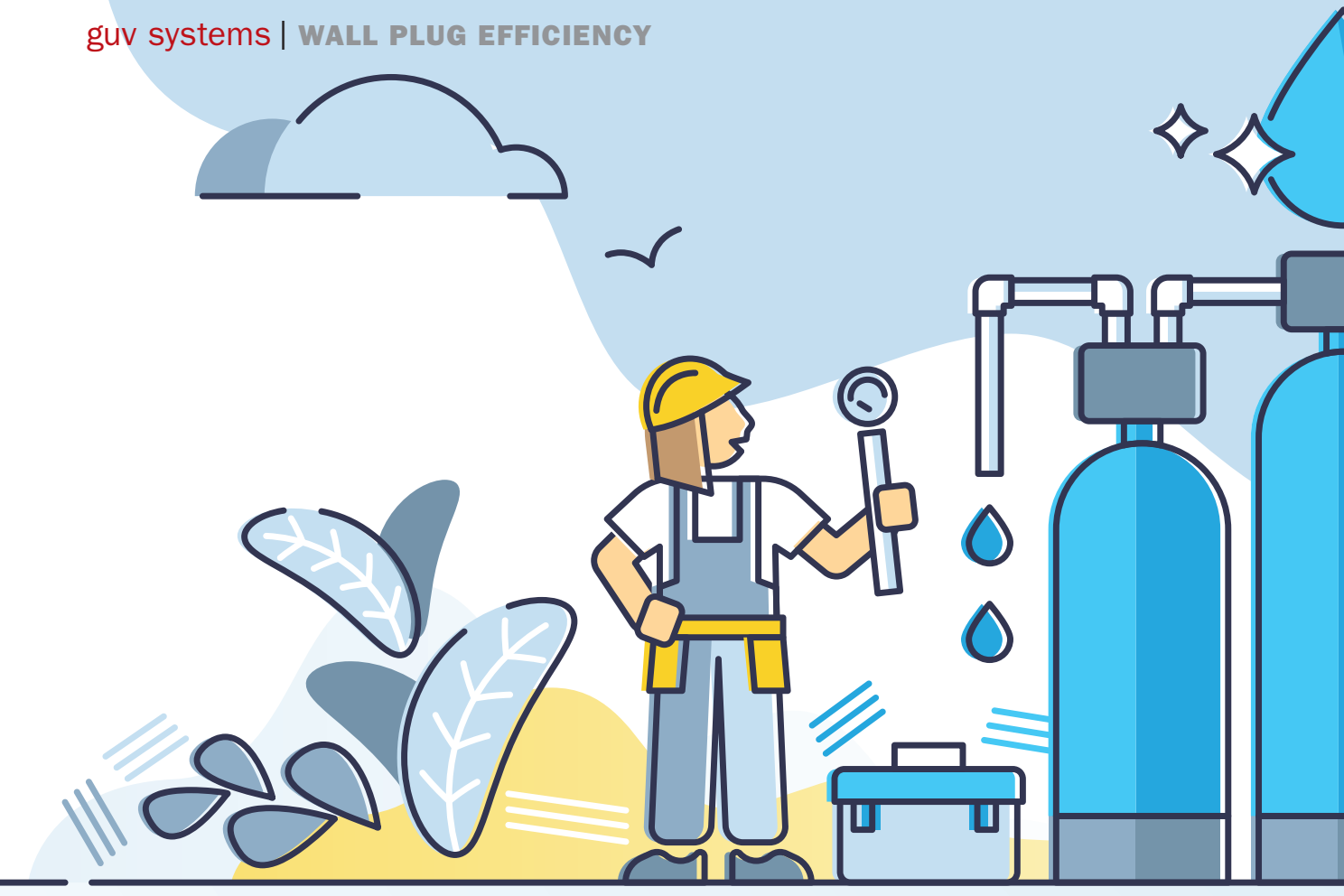
Audit tasks supporting code compliance

Now that we have explained what is required by the energy code, lighting professionals should incorporate the following lighting audit basics to support the options and requirements of the code. This will in turn minimize how many times the site needs to be audited for existing features.

Confirm the project "triggers" the energy code by reviewing the scope of the project, then document the existing wattage and how it will be permanently reduced to take advantage of indoor control exceptions and simplified compliance documentation for outdoor lighting.

Audit not only the luminaires of an existing site, but also the existing controls, their location, and functionality. If control exceptions are allowed, existing controls may demonstrate compliance with the energy code as long as they support the required control functionality. Therefore, designers and installers must be aware of all control requirements, and how they may change what is collected during an audit for indoor room configuration including windows and skylights (daylighting controls); room size and type (multilevel and shut-off controls); general lighting versus all other lighting (separate switching, daylighting, multilevel ,and demand responsive controls); and existing controls and how they are wired within the space. For example, if the space is wired with A/B switching as was required in older codes for multilevel or daylighting, this may no longer be acceptable for current requirements associated with multilevel and daylighting and will most likely mean the space will need to be rewired.

The tables accompanying this article provide a brief reference for energy code compliance and lighting audit considerations. For more in-depth information, guides, and forms to help with energy and lighting project audits, visit energy codeace.com.



Rethinking wall plug efficiency for UV-C LEDs in water disinfection

UV-C LEDs have advanced on a wave of interest in disinfection technology, but **EOIN CONNOLLY** and **RAJUL RANDIVE** advise water-disinfection system OEMs to compare light-source WPE in operation alongside energy costs and microbial targets to understand application performance versus budget.

Advances in ultraviolet C-band (UV-C) LED performance have accelerated in the past five years. Coupled with the COVID-19 pandemic and awareness around touchless disinfection, activity in the germicidal UV space has led to more comparisons between UV-C LEDs and mercury lamps. One recent debate has been on the wall plug efficiency (WPE) of UV-C LEDs compared to legacy disinfection technology. WPE is the ability of a device to convert energy into light. Some industry stakeholders have proposed that UV-C LED adoption in germicidal UV (GUV) applications will be limited until the devices can match the performance of existing commercial mercury lamps.

Doubt around readiness of UV-C LEDs for widespread adoption has previously been debated with respect to power and lifetime. But as more OEMs evaluate the technology and lean into its inherent benefits around design flexibility and on-demand operation, market leaders can see that the technology is in fact ready, especially for low-flow water disinfection applications. Intelligent designs that optimize the placement of LEDs, water flow, and duty cycle parameters have driven commercially available UV-C LED–based disinfection reactors that exceed performance requirements.

Why is there debate around WPE? Simply stated, the WPE of UV-C LEDs

EOIN CONNOLLY *is president and CEO, and* RAJUL RANDIVE *is director of global application engineering at Crystal IS, a UV-C LED developer based in Green Island, New York.*

Illustration 215264951 © VectorMine | Dreamstime.com

is still relatively low — between 3% and 10%. In fact, most of the energy applied to the device is still converted into heat. However, just as with power and lifetime, performing apples-to-apples comparisons between WPE of UV lamps and UV-C LEDs still doesn't make sense. Although it is an important metric, WPE is not the sole measure of progress for this technology.

Materials influence WPE

Current WPE of UV-C LEDs is in the single digits, with most commercially available UV-C LEDs in the range of 3% to 6% depending on the product. Improved LED efficiency can be achieved at multiple points within the device, commonly categorized as either internal or external efficiency.

Internal efficiencies can be improved by reducing defects and dislocations in the epilayers of the substrate material. External efficiency can be improved by redesigning the device for better light extraction.

Many UV-C LED manufacturers grow structures on bulk sapphire, a low-cost, transparent substrate. However, sapphire has lattice and thermal expansion mismatch with the nitride layers, creating an increased number of dislocations in the material, which fundamentally limits the internal efficiency for sapphire-based UV-C devices. Manufacturers using bulk sapphire as a foundation focus on improving extraction efficiency to improve the overall WPE for their devices.

Manufacturers that use bulk aluminum nitride (AlN) substrates have an inherent internal efficiency advantage — more specifically, the internal quantum efficiency (IQE), which is the percentage of electron-hole recombination that results in a photon as opposed to the heat that is generated when an electron encounters a dislocation defect. Devices grown on AlN have demonstrated more than double the IQE at UV-C wavelengths compared to those grown on sapphire substrates. Thus, manufacturers using bulk AlN as the foundation for their UV-C LEDs seek to improve WPE through improved internal *and* extraction efficiency.

Calculation of annual operating cost based on UV light source WPE.

Light source	UV Lamp	UV-C LED A	UV-C LED B	UV-C LED C
WPE (%)	30	2.5	5	6
kWh per year	53	37	20	15
Annual operating cost	$8.74	$6.10	$3.30	$2.47

Source: Crystal IS calculations.

Adoption increases despite current WPE

Over the past few years, adoption has increased for UV-C LED–based technology

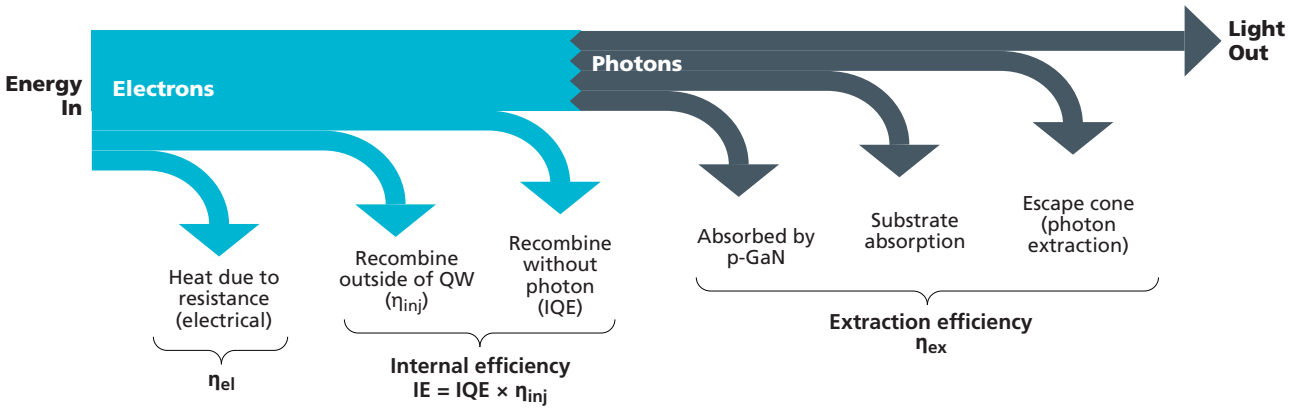


FIG. 1. Illustration of efficiency loss in a UV-C LED device. Image courtesy of Crystal IS.

in point-of-use (POU) water systems that operate at flow rates of up to 5 gallons per minute (gpm). Point-of-entry (POE) systems are generally defined as having a flow rate of 5 to 50 gpm, and we are seeing adoption of UV-C LEDs in the lower-flow systems. Industrial, wastewater, and municipal treatment is traditionally defined as flows of more than 50 gpm. POU and POE systems will typically operate at a low duty cycle, whereas the high-flow systems have more continuous operation.

Wall plug efficiency and duty cycle go hand in hand. The low duty cycle in POU and POE means that a WPE between 3% and 6% is more than adequate. Higher WPE is favored for higher flow rates to reduce heat load, because these systems demand more LEDs to reach appropriate disinfection dosage requirements.

Generally, OEMs considering UV-C LED–based product development plan ahead for more than a simple light source swap from lamp to LED. They often redesign applications to take full advantage of the LED benefits such as smaller footprint, instant on/off, and wavelength effectiveness. As they design such disinfection products, they can optimize system operation so the WPE parameter becomes less important with regard to total energy consumption.

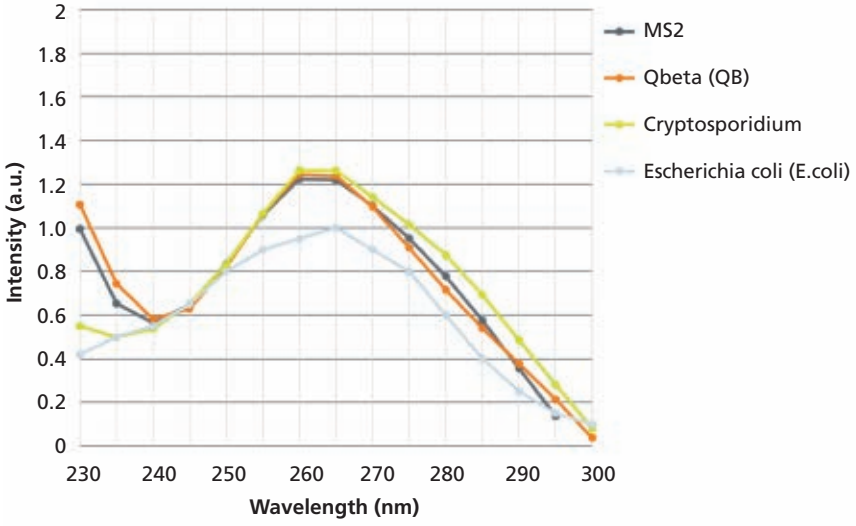


FIG. 2. Absorption curves for common target microbes in water disinfection applications. Created by Crystal IS; adapted from https://scholar.colorado.edu/downloads/rn301175t.

Impact of WPE in a POU water disinfection system

We can use a residential POU water disinfection system design for WPE and operating cost comparisons. The impact on total cost of ownership is a common benefit for consumer POU applications, as LEDs operate only while disinfecting. Mercury lamp–based systems will operate with an idle mode or lamp cycling to reduce the impact of lamp warm-up time on the user.

A system using a 11W lamp may consume only 5.5W while in idle mode. It would potentially operate at full power 10% of the time and in idle mode the other 90% of the time. At this rate, the system would draw a little over 53 kWh per year from the building electrical supply. According to the U.S. Department of Labor, as of May 2023, the average electricity kWh cost in the U.S. is $0.165, bringing the operating cost to just under $9 for a typical year.

If we consider the same system performance with an LED-based design, we can evaluate the annual energy cost for a few different LEDs with varied WPEs (see table on p. 21). Although we can assume the same operating time — 10% on/90% idle — typically when an LED-based system is at idle, there is no power draw from the light source.

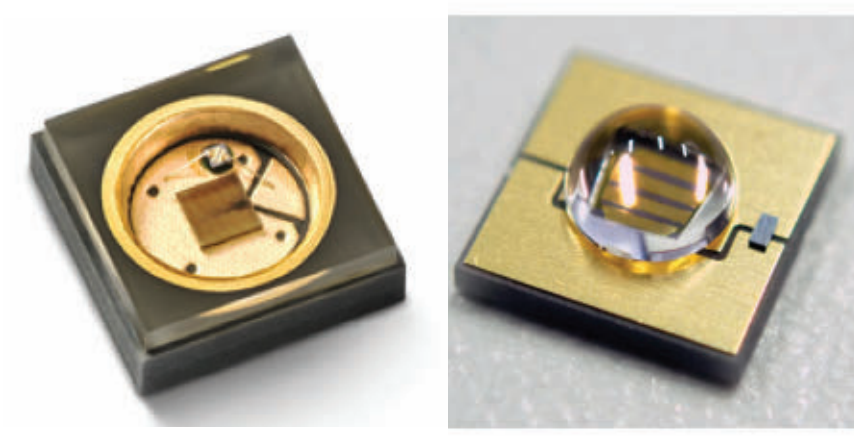
Switching from a lamp-based system to the UV-C system saves the end user anywhere from 30% to 70% on energy costs depending on the UV-C LED

employed. However, an improvement from 5% to 6% WPE provides less than $1 in annual savings. While the switch from lamp to LED is compelling when paired with the other sustainability advantages, the impact of a discrete LED's WPE on the end consumer is negligible — particularly at the current range of WPE across commercially available UV-C LEDs. For the lower-flow POE market in the 5 to 12 gpm range, a 5% WPE seems to be the threshold for broader market adoption.

Design discussions concerning WPE often center around reducing the number of LEDs and decreasing heat load to lower overall system cost for the OEM. This becomes less about the WPE and more about the efficiency of the disinfection power employed, which is the impact of the total UV-C power on the target microbe at the target wavelength.

Disinfection systems must meet a particular disinfection performance based on a target microbe or biodosimer being used to develop the GUV system and that biodosimer's spectral response. The biodosimer is a surrogate test microbe used to ensure the system delivers the claimed disinfection performance for the intended application. These microbes are often defined by industry standards organizations such as the National Science Foundation (NSF) or Environmental Protection Agency in the U.S. However, some manufacturers may prefer to use a specific microbe based on other regional market requirements. For example, the NSF defines Qbeta as the target microbe for systems seeking certification, while an OEM targeting the European market would design with Pseudomonas A.

Referring back to the table, since UV-C LEDs B and C have very close WPEs, we can then compare the disinfection performance and cost for two system designs using these LEDs. LED B with the 5% WPE offers power output of 160mW at 265nm (a commonly used UV-C disinfection wavelength), while LED C with a 6% WPE emits 140mW at 275nm. A system targeting *E. coli* bacteria would require 20% more power in the LED C package to meet the same disinfection performance as the system using LED B. Although there may be a benefit in WPE and the annual operating cost to the end user, when looking at the LED budget in the overall system, LED B becomes the more attractive option.



UV-C LED available in 2016
Size: 3.5 × 3.5mm
Power: 30mW
Wall plug efficiency: 0.75%

UV-C LED available in 2023
Size: 3.5 × 3.5mm
Power: 160mW
Wall plug efficiency: 5%

FIG. 3. UV-C LED footprint remains the same, but output power and WPE have increased performance over the past several years. Image courtesy of Crystal IS.

Considerations for scaling to large-flow, continuous disinfection

In the current addressable applications around point-of-use, point-of-dispense, and lower-flow POE applications, existing commercial UV-C LED performance meets OEM requirements — including the WPE performance. There is some early adoption in the industrial water treatment sector, particularly in beverage and pharmaceutical processing and dispensing equipment that operates intermittently. These industries are looking to take advantage of other key LED benefits, such as reducing unplanned maintenance that will offset an increase in system cost.

As we look at higher-flow use cases in municipal and wastewater applications, WPE is likely to become more important. Legacy large-scale systems use massive lamps that consume a great deal of energy — thus energy efficiency may hold more weight than other parameters when developing such systems.

The industry is just beginning to see UV-C LED–based equipment for these applications and already early adopters are reimagining what a typical reactor design looks like. For example, new LED systems are employing external cooling methods, as opposed to process water like legacy systems. Leaders in this space will continue to challenge conventional wastewater and municipal reactor designs to leverage UV-C LEDs, just like POU and POE OEMs are doing today, scaling them to even greater benefit as the system deployments serve a larger population.

Form follows function when lighting educational spaces

Lighting design priorities remain the same despite how schools and learning have evolved, as seen in this case study of Powel SLAMS, designed by Rogers Partners with lighting designer The Lighting Practice.

Academic lighting design remains rooted in practicality. That's not to say that the spaces are stagnant or that the challenges of lighting them aren't real. It's simply a matter of balancing form and function, along with practicality and technology, while making programming the priority. Michael Barber, principal, The Lighting Practice, Philadelphia, explained: "You don't need to specify tunable light sources, color changing fixtures, or technologically cumbersome products. I try to keep it simple. It's the union of light and architecture, with a focus on the program. At the end of the day, it's got to be functional."

JANA MADSEN *is a freelance writer covering the architectural, buildings, and construction industry.*

The Lighting Practice has built a portfolio of extraordinary projects based on the fundamental principles of careful listening, collaboration, and dedication to achieving the vision of their clients. The recent Powel SLAMS K–8 school project is just one example.

Opened in 2021, the Powel SLAMS school co-located Powel Elementary School and Science Leadership Academy Middle School (SLAMS) on the Drexel University campus. The 87,000-square-foot, two-story building in West Philadelphia is now open to 720 students.

Barber's team carefully tailored the lighting design at Powel SLAMS to the function of school spaces. "We were engaged in a few planning and programming sessions to understand what was most important to the client and how the lighting should function and operate," said Barber. Wayfinding graphics were lit to make them obvious and easy to read. The gated playground was outfitted with building- and pole-mounted small aperture accent lights for security and safe play. And the cafetorium (a multiuse space that doubles as a cafeteria and auditorium) contains downlight cylinders that provide functional light on lunch tables and track lighting fixtures to deliver accent illumination in areas where a stage/podium can be located.

With an emphasis on active learning, interaction, and engagement, the classrooms at Powel SLAMS are lit for high visual acuity. Students today work more collaboratively than in the past. "The concepts are still the same, though: put lighting on writing surfaces and provide even ambient illumination," Barber said. Projections, smart boards, and other tech tools make minimizing glare and reflection a priority, as well as recognizing that all areas of the classroom are being used for instruction. "We have to treat the room

Albert Vecerka/Esto

Albert Vecerka/Esto

Left: The Powel Science Leadership Academy Middle School (SLAMS) on Drexel University campus in West Philadelphia.
Above: Functional illumination for writing surfaces is balanced with access to daylight at Powel SLAMS.

more evenly. Writing surfaces are all around the room now," he added. The high ceilings of exposed concrete deck meant that a combination of direct/indirect lighting fixtures had to compete for space among acoustic panels to provide even illumination in classrooms. Downlights in the soffit provide light on writing surfaces.

Learning and collaboration also happen in areas outside the classroom and the lighting design supports that. "A corridor isn't just a corridor anymore. Circulation areas now have spaces carved out of them where people can sit and gather," Barber explained. At Powel SLAMS, circulation paths contain larger public break-out areas. The Lighting Practice integrated cove lighting to emphasize the verticality of these spaces. "In those larger public areas, we tried to make the lighting go away as much as possible and focus on the architecture, the natural light, and views to the outside," he added.

Glazing heights are maximized at Powel SLAMS and natural light and electric light are carefully balanced to provide even light levels. "Access to natural light is critical in learning

Axis Lighting

Educational lighting design supports special needs

Helping students achieve success and reduce disruptive behavior is critical for schools. Building designs, particularly for those focused exclusively on serving special needs students, must consider sensory challenges and environmental impacts on behavior and learning.

To help their developmentally delayed children, Menachem and Devorah Leifer started the Donald Berman Yaldei Developmental Center (Yaldei) in Boisbriand, Quebec in their home with three children and three staff members. Word of mouth about the school's unique approach led to expansion.

In 2016, the school purchased a 1960s-era building to accommodate more than 300 students. The three-story building would allow the children to remain in one facility all day for therapy and school. Separate therapy rooms would be located on

environments, but you don't want the deeper ends of the space to feel cavelike," Barber noted. Teachers have the option to use window shades and dimmer controls to achieve a comfortable learning environment. Classrooms also have daylight sensors. The Lighting Practice provided guidance on the lighting controls for the school, which is a networked system. "There is a central back-end, a brain, that controls everything and allows for timeclock control," Barber said. "The idea was that in typical classrooms, a teacher can dim and control the lighting fairly easily without having to call the IT guy."

The Lighting Practice worked collaboratively with the architect, Rogers Partners of New York, to ensure the lighting adhered to a minimal aesthetic. Around the perimeter of the cafetorium and gymnasium (two spaces on opposite ends of the building), an inexpensive lighting system illuminates the upper portions of an acrylic façade. "It creates this luminous halo around the tops of these two spaces and bookends the building," Barber added. Otherwise, the school's lighting is integrated so harmoniously, you hardly notice it. "If the lighting goes away, honestly, we've done our jobs."

This article originally appeared in the May 2022 issue of Architectural SSL *magazine.*

the second floor, classrooms and administrative offices on the first floor, and additional classrooms on the third floor. Extensive renovations were needed to accommodate the students' special needs. In 2017, after a broad search and numerous presentations by architecture firms, the school's executive board retained Stendel + Reich Architecture Inc.

The overall goal was to create a fun space that would reduce children's anxiety. To help achieve this, Cliff Stendel, associate principal at Stendel + Reich, learned about the different disabilities that the Yaldei Center serves before developing plans to present. Stendel also drew on his previous experience in designing Alzheimer's facilities to accommodate unique cognitive behaviors. For example, when

Axis Lighting

Alzheimer's patients get to the end of a corridor they still want to walk straight and don't realize the need to turn. This also holds true for many Yaldei students. Stendel created oval corridors so the students could easily navigate turns.

Color correlation is another key part of the facility design. While many Yaldei students can't read, they are able to identify colors. For instance, a blue floor tile corresponds with a blue classroom door that is also carried through with hanging blue acoustic ceiling panels.

Stendel's lighting plan had to address varying needs and developmental issues without creating conflict between them. For example, he needed to consider if a design would work for children who are hypo-sensitive to physical or environmental stimuli while also taking into account hyper-sensitive students. Lighting needed to prevent those who are sensitive to bright lights from being adversely affected and distracted by them while also providing enough illumination to children who require more light. Therefore, Stendel had to identify luminaires with glare control and lower intensity.

When Montreal-based Axis Lighting learned about the renovations, the company immediately offered luminaires to the Yaldei Center, with which it has a long relationship.

Axis' range provided Stendel the opportunity to specify luminaires that complement the facility design and accommodate a complex ceiling plan. Stendel selected 152 total lights for renovation Phases 1 and 2, which includes Pixel recessed downlights with MikroLite optics that are installed over each classroom door.

Stendel wanted to avoid using typical 2×4 fluorescent or LED troffers in the classrooms, so he selected skinny strips in various designs. He wanted to ensure that a hyper-sensory child who might be bothered by light would find these fun and less institutional.

Linear luminaires include Edge 2, an ambient LED fixture with a two-sided lens that produces vertical illumination for improved facial recognition; the versatile Beam 3; Beam 2 square, a compact linear pendant form with SurroundLite technology that enables generous spacing and high uniformity; and Sculpt linear and pattern.

Finally, the semi-circular Sketch fixture mimics the curve of the circular entrance ramp while delivering comfortable and efficient illumination.

MICHELE BARTOLINI is *senior marketing director of Canada-based Axis Lighting.*

FULL TEXT AND PHOTOS ONLINE: ledsmagazine.com/14291024

Image courtesy of TFWB Engineers

Simplify school lighting systems with LLLC

APRILLE BALANGUE explains how designers and engineers can validate the performance and experience benefits of luminaire-level lighting controls in school settings.

Comfortable lighting and reliable functionality create a viable space for public buildings, such as schools, that serve people with a variety of experiences and needs.

Recently, the team at TFWB Engineers was charged with retrofitting a hybrid gym and auditorium space at a western Washington K–8 school, which serves 650 students and is home to a district's deaf and hard-of-hearing program.

The new 80,000-square-foot facility engages the Madrona School's (above) valued outdoor environment by embracing exterior circulation, eliminating hallways, and maximizing spaces for learning and playing. Biophilic or nature-inspired design in schools has been shown to positively impact the wellbeing and performance of all students. That effect is multiplied for students who are deaf or hard of hearing, as they depend heavily on visual cues for learning and to feel safe and comfortable in various settings.

The entire project team wanted to deliver a system that would respond to the student's activities, so I turned to networked controls in the project design specification. The benefits of luminaire-level lighting controls (LLLC) were immediately clear to me. The technology offers levels of granular lighting control and system-wide responsiveness previously impossible, as well as clean, wire-free installation and function.

The challenge lay in helping other project stakeholders — including contractors, building owners, and school district administrators — understand

APRILLE BALANGUE *is a principal engineer at Travis Fitzmaurice Wartelle Balangue Engineers, based in Seattle. She collaborates with BetterBricks, a commercial resource of Northwest Energy Efficiency Alliance (NEEA), as a consultant in lighting design and controls.*

Madrona images courtesy of TFWB Engineers.

the technology and unknowns. I would have to clearly communicate the pros and cons to convince them, but it would be worth it, since LLLC would allow us to maximize the functionality of flexible digital lighting and controls technology.

LLLC simplifies and saves money

While much of the school's lighting design — including non-LLLC controls and significant daylighting — was already in place, I recognized LLLC was the ideal recommendation, although it was still fairly new to me and my industry colleagues. As suspected, school administration officials initially demurred, with concerns stemming mainly from a lack of familiarity with the technology and questions about cost and maintenance.

Like many designers, I have a concrete understanding of the hidden functionalities of wireless technology, but for those outside our industry, the physicality of wiring offers a sense of familiarity. Non-industry stakeholders need to experience an LLLC-lit environment firsthand, because adopting new technology feels risky. They need to witness the benefits to overcome their resistance to new approaches. My method of presenting LLLC in design projects is three-fold: First show the beauty; explain end user controls; and outline the costs and savings involved.

By deploying LLLC, the ability to illuminate only where and when needed leads to immediate energy savings. Furthermore, eliminating wires and conduits can significantly reduce installation labor. Case studies have shown that labor can drop from an average of 18 hours to just four in a typical classroom lighting installation, with similar savings in low-voltage wiring costs. Additionally, wireless LLLC creates a cleaner aesthetic by condensing multiple sensor functions into a single integrated sensor per fixture, as it reduces wiring infrastructure.

Rendering courtesy of ARC Architects with LLLC and CLP construction.

Top: Washington State's Madrona School relies on LLLC. Bottom: A clean, wireless aesthetic has been prepared for Chief Kitsap Academy's CLP common area design.

Budget is a central concern for many of the projects we work on, especially for public institutions such as schools. The initial cost lift for the luminaires with sensors is typically offset by the more significant labor and wiring savings, so LLLC offers the most value over time. Furthermore, LLLC helped Madrona School meet Washington State's progressive energy codes, saving time and effort for administrators tasked with code compliance while ensuring that local buildings are doing their part to conserve energy and protect natural resources.

For our stakeholders, the work pays off in the form of a beautifully lit area that can be programmed and easily reprogrammed with a tablet. The flexibility

offered by Madrona School's new LLLC high-bay fixtures means that students on one end of the space can play a sharply illuminated pickleball match, while on the other end, another group can arrange scenery and set lighting levels for a musical performance.

Early successes evolve standard practices

At its core, lighting is a sensory experience. An environment illuminated to meet its inhabitants' needs supports the body and the brain in the same way that music performed in a suitable acoustic environment does. I have witnessed the childlike wonder of stakeholders touring a space designed with LLLC, and their response is simply, "Can we do this, too?"

Based on the positive reception to the Madrona project, our team has proceeded to universally specify LLLC for new projects as shown here. This includes a multifunctional communal area for the Suquamish Tribe's Chief Kitsap Academy, a new administration building for the Bellingham School District, and the

Left: Madrona's well-lit gym facilities. Bottom: Bellingham School District upper floor will have large ceiling fans with LLLC embedded directly in the fixture.

Rendering courtesy of RMC Architects.

Top: At Mount Vernon Library Commons, the book collections space will feature multiple overhead fixtures with embedded LLLC. Rendering courtesy of TFWB Engineers. Right: Linear luminaires balance with daylighting at Madrona School.

new Mount Vernon Library Commons — all in Washington State. These projects will benefit from LLLC functions for embedded occupancy, daylighting, and daylight sensing as well as the aesthetically pleasing, wire-free views of wood elements and the smooth lines of continuous load path construction — not to mention reduced costs and increased future-proofing.

The less-is-more appeal of LLLC — combined with flexibility, cost savings, and the growing list of exemplary buildings — is reducing the need to sell stakeholders on the technology. Instead, we can focus on collaborating with them to use LLLC as the springboard for the present and future of their buildings. The benefits are not limited to lighting; they extend to the system's ventilation/HVAC and security capabilities, issues of paramount importance for our communities.

During my decade-plus experience, I've always believed in the power of lighting — the beauty and function it brings to a space. Now, a new chapter is unfolding and it's exciting to see how these advanced lighting and controls can enhance the community's health and happiness in educational environments and other public buildings.

Image Credit: onurdongel / iStock / Getty Images Plus

DALI supports standardized wireless lighting control architectures

PAUL DROSIHN summarizes several approaches — including hybrid wired/wireless and full wireless — to implement interoperable controls systems that fully leverage the connectivity, bidirectionality, and lighting-specific data capabilities enabled by the DALI protocol.

Contemporary lighting technology has evolved compared to only a few years ago, featuring energy-saving LEDs and sophisticated control systems combined with sensors and IoT devices. This connected ecosystem creates opportunities for attractive, efficient lighting projects that can be controlled at the touch of a button or a smartphone's screen, or even respond to the world around us.

Conventional lighting systems have been controlled using wired networks, but recently interest in wireless connectivity methods has increased. In fact, the global market for wireless smart lighting control systems is estimated to be around $6 billion, growing to nearly $19 billion by 2030, according to research firm Research and Markets.

Wireless control systems can be easier and quicker to install due to less wiring needed — particularly in older building retrofits, which may set restrictions on where wires can run. Quicker installation translates into lower labor costs.

The lack of wires can also make a system more flexible and scalable, with the freedom to move luminaires and add new devices.

Wireless lighting systems are typically organized in a mesh configuration, where each device or node is connected to multiple other nodes. This increases reliability, as there is no single point of failure, and control messages are automatically rerouted if one node fails.

However, there are still scenarios where a wired solution is preferred or even may be mandated. In some circumstances, hybrid solutions may be desirable. Some technologies enable choice and keep future options open by enabling wired and wireless lighting-control networks to operate together.

Interoperability with a standard protocol

Whether wired or wireless, a lighting control system requires each device to be capable of communicating with the others. Such interoperability can only be achieved with a suitable standard, which manufacturers all agree to follow.

In lighting control, the Digital Addressable Lighting Interface (DALI) is likely the most widely known open standardized protocol. It has been deployed in countless applications around the

PAUL DROSIHN *is general manager of the DALI Alliance, the global industry organization for DALI (Digital Addressable Lighting Interface) protocol standardization and promulgation.*

world over many years. Based on the open global standard IEC 62386, DALI is an established protocol for bidirectional digital communication between lighting control devices and sensors. DALI devices are individually addressable, so it fits well with other IoT systems.

DALI is managed by the DALI Alliance, an open consortium of lighting companies with more than 350 members globally. The alliance drives the growth of DALI-based solutions and operates the DALI-2 and D4i certification programs to ensure cross-vendor interoperability.

How DALI supports wireless lighting

Typically, DALI uses a dedicated two-wire bus for communications between devices. However, more recent developments offer two alternative approaches to combining DALI lighting control and wireless connectivity:

- Standardized gateways between DALI and wireless ecosystems — starting with specifications for Bluetooth mesh and Zigbee from the Connectivity Standards Alliance (CSA).
- DALI+, a new specification that supports using a wireless architecture instead of wires for a DALI system.

Both approaches have merits, and having two options gives designers the flexibility to choose the right control system for a specific application. A third option — the capability to combine wired and wireless devices in a system — further expands flexibility.

Wireless to DALI gateways

Wireless to DALI gateways enable existing wired DALI devices to be used in a non-DALI wireless ecosystem. The gateways translate commands from the wireless side so the wireless ecosystem can control and query the DALI devices as if they were part of the wireless network.

Figure 1 shows how a gateway participates in the wireless ecosystem. The gateway contains a DALI application controller that connects to devices in the wired DALI network. The gateway architecture enables the wireless ecosystem to control and query DALI control gear, such as LED drivers, as if the DALI devices were part of the wireless network.

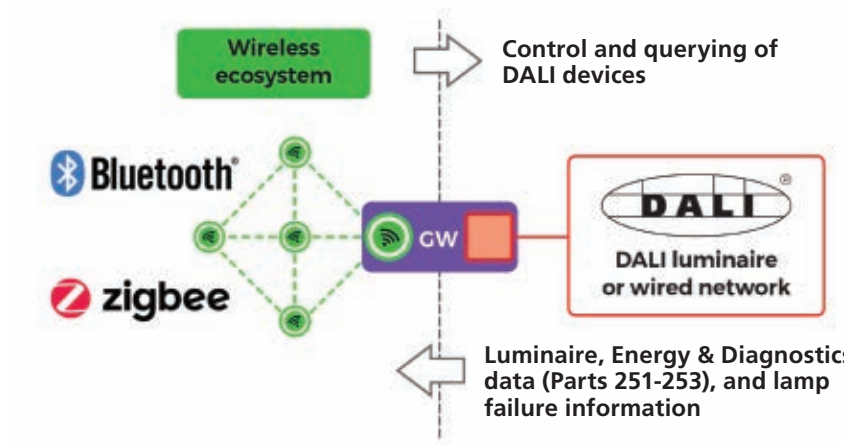


FIG. 1. Gateway (GW) between a non-DALI wireless ecosystem (Bluetooth mesh or Zigbee) and a DALI system. All figures courtesy of the DALI Alliance.

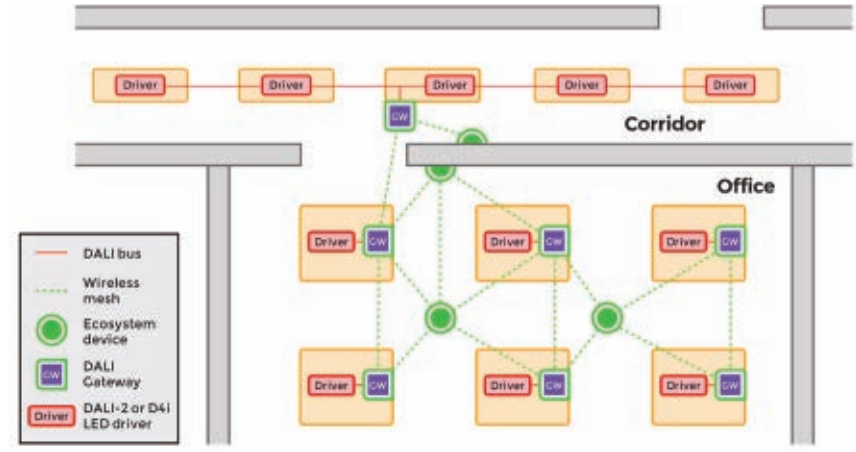


FIG. 2. In a wired/wireless hybrid scenario, the office luminaires each have a gateway that forms part of the wireless network. In the corridor, a wired DALI line connects all the luminaires with a single gateway that also participates in the wireless ecosystem.

DALI has specified two such gateways, with Bluetooth mesh and Zigbee as the wireless protocols, and other protocols may be supported in future. The DALI devices are automatically discovered and addressed by the gateway before joining the ecosystem network. Security is ensured via the existing features of Bluetooth mesh or Zigbee as appropriate. Readers can learn more about the inherent security capabilities from past *LEDs Magazine* articles on connected lighting networks and Bluetooth features.

In operation, the wireless devices talk to the gateway using their existing protocol (Zigbee or Bluetooth). They can control light output and fading of DALI devices via the gateway, and they can read lamp failure information from the DALI devices, as well as selected data such as energy usage and diagnostics.

Note that application controllers in the DALI network cannot control, configure, or query devices in the wireless ecosystem. This means that the wireless ecosystem is effectively the primary control and the DALI system is subordinate.

It might seem simpler to implement the entire network using Bluetooth mesh

or Zigbee. However, one benefit of using the gateway specifications is that existing DALI products — especially LED drivers — can be used. The market has many DALI-2 and D4i certified products from a wide range of suppliers, providing choice and future-proofing.

Another reason to base a lighting control system around DALI is that the protocol was developed specifically for lighting and has tailored lighting-control features, as well as providing access to luminaire, energy, and diagnostics data. Other protocols cannot offer the same rich and broad set of standardized, lighting-specific features.

Figure 2 illustrates an example of gateway use in two scenarios. In the corridor, a single gateway allows the wireless ecosystem to control a wired network of DALI luminaires. In the office, each luminaire has an individual gateway that shares the wireless network with other wireless controllers and sensors.

What does DALI+ offer?

The second approach to wireless lighting control is DALI+, which uses DALI over wireless or internet protocol (IP)–based networks.

DALI+ devices communicate using existing DALI commands carried over a wireless or IP-based link, rather than the dedicated pair of wires used by DALI-2 and D4i.

DALI+ builds on the proven DALI lighting-control features in wired systems and offers access to the same data from control gear, luminaires, and sensors. All DALI control gear and control devices standardized under IEC 62386 can be implemented in DALI+, including LED drivers, color-controllable drivers, emergency drivers, application controllers, push buttons, and sensors.

In some systems, there may be a need to combine DALI+ and existing wired DALI systems or luminaires. The DALI commands and features are the same for DALI+ and wired DALI. A new type of device known as a bridge enables application controllers in the DALI+ network to access and control the DALI wired control gear and control devices (Fig. 3).

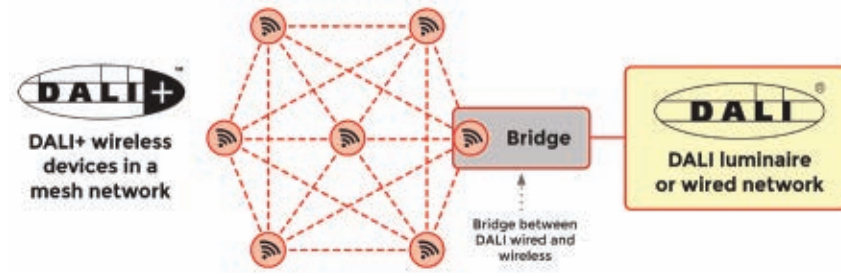


FIG. 3. DALI+ enables devices to communicate using existing DALI commands carried over a wireless medium. Bridges link wired and wireless networks, using the DALI protocol throughout.

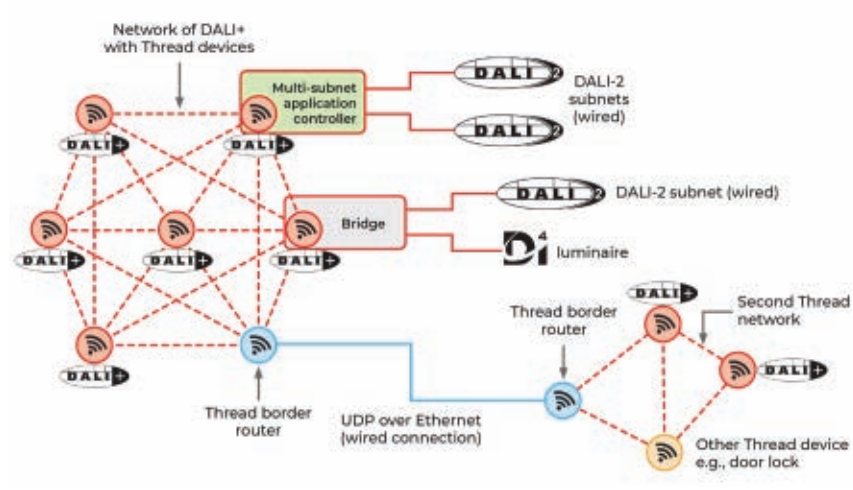


FIG. 4. An example of a complex system comprises two wireless Thread networks connected with an Ethernet cable via Thread border routers. A DALI+ bridge provides connectivity to two DALI wired buses (one of which is a D4i luminaire), and a multi-subnet application controller provides interfaces to two further wired subnets.

For more complex systems, a backbone such as Ethernet can be used to connect multiple wireless DALI+ systems. Additionally, DALI application controllers can support multiple subnets, which may comprise any combination of DALI+ and wired DALI subnets (Fig. 4).

Which network protocols can be employed?

Several wireless technologies can be used for lighting control. Typically, it makes sense to use a widely adopted standard to increase flexibility, avoid lock-in to one particular vendor, and leverage interoperable hardware devices from various suppliers.

The DALI Alliance has published two gateway specifications to cover wireless-to-DALI gateways with either Bluetooth mesh (Part 341) or Zigbee (Part 342). The same certified DALI-2 or D4i drivers can be used with either a Bluetooth mesh or a Zigbee gateway.

Initially, DALI+ supports Thread, an IP-based, low-power, wireless mesh networking protocol using 6LoWPAN wireless technology. Thread's existing authentication and encryption methods ensure security, and the DALI+ lighting system can take advantage of other Thread features, such as self-healing and automatic configuration. DALI+ with Thread also allows the use of IPv6 addressing, which means the number of devices in a DALI+ system is virtually unlimited for all practical purposes.

Other Thread devices may be used in the same Thread network as the DALI+ devices, increasing flexibility for system designers to add non-DALI devices such as sensors or door access hardware. Thread border routers allow connection through other *Continued on page 36*

Energy-harvesting light switch technology meets 2023 NEC specification

The NFPA 70-2023 National Electrical Code specification for wall-mounted devices eliminates stand-alone battery-powered light switches. **GRAHAM MARTIN** explains how energy harvesting devices can meet the need for wall-mounted switches that are safely operable when the power goes out.

Adopted in all 50 states, the National Fire Protection Association (NFPA) 70: National Electrical Code (NEC) is the country's benchmark for safe electrical design, installation, and inspection to protect people and property from electrical hazards in residential, commercial, and industrial settings. It was first published in 1897 as a response to the high risk of fire hazard in the early days of electrification and the need for fire insurance criteria. This set of standards and guidelines informs electricians and individuals opting for a DIY approach of installation, operation, and maintenance procedures in alignment with fire insurance requirements. Updated every three years, the NEC is recognized by the American National Standards Institute (ANSI) and comparable to other international standards, such as the German DIN VDE 0100 norm.

Infringement of the NEC comes with the risk for consequences. For example, a homeowner could face penalties or lack of insurability for DIY installation of noncompliant devices that result in an electrical hazard. Although the NEC is not federal law and thus not directly enforceable by the federal government, it is adopted by state and local governments that enforce compliance through building codes and inspections. As a result, requirements and enforcement mechanisms vary by location.

The 2023 NEC adds new measures to ensure safety if a battery fails in a switch or wall-mounted control device in Section 210.70 Lighting Outlets Required,

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Energy harvesting wall-mounted devices can circumvent concerns about operability when building power goes out.

All images courtesy of EnOcean Alliance.

which applies primarily to dwelling spaces, including habitable rooms, kitchens, bathrooms, toilets, laundry areas, basements, attics, utility areas, and garages, as well as hospitality facilities and student accommodations. Specifically it states, "Lighting outlets shall be installed where specified in 210.70(A), (B), and (C). The switch or wall-mounted control device shall not rely exclusively on a battery unless a means is provided for automatically energizing the lighting outlets upon battery failure."

The failure of a battery in a wall-mounted control device serving required lighting outlets should not prevent the safe egress of a habitable room, attic, or basement. Having utility power present with no way to energize the lights due to a bad wireless switch battery is hazardous to occupants.

In practice, this standard prescribes any wall-mounted switch or control device for room lighting to be permanently connected to a constant power supply — even if the switch is principally battery-powered and governs an appliance wirelessly or has an override backup solution in the system, such as a line-powered occupancy sensor to ensure lighting outlets are energized in the case of switch battery failure.

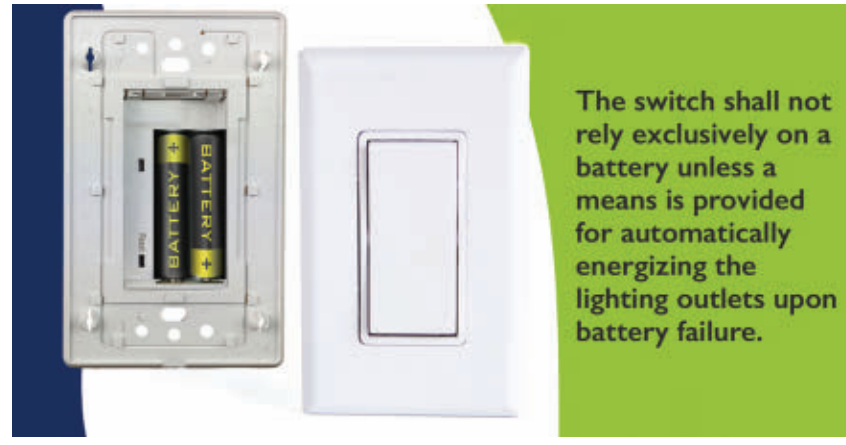
This effectively requires extra wiring — though wiring inherently constitutes a potential fire hazard in itself. According to the NFPA, "Electrical distribution or lighting equipment is the third-leading cause of home fires, and the fourth-leading cause of home fire deaths. Conditions that make these fires possible can occur long before a fire presents — largely as a result of wiring being installed or repaired incorrectly, or when receptacles, power strips or cords are overloaded, etc."

In practice, the implementation of the 2023 NEC 210.70 requirements obsoletes the majority of today's battery-powered wireless switches utilizing Bluetooth, Zigbee, Z-Wave, LoRa, or proprietary wireless technology as stand-alone devices due to their lack of backup AC power.

Mechanical energy harvesting

As an alternative to pulling additional cables or installing additional devices to lighting systems to make them NEC 210.70 compliant, owners can use energy harvesting to power switches and wall-mounted devices. Mechanical energy harvesting has been used for decades in multiple ways, such as bicycle dynamos that power lights by harvesting energy through the motion of the wheels, or a watch that charges itself through the motion of the wearer's wrist during everyday use.

Similarly, miniature electromagnetic energy harvesters have been used in automation systems over the past two decades. The act of pushing a button or



With modifications to the 2023 NEC, stand-alone battery-powered light switches are no longer allowed for installation compliance.

walking across a floor creates mechanical energy, which is then converted to electrical energy to power electronic devices.

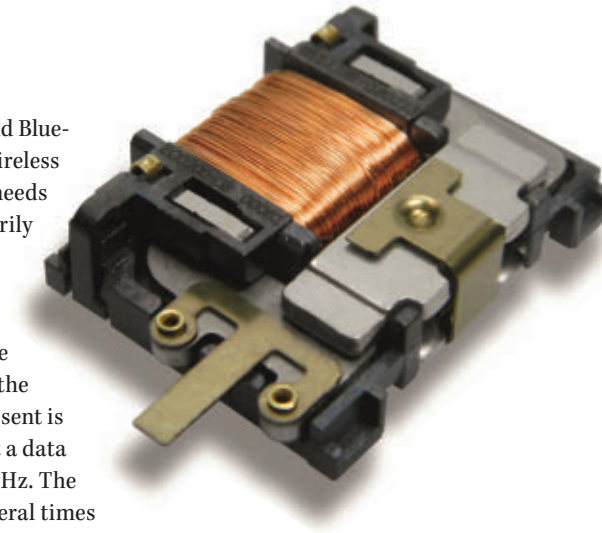
A magnet moving axially through the center of a coil will induce a voltage across the coil terminals. One practical application occurs in shaker flashlights that one can vigorously shake back and forth, causing a magnet to move through a multiturn coil, which ultimately provides charge to the battery.

In automation systems that send control or monitoring signals, turning a door or window handle can send a signal to alert security or to activate/deactivate lighting and HVAC systems. Similarly, the energy harvested through pushing, pressing, and releasing a switch can feed an ultralow-powered wireless module, telling a light to switch on or off, or to dim up or down. Electronics have improved to the point that an energy harvester can be sized to fit into a standard format switch or handle while creating enough energy — 120µW — to send multiple signals at every use.

International Open Wireless Standard ISO/IEC 14543-3-10 (Europe) and 14543-3-11

In 2012, the International Organization for Standardization and the International Electrotechnical Commission created and released the internationally standardized ISO/IEC 14543-3-10/11 wireless protocol, which is similar to wireless standards such as Wi-Fi and Bluetooth. It is optimized for wireless solutions with low energy needs that can be supplied primarily by energy harvesting.

To minimize the energy consumption and interference potential while maximizing indoor range, the minimum telegram length sent is only about 1 millisecond at a data rate of 125kbit/sec at 902MHz. The telegrams are repeated several times within 40 milliseconds, avoiding collisions of telegrams and numerous switches, and many sensors can be operated in parallel without any problems. Each radio module, such as a switch or controller, has a 32-bit unique identification number. The radio range is up to 1,000 feet in open spaces and about 100 feet in buildings. These radio waves can easily penetrate walls and offer robust transmission power. At the same time, the high-frequency radiation is 100 times lower than in classic wired solutions.



Energy harvesting devices employ mechanical or magnetic methods to generate energy for powering a switch or wall-mounted control, thus eliminating the need for batteries and reducing wiring.

Global standard support

The EnOcean Alliance, a nonprofit educational organization founded in 2008 that has more than 400 member companies, enables a multivendor ecosystem based on the ISO/IEC 14543-3-10/11 wireless standard. As a promoter of this global standard, this open organization is committed to enabling interoperable ecosystems for smart homes, buildings, and spaces based on the maintenance-free radio standard. As a result, building owners can deploy products from different manufacturers in one system because the devices all speak the same standardized language. Currently, dozens of manufacturers offer such energy-harvesting light switches that follow the standard.

Energy-harvesting switches and wall-mounted devices are a smart way to comply with the new NEC requirements. They also reduce the fire risk from bad wiring; decrease carbon footprint, thanks to reduced materials usage; and lower maintenance by eliminating battery changes.

DALI continued from page 33

IP-based physical layers — for example, Ethernet or Wi-Fi — which supports highly scalable systems.

The use of an IP-based carrier, such as Thread, for DALI+ also opens the possibility to integrate the lighting system with other functions, such as HVAC or building access, via a building's IT infrastructure.

Conclusions

DALI is the established standard for digital lighting-control systems, and the DALI Alliance now enables lighting system designers to work with wireless connectivity supported by proven technology and wide industry adoption. The DALI Alliance is developing robust certification programs for the new wireless approaches.

There are two distinct options for wireless: Wireless to DALI gateways allow existing DALI-wired products to be used in a non-DALI wireless system; and DALI+ enables devices to communicate using existing DALI commands, carried over a wireless or IP-based medium.

Whichever option best suits lighting designers, the addition of wireless to the familiar DALI standard extends choice and creative freedom. At the same time, it ensures designers can rely on rigorous standardization and certification, along with DALI's lighting-specific capabilities, such as precise dimming and color control.

For offices, homes, factories, and other smart buildings, the combination of wireless and DALI brings unparalleled flexibility and control, along with a roadmap to add new standards and features in the future.

DALI is a registered trademark of the DALI Alliance.

Environments CEO looks to build a better commercial experience using digital twins

ERIN MCDANNALD explains how her company's metaverse platform can demonstrate lighting and IoT capabilities to clients as well as collaborate with colleagues.

LEDs Magazine caught up with Erin McDannald, CEO of Baltimore-based manufacturer's representative and design services firm Lighting Environments, as well as the more recently launched Environments, an IoT technology integrator that has developed a software-driven digital twin of its business space and now offers this capability as a service.

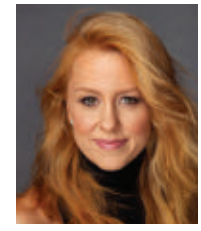
LEDs: Tell us how you came to launch Environments.

McDannald: In 2020, our team at Lighting Environments launched Environments as an IoT-connected integration company. We were selling Enlighted and other sensors; they were going into our fixtures, and we were connecting them to software and making them work. We began to realize that integration was hard without having a software product, so we began to design our own software.

LEDs: Initially, how did your firm utilize the software? How did it lead to merging data with developing a digital twin?

McDannald: We were trying to make sense of all the data from the sensors. I couldn't figure out a return on the investment. It was something that we were taking online to sell, so I wanted to leverage this data. It requires the ego to let go of lights and think about how people interact in the space. Even then, lights are still very much the backbone of a digital IoT layer. That goes in between the physical world and the digital twin, which is a virtual space built to look exactly like your space, or the space that you're designing for, wherever the OT layer is going in.

With these floor plans connected to our facility's IoT layer, we were pulling in data to the digital twin, such as people mapping, lux levels, and air quality levels. We started to analyze data in spaces in a 360-degree way. At first, we thought that our space was being utilized at 50% based on our people counters. But add in heat mapping sensors, and we learn that employees are using 100% of our real estate. The correlation of activities is a result of these real data scenarios.



ERIN MCDANNALD

LEDs: You've spoken about "building the future workplace in the metaverse." Can you summarize how the metaverse became a part of your business?

McDannald: The metaverse design came from taking our occupancy and usage trends in a new direction. We moved into a new physical office, pre-pandemic. Then we were sent home [during lockdown]; we couldn't use the showroom or sell in person. For Lighting Environments, we had this digital twin that we were pulling data from. I asked [the developers] if we could put people in there, and the answer was yes.

So the question became: "If I can put people in there, can I use that digital space in the same way I use the physical space?" — which is for collaboration, to understand energy usage, and as a branded experience for e-commerce.

At that point, we were trying to sell lights from the digital twin, as well as trying to understand our facilities management. All of those things can take place from one drawing that mimics your physical space. Because lighting is the largest electrical infrastructure in the building, that's where we have all the sensors collecting the data that we can add to the digital twin.

LEDs: What is next for Lighting Environments and Environments?

McDannald: We're going to spend a lot of time [with clients] in the commercial workplace, because we think that's the biggest opportunity. We have connected the physical and virtual world. With that in mind, we are showing clients around; we usually go from Zoom [meetings] to the metaverse.

It is interesting how this experience drives lighting decisions. When the lights provide that much data, it's a lot easier to defend a higher price point because the ROI is there and more quickly evaluated.

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