

# LEDs MAGAZINE®

TECHNOLOGY AND APPLICATIONS OF LIGHT EMITTING DIODES

APRIL/MAY 2023

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APRIL/MAY 2023 ISSUE 147

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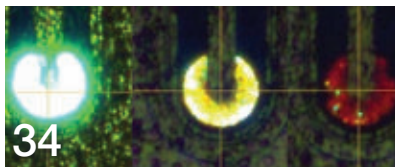
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# Financial incentives make energy transition more accessible



Spring has arrived, which at my former residence in Washington, D.C., meant a dramatic drop in electric bills as the rooftop solar panels basked in longer doses of direct, high-angle sunlight. Our use of grid-supplied power would often drop into negative territory through the fall, thanks to net metering.

A solar renewable energy credit program offered by the District, combined with the federal solar investment tax credit, had given us the extra push to install the panels and reduce our reliance on fossil fuels (the local utility sourced only 7% of its electricity from renewables). With hope, the continued offering of local and state energy incentives, coupled with the Inflation Reduction Act's slew of energy-related credits and deductions for individuals and businesses, means that our collective reliance on fossil fuels will decrease. This trend needs more momentum stat if we have any hope of limiting global warming to 1.5°C (2.7°F) above pre-industrial averages, lest we

face the risk of irreparable damage to ecosystems and habitats worldwide.

In March, the U.S. Energy Information Administration delivered a sliver of hope to concerned global citizens with news that electric power generated from renewable sources surpassed that generated from coal last year for the first time. "Renewable energy is now the most affordable source of new electricity in much of the country," said Gregory Wetstone, president and CEO of the American Council on Renewable Energy, in an Associated Press story.

However, the country's reliance on the burning of another fossil fuel ticked up. Natural gas was our largest energy source, providing 39% of our power demand in 2022, up from 37% in 2021. Natural gas-fired generation does produce less than half of the carbon dioxide emissions produced in coal-fired generation — but renewables produce zero emissions once their infrastructure is in place.

Back to the "glass is half-full" perspective, we can improve our energy efficiency significantly today. One of the more accessible technologies is, no

surprise to our readers, LEDs. By now, we all know LEDs can use up to 90% less energy than incandescent lamps, and up to 80% less energy than fluorescent. Lighting accounts for nearly 20% of global electricity usage, so converting every traditional light source would give our race to zero carbon emissions a boost. Networked lighting controls can further notch down our power demand, with the added benefit of improving the occupant experience.

In this issue, the Lighting Controls Association rounds up outstanding rebates to upgrade lighting and controls that commercial building owners should take advantage of before all installations are expected to be LEDs — and before building codes calculate baseline efficiencies assuming the installation of LEDs (p. 25). We also visit two landmark projects in the Kansas City region that achieved their ambitious sustainability goals with the help of LEDs (p. 20).

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## We can't stop talking about energy ... and money

In a blog, managing editor **CARRIE MEADOWS** explains why the industry can't separate energy and cost concerns from innovation and evolution in lighting.

We've published a lot of energy-focused business and lighting application stories of late. And yet ongoing discussion among industry colleagues and leaders across the manufacturing, specification, and design chain indicates that we collectively need to "move on" from the energy efficiency narrative around LED-based solid-state lighting.

The common argument is that the more we focus on the dollars and cents of energy metrics as a driver for LED lighting and controls systems, the longer it takes for true innovation in form, function, and design execution to take place.

I'll be the first to admit that editors at *LEDs Magazine* have made such remarks ourselves. Indeed, our esteemed former chief editor Maury Wright had often opined that LEDification 2.0 should and would go beyond the long lifetime and low energy requirements of LEDs to more sophisticated capabilities. However, I'd like to curb any question about whether I think that indicated the energy efficiency story was "over."

Economic pressures on businesses — and industries — will always exist. And a greater public awareness of grid instability means the load of existing buildings and public lighting needs to be addressed.

I don't think you can *have* a conversation about innovation in lighting, controls, and integration into the built environment without considering the influence of energy, climate, decarbonization, and the long-trail impacts of materials, components, and supply-chain logistics on the finished products, design practices, and end results. Again, the current perception is that it costs a lot more to *prioritize* those changes in sourcing and manufacturing operations, but there are companies showing they can do it and that customers want them to.

How can we speak about preserving dark skies for communities and the natural world without appreciating what an ideal outdoor area luminaire does *not* do — emit stray light, cause glare, maintain full light levels at all times of day? Which, by the way, wastes

photons and thus circles back to energy consumption.

How can we admire new office concepts designed to engage employees in gathering without noticing that the lighting layout enables the flexibility to move furnishings, repurpose the space, and add seating whenever the need arises? This can be done without rewiring the space or adding more luminaires for different seating layouts (involving more power, more labor, more expense), while also leveraging skylights and windows.

How can we learn about a firm designing its horticultural luminaires to meet the needs of the growers — rather than convincing them they must have additional features that waste photons, which should be delivered to plants for best yields and return on investment — without observing the impact of reducing opex and capex for controlled environment agriculture operators?

We will always circle back to a conversation about cost and sustainability intersecting with functionality. The lighting community is being tasked with prioritizing all three factors while achieving new levels of aesthetic impact, addressing social justice and equity concerns, and respecting the unique goals of each project. If that's not an incubator for innovation, I don't know what is.

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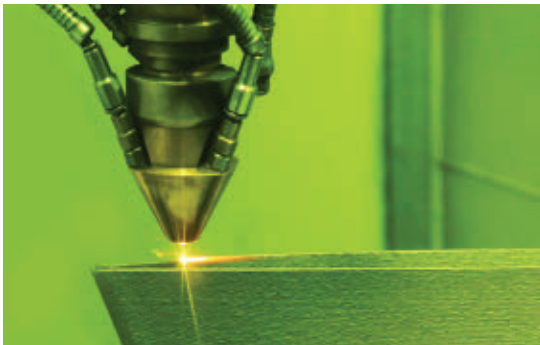
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## EVENTS

### Conference will examine 3D printing of optics, heat sinks, and electronics

In San Diego, the Aug. 20–24 conference running as part of the SPIE Optics + Photonics 2023 exhibition will include a strand focused on using 3D printing for lighting components and systems. Nadarajah Narendran, director of research for the Lighting Research Center at Rensselaer Polytechnic Institute, will co-chair the 3D Printing for Lighting Conference in partnership with SPIE.



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3D printing can offer advantages and benefits in costs, environmental impact, customization, and quality. The technology is also known as additive manufacturing because it builds up objects one layer of material at a time. ◀

**MORE:** [ledsmagazine.com/14290366](https://ledsmagazine.com/14290366)

## HORTICULTURAL SSL

### Fluence says LEDs reduce disease in greenhouse

Growers who deploy LED lighting rather than conventional high-pressure sodium (HPS) in the greenhouse lower the risk that their plants will succumb to pathogens because LEDs provide a more stable heat environment, according to LED lighting vendor Fluence.

The Austin, Texas–based division of Signify noted in its blog: “HPS lights produce a significant amount of heat. However, when they are turned off, the resulting changes in the environment can leave crops more vulnerable to condensation and pathogens as they cool faster than other surfaces. This poses obvious but avoidable risks.

“Under LED lights, the environment is less affected by heat produced from lighting, relying instead on the more precise HVAC system designed exactly for the



Fluence

management of maintaining set points in temperature and humidity.”

By relying strictly on HVAC controls and eliminating the heat fluctuations incurred when HPS lights are switched on, growers facilitate stability that helps plants thrive, Fluence said. ◀

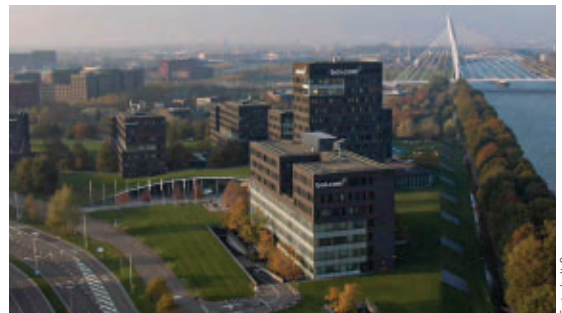
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## CONNECTED SSL & CONTROLS

### Fagerhult: IoT may finally emerge from infancy

The extended takeoff period for connected lighting is roughly a decade old, but recently Fagerhult CEO Bodil Sonesson indicated that connectivity is now a “business driver.”

“We see very positive development,” Sonesson told an inquiring analyst on a financial results call. “We see bigger and bigger installations.” She cited a recent smart building project in Holland as an example.



Fagerhult Group

Fagerhult outfitted the headquarters of online retailer bol.com (shown below), in Utrecht, with luminaires equipped with Fagerhult’s Organic Response sensors.

According to Fagerhult, the smart lighting system is reducing electricity by 60%, assisting in navigation and wayfinding, and helping employees find available work areas. ◀

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VIDEO



INTRODUCTION



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**ARCHITECTURAL LIGHTING**

**Glamox switches to recycled aluminum in luminaires**

LED lighting vendor Glamox has started to use recycled rather than new aluminum in some of its luminaires to help reach its promised net-zero greenhouse gas operations by 2030.

The Norwegian firm has already made the replacement on its C80 range, and it plans to do the same on its C35 and C95 lines.



Aluminum production is a highly energy intensive process, involving considerable electricity and CO<sub>2</sub> emissions during at least two stages: extracting alumina from bauxite ore; and then smelting it into aluminum metal.

Aluminum recyclers melt the metal for reshaping and reuse. Estimates of how much energy it saves can vary upwards to more than 90%. With the switch, Glamox claims it will reduce emissions of “CO<sub>2</sub> equivalents” from manufacturing the aforementioned luminaires by 63%. ◀  
**MORE:** ledsmagazine.com/14291726

**LED & SSL BUSINESS**

**New ams Osram CEO set to take on micro LEDs and more**

Ams Osram’s back-to-the-future CEO Aldo Kamper took the reins in early April, with more extensive duties than previously disclosed.

The former head of Osram Opto Semiconductors returned to replace Alexander Everke as corporate ams Osram CEO, as well as chief of the Osram division. The extra duty is notable because it emphasizes the importance of Osram’s LED operations and especially the soon-to-be micro LEDs on which Everke has staked significant future business. Kamper had a



big hand in early micro LED development plans before he left Osram back in August 2019, about a year before ams won regulatory approval to take over Osram.

As head of the Osram division, Kamper replaces Ingo Bank, who has been serving double duty as ams Osram CFO and head of Osram. Kamper will also serve as interim CFO until Rainer Irle assumes the role in July. ◀

**MORE:** ledsmagazine.com/14291880

**ESG INITIATIVES**

**Signify on track with environmental and health goals**

The world’s largest lighting company is in the middle of its second “Brighter Lives, Better World” five-year plan to increase sustainability, wellness, and equality activities. Signify recently reported that it is on course to hit most of the objectives.

One target is to increase the percentage of revenue the company derives from sales of “circular” goods, defined as “products that can be reprinted, refurbished, reused, or recycled” to 32% by 2025. At the end of 2022, it hit 29%, a number that CEO Eric Rondolat said puts Signify “on track” for 2025 and marks a significant rise from the 16% of baseline year 2019. Most of the revenue related to luminaire sales, he said.

Signify’s circular products include 3D printed luminaires; a pendant line called Coastal Breeze (shown) uses material



from discarded fishing nets as manufacturing filament.

The only area where the company is behind its 2025 goal is “women in leadership.” Signify wants to have 34% of its leadership roles filled by women by 2025. At the end of 2022, the percentage was 28%. While that was up from 2019’s 17%, “we are slightly off track,” Rondolat said.

In the fourth quarter, he continued, Signify implemented new measures for hiring practices and internal talent development to address the gap. ◀

**MORE:** ledsmagazine.com/14291026

**RESEARCH**

**Astronauts busily tend tomatoes on ISS**

Horticultural SSL might be experiencing a slowdown on Earth, but it has already had a busy spring 230 miles above the planet, where astronauts on the International Space Station (ISS) can’t keep their hands off the LED-nurtured tomatoes.

ISS staff have been tending to the Red Robin dwarf tomatoes, which seem to have prospered since the crew began preparing to grow them in early December.

The new batch marks the first time that NASA has raised tomatoes for picking and eating in the spacecraft’s Veggie chamber, which is the longest running of at least three different hor-



tical facilities that the agency runs on the craft.

The astronauts have plenty of science projects to tend to, but LED horticulture should continue to get pride of place on their to-do list, as it is the means by which people most likely will be able to eat in future space travel and colonization. ◀

**MORE:** ledsmagazine.com/14291416



# PRODUCT | spotlight

## DECLARE-LISTED LIGHTING

In a recent interview (see page 27), Finelite R&D vice president Aaron Smith noted that transparency initiatives such as the International Living Future Institute's "Declare" label have grown noticeably within the past two years, with more than 50 listed lighting products at the time of publication. This featured selection has been filtered to those with the Declare label, although IFLI offers additional levels of certification and compliance through the program.

COMPILED BY CARRIE MEADOWS



### HP-2 WS steel slot luminaire, Finelite

More than 90% of the manufacturer's Steel Luminaire lineup is third-party verified LBC Red List Approved. The HP-2 WS recessed perimeter slot luminaire (shown) delivers up to 796 lm per foot, with tailored lengths down to 1/16-inch intervals (minimum 2 feet). The linear luminaire is available with a post-ceiling threaded rod or pre-ceiling wall mount. Regressed 2-inch optics and telescoping sections enable precise fit into corners.

[FINELITE.COM](http://FINELITE.COM)



### Edge Series, XICO Lighting

SmartBeam adaptive wavefront technology from FusionOptix infuses Edge Series luminaires with precise beam control and uniformity, achieving multiple glare-free distribution options. The reduced footprint and optical efficiency of each fixture helps designers ensure no light is wasted. The Edge Solo275 (shown) features a 1x2.75-inch profile available in recessed, surface, pendant, and wall configurations. The luminaires are composed of 99% recyclable materials.

[XICOLED.COM](http://XICOLED.COM)



### Arca Pro, Selux Corp.

The slim profile of the Arca Pro post-top luminaire can be configured with multiple heads at various heights for outdoor walkways, roadways, parking lots, and plazas. The luminaire design complies with International Dark-Sky Association requirements, producing zero uplight and minimal glare and light trespass. A Gen 5 silicone lens recessed into the IP66 enclosure allows for a range of precision light distribution options.

[SELUX.US](http://SELUX.US)



### Linea, Luxxbox

The Linea acoustic-dampening LED linear pendant is fabricated with recyclable PET panels, offered in a broad range of shielding options, colors, textured and patterned finishes, heights, and lengths for noise management and ambient illumination in open indoor areas. A plug-and-play power connector simplifies installation of multiple runs. Some fixture parts can be returned and recycled via the company's product stewardship program.

[LUXXBOX.COM](http://LUXXBOX.COM)



### Linear fixtures, Lightly

Lightly fixtures are customized with combinations of lightweight wood, wool, and hemp finishes that reduce embodied carbon due to shipping compared to conventional metal fixtures. The nontoxic adhesives and stains are free of volatile organic compounds. Butterfly (shown) uses an open-web optical profile with concealed LED engines to deliver 80% indirect and 20% direct illumination with either static or tunable CCTs with at least 90 CRI.

[LIGHTLY.COM](http://LIGHTLY.COM)



### Airelight Ceramic LED luminaires, Goldeneye, Inc.

Goldeneye's Airelight family, which includes Linear SC, Linear ES, and Squares models, employ a ceramic-based emitter that serves as LED light source, heatsink, and interconnect. This enables a thin and lightweight luminaire suitable for mounting options such as embedded, surface, T-bar, and pendant. The 24VDC, linear or squared-shaped sources deliver up to 1,110 lm/ft at 130 lm/W, with 2700K, 3000K, 3500K, and 4000K CCT options.

[GOLDENEYELIGHTING.COM](http://GOLDENEYELIGHTING.COM)

# Cosmicnode

EDITED BY CARRIE MEADOWS

Three years ago, Sharan Avati, Sanu Davis, and Vinay Hiremath combined their experience and skill sets in wireless technology, product development, and business development to found Cosmicnode, a firm dedicated to providing reliable, low-latency, and scalable wireless lighting controls for smart building and horticulture automation.

Along with a bachelor's degree in electronics and communication, founder and CEO Avati brings more than 15 years of expertise in the field of wireless mesh technology, which led to Cosmicnode's foundational wireless mesh platform. Co-founder Davis holds a bachelor's in electrical and electronics and 15-plus years of experience in product development and quality assurance in the building automation and lighting industry. And co-founder Hiremath, who holds an MBA in sales and marketing, brings 15-plus years of experience in business development and customer engagement to the team.

Since starting in an attic in 2020, Cosmicnode has transformed into a fast-growing startup headquartered at the High Tech Campus in Eindhoven, the Netherlands, and received funding in 2022

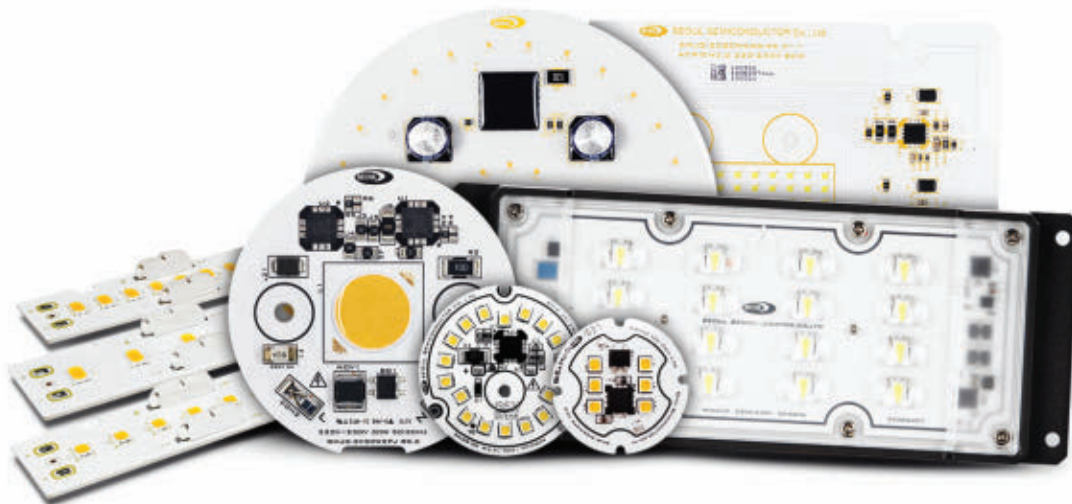
from Limburg, Netherlands-based venture capital firm LIOF. Currently, a team of 25 "Cosmics" is spread across the Netherlands, Germany, U.K., and India.

**Firm mission:** Our mission is to unlock the extraordinary potential of multiradio wireless mesh controls for a better world. We are driving innovation and technology by transforming buildings and greenhouses globally with the help of a data-driven IoT platform. Our wireless lighting solution enables OEMs, lighting manufacturers, integrators, and installers to incorporate reliable and robust wireless lighting controls technology into their product ecosystem.

Cosmicnode founders (l to r) Sanu Davis, Sharan Avati, and Vinay Hiremath celebrated their first horticultural lighting controls system deployment in 2020, connecting more than 2,000 nodes in the mesh network scheme.

All images courtesy of Cosmicnode.





# Any Module. Any Application.

Take control with Seoul for faster and more competitive ways to market.

**Seoul Semiconductor** provides customers with advanced module capabilities and technology solutions that extend across a wide range of application and performance requirements. As the #2 LED manufacturer in the world (non-captive), Seoul has a proven track record of success in helping customers to simplify their processes and save on production costs, all while taking advantage of Seoul's vertically integrated technology and quality. Partner with Seoul to increase your speed to market or expand your capabilities into new areas without investing in added equipment or staff expertise. From linear DC designs to complex AC engines driven by proprietary Acrich and Wicop technologies, Seoul Semiconductor can seamlessly support even the most complex custom and reference module designs in a timely and professional manner.

**Linear reference modules** are available as an excellent turnkey solution for projects of any size. The HE, SE, and Industrial Series reference modules utilize Seoul's flagship

high efficacy 5630 LEDs to deliver efficacies from an upper range of 189 to 202 Lm/W at typical driving currents. The Value series is the perfect alternative for cost-sensitive projects, featuring similar technologies but with a high performing and cost effective 3528 package in place for efficacies up to 189 Lm/W at typical driving currents. Each linear reference module is UL and CE recognized, features uniformity of light and color (3 SDCM Standard), and comes with a Zhaga compatible mounting pattern for easy installation.

**Seoul takes pride in offering a variety of modules for specific lighting applications** including round, tunable white, outdoor Wicop engines with heat sinks and optics, proprietary blackhole lenses for increased uniformity and decreased optical depth, and Acrich AC modules that range 4-105W with an added benefit of being Triac dimmable. Seoul can also integrate the NanoDriver into modular solutions for a product that is both low flicker and Title 24 compliant.

## FEATURES

- Vertical integration allows variety of technology and footprint choices including 3030, 5630, 3528, Wicop, 3535 and 5050
- Custom and reference designs available
- DC & AC designs
- Several lens options for both high power and mid power designs
- 3 SDCM standard
- Multiple design, manufacturing, and support locations
- Numerous reference designs available through Future Electronics

## APPLICATIONS

- Street & area
- Indoor commercial
- Industrial
- Residential
- Driver on board
- Color tuning



**SEOUL SEMICONDUCTOR**

[www.SeoulSemicon.com](http://www.SeoulSemicon.com)



**What we are known for:** Our low-latency wireless lighting controls that support smart building automation and horticultural lighting as it scales to larger enterprises.

**First commission:** In just three years, we have already made good on our aim to provide automation for a more sustainable future. We deployed our first wireless mesh controls system in the horticulture industry in summer 2020 in the Netherlands. The system comprises 2,400 nodes with wireless plug-and-play controllers, an IoT gateway, a Modbus gateway integrated with a climate computer, and on-premises spectrum controls application.

**Industry generalization or perception that should be debunked:** We are challenging the industry myth that

wireless solutions cannot be reliable and scalable. We have debunked this by successfully deploying more than 100,000 wireless nodes in greenhouses and buildings globally.

**Top industry concern today:** That current wireless systems are not interoperable; they are not flexible for third-party integration; and there is a lack of standardization.

Yet in record time, we have achieved wireless control of more than 10,000 grow lights in a single network. Cosmicnode is integrated with all the leading climate computer companies in the world using our proprietary simple and flexible Modbus protocol. Its robust wireless multiradio platform, with scalability for up to tens of thousands of nodes and the flexibility to provide dynamic zoning of lamps and sensors, is one advance

Cosmicnode wireless controls are deployed with stand-alone sensors at a Belgian factory.



over existing products. Another is its multiradio mesh system, which helps extend the range and bandwidth beyond what is customary for wireless controls, operating without interference in a dense network and enabling large amounts of data to be collected.

**What are you currently working on?**

We are developing our new Infinity IoT platform that provides robust, highly scalable, and reliable multiradio wireless lighting controls for commercial and industrial applications. It can transform buildings by fulfilling light management, occupancy management, asset tracking, and environmental analytics for applications, including commercial offices, industrial, retail, parking, street lighting, public spaces, and sports stadiums.

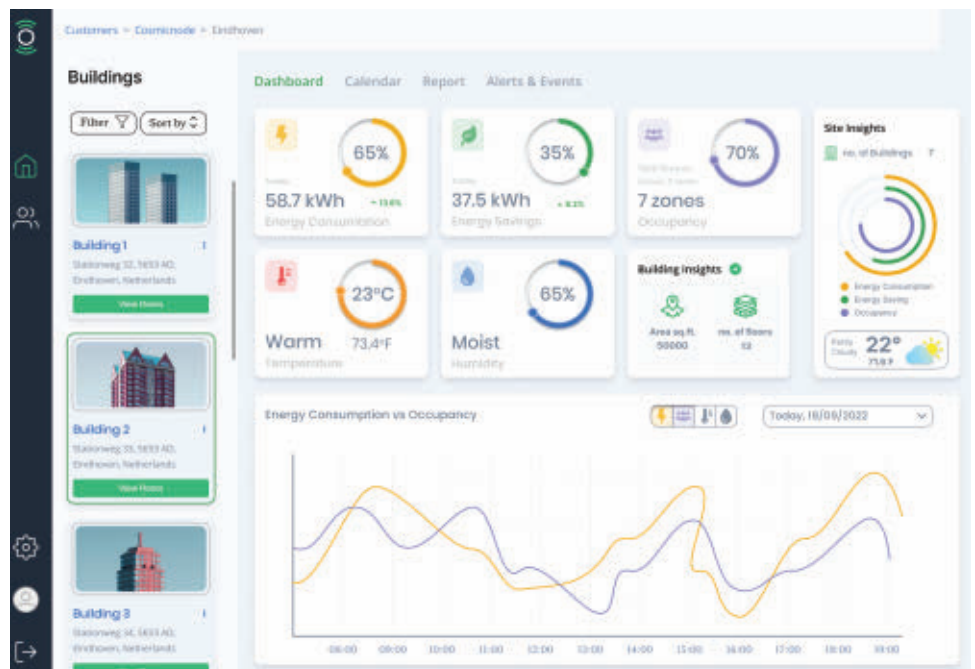
This approach to building automation has the ability to significantly reduce energy consumption and increase operational efficiency, with the continued push toward lower carbon emissions and a net-zero world. Our controls and automation solutions reflect the value of our brand culture — customer first, innovation, ownership, and integrity.

**Technology, product, or designer you admire:**

The interoperability between lighting and controls has been showcased by DALI, the

Above: Technicians install wireless controls connected via the Cosmicnode system at a warehouse in the Netherlands.

Right: Cosmicnode platform displays energy, occupancy, climate condition, and building or campus footprint insights in a user-friendly dashboard interface.

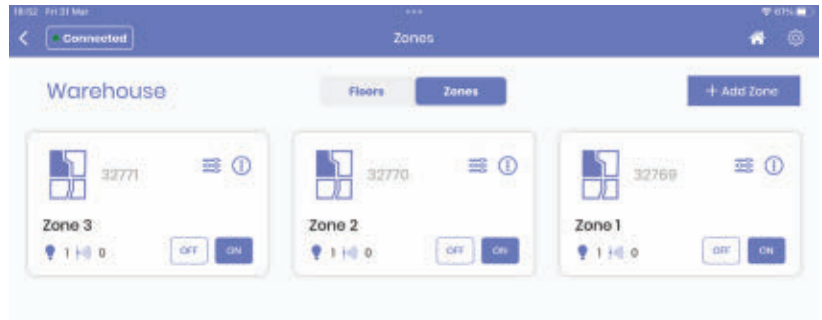


internationally standardized protocol for digital communication between lighting control devices, and Zhaga, an industrywide consortium aiming to standardize specifications for interfaces between LED luminaires and light engines.

These innovations will prove fundamental to furthering and future-proofing an ecosystem of lighting hardware and controls that can support modularity, product upgrades, and a greater variety of components that communicate properly with one another.

**What should the lighting and controls industry talk more about?**

One of the ways that the lighting and controls sectors can join together to benefit the industry is through truly using light as a digital data point. Lighting comprises a large portion of a building's infrastructure — it is required in all buildings and



with placement throughout the entire space.

This existing ubiquitous infrastructure can provide the backbone for value-added services such as occupancy management, space management, asset tracking, and building analytics that support facility return on investment by reducing operating expenses and delivering real-time information for security, health, and resource management.

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The wireless system can be configured into multiple zones for more granularity of control settings, data collection, and analysis of specific areas in this industrial environment.



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# How the industry can standardize circadian lighting

**MARTIN MOORE-EDE** responds to the recent finding of scientific consensus on circadian lighting and advises the lighting industry on steps it can take to develop an evidence-backed strategy for risk management before regulation rules all.

**A**s recently reported by *LEDs Magazine*, a consensus now exists among leading scientists that light fixtures and lamps should be designed to support healthy circadian rhythms. Surveying 248 scientists, who have collectively published 2,697 peer-reviewed scientific articles on circadian clocks and light, Circadian Light Research Center and its academic partners found 24 conclusions emerged, including:

- The widespread introduction of circadian lighting that adjusts light intensity and blue content across day and night can maintain robust circadian entrainment and health.
- The most potent wavelengths for daytime circadian entrainment are 460–495-nm blue light near the sensitivity peak of the ip-RGC melanopic receptors.
- LED lights with high 460–495-nm blue content should carry the warning label “may be harmful if used at night.”

Now that the scientific community has spoken, where does the lighting industry go from here?

## Learn from other industries

Many industries have been confronted with inconvenient truths about newly discovered harmful effects of their products or business practices. How they responded and managed the issue played a role in determining whether they avoided public relations and market setbacks, cumbersome regulations, or expensive legal judgments. Whether discussing the carcinogenicity of fabric flame retardants, PFAS chemicals in nonstick Teflon pans, or ozone layer destruction by fluorocarbons used as air-conditioner refrigerants, the responses from industry typically can be described in one of three ways:

1. Denial — with or without denigrating those who raise the health concerns.
2. Acknowledge but ignore — stating that the data is inconclusive and needs further research.
3. Accept — and proactively develop a solution or replacement and communicate it effectively.


The first two responses may be reasonable if the data is limited or questionable. However, if pursued too far, such strategies can result in asbestos-scale liabilities or draconian regulations, if the scientific community broadly agrees a health hazard exists but is subsequently ignored.

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MARTIN MOORE-EDE, MD, PhD, CEO of CIRCADIAN and director of the Circadian Light Research Center, was also the founder and CEO of Circadian ZircLight, which was acquired in 2022 by Korrus, Inc., where he is now chief medical advisor.







A proactive response example comes from the petroleum industry. Circadian and sleep scientists in the 1990s had linked certain extended work schedules to a high risk of fatigue-related human errors. They showed that the risks could be successfully mitigated by using fatigue risk management systems (FRMS). Following a 2005 refinery explosion caused by operator fatigue, the oil companies came together under the American Petroleum Institute (API) and rapidly took charge of managing the risks of human fatigue. They avoided government regulations by developing their own RP 755 ANSI standards for FRMS.

Other industries, such as aviation, took no such proactive steps. After pilot fatigue caused an aircraft crash in 2009, Congress imposed a new law mandating fatigue risk management with no industry input.

#### What's the best strategy?

Given the broad scientific consensus on circadian lighting, the impact of blue light wavelengths on circadian rhythms and health is undeniable. Even among scientists who can only justify funding when the research outcome is uncertain, 93% of survey respondents agreed that the most potent wavelengths for daytime circadian entrainment are 460–495-nm blue, and 85% confirmed that blue light at night disrupts circadian rhythms. They also agreed that circadian disruption by light at night is associated with significantly increased rates of obesity, diabetes, and breast cancer. Furthermore, 93% agreed that increasing the energy efficiency of lights is desirable, but not if it increases the risks of circadian disruption and serious illness.

The development of blue-chip LEDs has revolutionized lighting and enabled enormous improvements in energy efficiency and product lifetime. From 1% market share in 2013, LED sales have grown to over 80% market share today. However, less than 0.5% of these LED lights modify light intensity and blue content by time of day. While we need to limit the use of blue-chip LEDs to daylight hours, the good news is that LED

spectral engineering has enabled the development of white light with little or no blue content for nocturnal use.

#### Five recommendations to address circadian lighting

How can the \$100 billion global lighting industry minimize its liability by smoothly transitioning to circadian-modulated lighting to protect end user health and wellbeing? Next, I

## The industry must collaboratively define evidence-based circadian lighting and deter unsubstantiated “circadian lighting” product claims.

share lessons from my experience of advising the API as it took charge of the petrochemical industry's transition to FRMS.

**Move quickly.** As soon as employee fatigue and circadian disruption was identified as a key contributor to major accidents, the API formed a task force of senior health and safety executives from major oil companies — including ExxonMobil, Chevron, Shell, and BP — and representatives from other industry associations and agencies. The API did not require all major oil companies to participate but ensured an adequate and influential quorum. The API also preempted regulatory intervention by broadly communicating the industry's risk management plan.

**Hold hearings.** The API invited scientific and other subject matter experts to present the relevant research and the available evidence-based solutions. It was important to avoid undue influence from any one self-interest group — that might promote a specific scientific paradigm or model — by ensuring that representatives of all significant stakeholder groups could participate and be heard.

**Translate the scientific input into actionable, pragmatic conclusions.** Many scientists enjoy debating

esoteric and abstruse details. In contrast, the API task force focused on clarifying what was important, proven, and could be acted upon from the science, and what scientifically validated information could be reasonably put into practice.

**Draft an ANSI standard for the industry.** The API task force developed a consensus document that defined the problem, appropriate nomencla-

ture, and practical steps to introduce and comply with the scientifically based solution — in this case, the FRMS for the petrochemical industry. The standard was circulated to the industry and other stakeholders for comment, and comments were systematically addressed.

**Publish and commit to reexamine in five years.** The participants fully understood that operational and implementation experience and new scientific discoveries would necessitate updates and changes to the standard. The API published the first RP 755 standard for FRMS in 2010; the latest revision is dated 2019. Notably, based on advances in circadian science, the 2019 RP 755 standard added the requirement that “light sources at night should minimize circadian disruption.”

#### Apply lessons to lighting

Many of these lessons apply to managing the transition of the lighting industry to healthy, circadian-modulated lighting. The industry will benefit from taking proactive measures before pressure builds to regulate and before a liability develops because of a failure to implement healthy lighting. Above all, the industry must define evidence-based circadian lighting and

deter unsubstantiated “circadian lighting” product claims. Genuine adverse health consequences can occur if lighting products are falsely marketed as circadian. The Federal Trade Commission has fined companies marketing other devices and products with unsubstantiated health-related claims.

A lighting industry task force should manage the influence of Department of Energy policies and rules that are setting lumens-per-watt goals that do not take health into account. Input from various scientific groups — which separately advise key industry organizations such as the Illuminating Engineering Society, CIE, and UL — should be included in the discussion and help drive toward consensus for standardization of metrics and models.

### Conclusion

The survey of circadian scientists, “Lights Should Support Circadian

Rhythms: Evidence-backed Scientific Consensus,” shows that respondents agree on the basic notion that blue wavelengths are required during the

## LED spectral engineering has enabled the development of white light with little or no blue content for nocturnal use.

day but must be removed in the evening hours. Methods for implementing circadian lighting include spectral engineering, color tuning, dimming, or combinations of these technologies, but they will require standardization to ensure effectiveness. Intellectual property licensing may enable manufacturers to offer scientifically validated circadian lighting, and standards training for

lighting designers will be key. But we ought to develop an industry strategy to manage the transition to circadian lighting.

Now that the scientific community has agreed on the need for circadian-modulated lighting, this is the time for the lighting industry to harvest a commercial opportunity and greatly limit future liability.

*The author’s affiliated organizations research and develop circadian lighting technology for the commercial market.*



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Image courtesy of LightFair organizer IMC

## LightFair prepares to bring immersive, illuminating education to NYC

**CARRIE MEADOWS** shares what event organizers say LightFair attendees can expect from its educational sessions and tradeshow activities under a new distribution of responsibilities between IES and IALD.

Last June, professionals in the lighting industry hit the Las Vegas Convention Center’s West Hall to earn continuing education units, meet with nearly 300 exhibitors, and learn what projects, trends, and research have occurred in the community in the past year. The upbeat mood at LightFair 2022 showed that the industry was ready to engage again in-person — although perhaps less frequently, in order to accommodate exhibitor and attendee budgets and structure events around longer product release cycles. Beginning with the 2023 edition, which will be held at the Jacob K. Javits Center in New York, LightFair will become a biennial event, organizers announced in October.

LightFair followers may also recall that last July, event owners International Market Centers (IMC), Illuminating

Engineering Society (IES), and International Association of Lighting Designers (IALD) revealed a new structure in which IES staff would develop the conference’s core educational program and LightFair LIVE events, while IALD representatives would manage the tradeshow’s Designery, with 10 on-floor lighting design sessions and events dedicated to educational presentations and live installations.

Conference organizers recently detailed to *LEDs* some changes that they expect will better serve attendee schedules, allowing them to learn new and updated standards and practices, attend workshops, and see products applied through design demonstrations.

### Meeting structured and freeform needs

LightFair show director Dan Darby and IES director of education Brienne



Image courtesy of LightFair organizer IMC

Musselman elaborated on how the shift in conference and show-floor responsibilities would leverage IES' strengths and meet the expectations of lighting professionals. With more than 170 hours of educational programming to manage — and more than double the class choices as compared to 2022 — the conference advisory committee “reached new efficiencies,” they said, by holding only one in-person meeting and relying on remote collaboration to bring ideas to fruition. Advisers have also incorporated a two-hour break in the conference schedule for lunch and tradeshow time “so attendees can build their schedule balanced between courses and the show floor,” Darby said.

LightFair 2023 attendees can also plan their experience with the help of curated “Lightineraries” — preset schedules covering professional growth, environment and sustainability, light and health, or integration sessions. Registrants can still customize their agenda by selecting individual courses and sessions across the art, business, science, technology, and process tracks.

IES is “focused on high-impact education in less time, so we’ve moved away from two-day courses completely, allowing for flexibility in attendee schedules,” Musselman said, adding that workshops will range between three-hour and one-day options. In addition, those seeking to complete the



Image courtesy of ajay\_suresh via Wikimedia, CC BY-2.0

National Council on Qualifications for the Lighting Professions (NCQLP) lighting certification exam will be able to attend LightFair’s first-ever in-person LC study group, hosted by Craig Bernecker, professor of lighting design at Parsons School of Design and founder of The Lighting Education Institute.

IES has also taken on organizing the LightFair LIVE show-floor presentations, speaker networking opportunities, and the LightFair Sales Stars. The two-hour program will pit 10 lighting sales professionals against each other in a fast-paced competition that tests their skills in selling randomly assigned products within 2–3 minutes pitches to panelists Shirley Coyle, Mark Lien, Randy Reid, Erik Ennen, and Bob Preston.

## Immersive experience inspires circular design

In November, IALD launched a call for Immersive Lighting Installations, which will be showcased in the Designery area (Booth 3123) on the show floor. The IALD committee asked architectural and commercial lighting manufacturers to submit a proposal of an installation concept around the theme of the “circular economy.” Entrants were narrowed down to seven finalists and partnered with New York-based lighting design teams by IALD to develop a design plan, select their showcase products, and execute the installation in 400 square feet of exhibit space by opening tradeshow day, May 23.

“For the first time ever, LightFair attendees will have the opportunity to enjoy and be inspired by a high-design lighting competition across the show floor,” said Lea Tranakos, executive director of customer relations and tradeshow leasing at LightFair. “I have had the pleasure of working with the IALD to oversee every stage of the inaugural Immersive Lighting Installation design contest and cannot wait for LightFair attendees to see these notable brands’ and designers’ hard work deliver the ‘wow factor’ of lighting.”

A jury will assess the lighting installations “for conceptual clarity, collaborative presentation, and thematic execution,” according to a LightFair media announcement. IALD plans to evaluate the installations and announce the “Best Overall” execution by 5 p.m. EDT on May 23. The Immersive Lighting Installations will be open for visitors all three exhibition days.

The seven teams include:

- Brian Stacy, ARUP Lighting Design, with Casambi.
- David Ghatan, CM Kling Dynamic Architectural Lighting Design, with Boca Flasher.
- Teal Brogden, HLB Lighting Design, with Lumenpulse.
- Carla Ross Allen, Fisher Marantz Stone, with Focal Point Lights.
- Suzan Tillotson, Tillotson Design Associates, with Traxon e:cue.
- Emad Hasan, The Lighting Practice, with Cooledge Lighting.
- Jack Bailey, One Lux Studio, with Experience Brands.

The circular economy topic has spurred a number of industry interest groups and educational efforts, including the development of guidelines for life cycle assessment, products and materials transparency programs (see page 7), best practices for localized sourcing and manufacturing, design for disassembly (see page 27), and more. Participants at recent events from LightSPEC West to the newly launched Remanufacturing Lighting conference to LEDucation have provided updates on industry consortia, independent certification programs, and specific organizational tactics intended to relieve supply-chain concerns; reduce physical waste as well as carbon emissions; simplify product assembly, installation, and deconstruction; and minimize known toxic substances across the building and lighting sector. The installations aim to demonstrate the exciting possibilities that result when sustainability, dynamic design experience, and functional lighting products intersect in the built environment.

## Keynote addresses the power of darkness

LightFair’s 2023 keynote will be presented by Karen Treviño, who serves as Natural Sounds and Night Skies division chief for the National Park Service. Treviño will explain how her division collects data to help national parks safeguard an engaging experience for visitors while maintaining the needs of the park ecosystem, preserving the sensorial landscape for future generations. She will share the challenges of turning the initially small program into a national success, as well as outlining how outdoor lighting can impact natural resources in her presentation, “Chasing Darkness Into the Light: Preserving Night Skies in National Parks.”

**lightfair**


The LightFair 2023 conference runs May 21–25, while the tradeshow floor will be open May 23–25. Visit [lightfair.com](http://lightfair.com) for the full schedule and registration details.

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# Feats of green in the Heartland

LED products help two new builds score high LEED certification ratings in the Kansas City metro area.

**K**ansas City, where the Midwest gives way to the Great Plains, is a hub for efficiency and design innovation. Two of the region's latest architectural projects — an expansive international airport terminal and a suburban public works facility — recently earned high sustainability ratings with the help of solid-state lighting. Energy efficiency drew the projects' designers to specify LEDs over conventional light sources.

## A glowing global gateway

Designed by global architecture firm Skidmore, Owings & Merrill, the newest terminal of Kansas City International Airport, in Missouri, recently achieved LEED v4 Gold BD+C certification. The 1.1 million-square-foot facility is the first airport terminal in the Midwest and the second terminal in the U.S. to achieve this high rating.

Completed in February 2023, the project earned a significant part of its efficiency through LED lighting. The terminal deploys about 50 lighting solutions, totaling more than 14,000 fixtures.

Specifying LEDs contributed directly to the project's ability to earn LEED points related to energy performance, said Kathi Vandel, owner of LightWorks, the project's engineer of record. Based in Weston, Mo., the firm was commissioned for lighting design and engineering for the terminal, as well as a parking garage.

Layered, streamlined lighting choices reflect the project's linear nature and reinforce architectural themes of the I-shaped facility, Vandel said. The luminaire most commonly appearing is H.E. Williams MX4S linear downlight; the 6-foot-long frosted luminaire sets into the ceiling trough and is finished to match the striking hemlock. "Additional layers included clerestory uplights, beam uplights, and wall washing," she said. "All of these elements in the front-of-house public spaces utilized a 3000K color temperature to provide warmth to the materials while creating a welcoming ambience for the patrons."

LightWorks also collaborated on a custom fixture to create a continuous, inside-to-outside lighting element to meet architectural design specifications.



Lucas Blair Simpson © SOM

"We did have to work with the manufacturers to achieve the IP rating the project required on the exterior fixtures in a way that they seemingly looked like the same luminaire [inside]," Vandel said. The modified outdoor MX4S fixtures are IP65 rated; have gasketed diffusers and end caps and liquid-tight cord entries; and can withstand temperatures down to 40°C. Their mounting and conduit routing were also modified for installation.

A network of lighting controls by Crestron enables 0–10V dimming for most luminaires inside the terminal. "The lighting control system provided dimming and switching control for the public and back-of-house areas," Vandel said. "The entire facility utilized a combination of network and distributed control systems requiring a complex sequence of operations, plan layouts, schedules, and riser diagrams." As construction wrapped, the team finalized dimming levels for the various zones.

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SHEL EVERGREEN ([shelevergreen.com](http://shelevergreen.com)) is a science journalist and multimedia professional based in Colorado. She's produced work for MIT Technology Review, Ars Technica, Canary Media, and more. In her spare time, she volunteers as a mentor to young writers and hangs out in the mountains with her partner and pets.



**PROJECT CREDITS**

Kansas City International Airport  
 Architect: Skidmore, Owings & Merrill  
 Lighting designer: LightWorks, Inc.

Automatic controls, as well as daylight harvesting in specific zones, are utilized as required by the International Energy Conservation Code. “The daylight zone varies in size based on the parameters and the amount of glazing in the space,” Vandel said. For example, the terminal concourses have a 15-foot-wide perimeter band as a daylight zone.

As a final point of pride, the project team successfully obtained a LEED innovation credit for its complete use of SSL technology, because LEDs are free of mercury.

**Good, well-lit neighbors**

Just 27 miles south of the Kansas City International Airport, the town of Prairie Village, Kan., achieved LEED Platinum certification for its 20,000-square-foot public works facility, completed in 2022. Years prior, the city had conducted a feasibility study for its municipal structures to ascertain a maintenance strategy.



Lucas Blair Simpson © SOM

**Top:** The design team for Kansas City International Airport’s new terminal achieved a LEED innovation credit by specifying all LED lighting – more than 14,000 luminaires in total. **Bottom:** The H.E. Williams MX4S linear downlight appears in many locations throughout the terminal interior to reinforce the I-shaped plan of the facility.



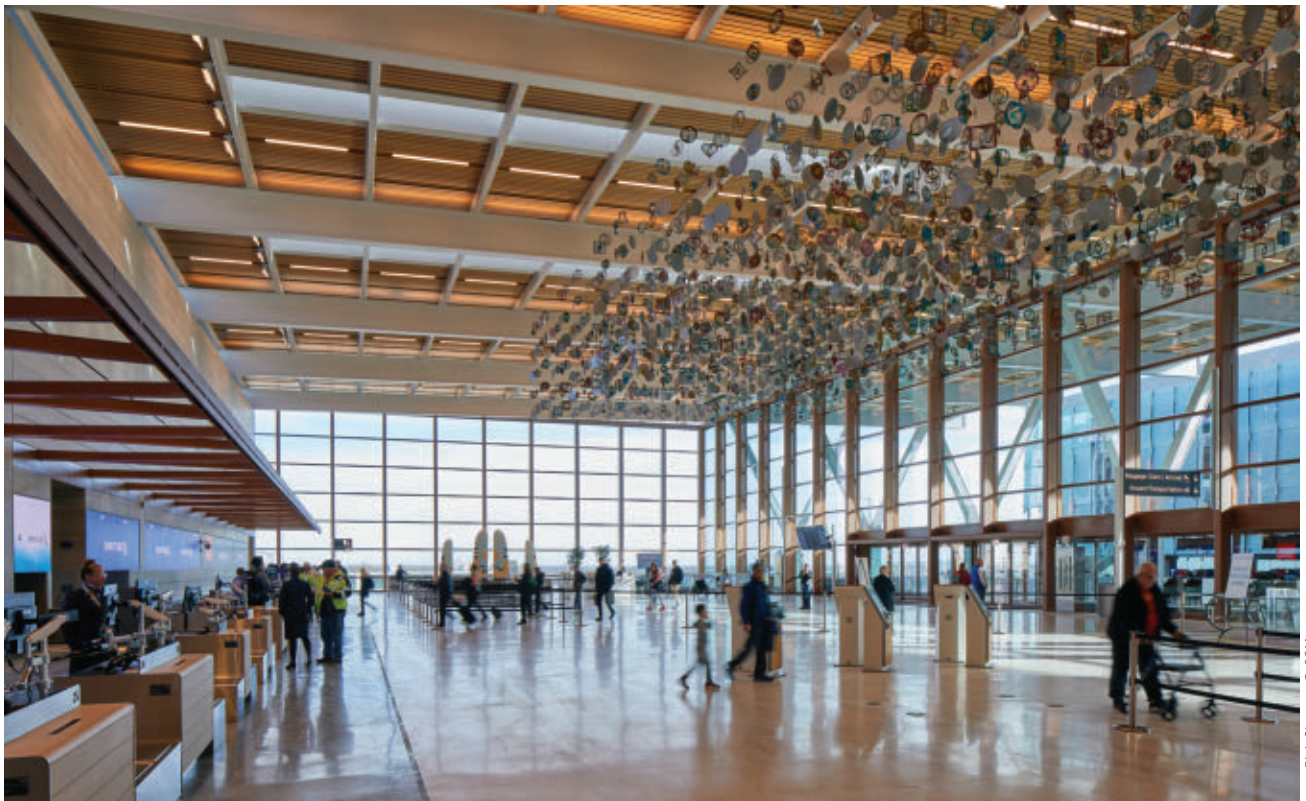
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When assessors evaluated the city’s public works facilities, they found mixed results. “We had some good structures, we had some OK structures, and we had some structures that were not worth buying a 5-gallon bucket of paint for,” said city engineer Melissa Prenger. The city council thought starting fresh made more sense and approved the construction of a new facility on-site. But the approval came with a caveat: The design had to aim for LEED Platinum.

Prenger knew this was a lofty goal. “LEDs were always a part of the conversation,” she said. “We decided early on that.” Their energy efficiency, array of possible color temperatures, dimming ability, and programmability were all desirable features, particularly because the public works facility is situated in a residential area.

From a lighting power density standpoint, LED lighting was also practically a prerequisite to meet ASHRAE 90.1, according to Brent Adams, electrical engineer and principal board member at Clark & Enerson, the project’s architect and lighting designer. All 36 lighting solutions specified for the facility are LED, he said. Interior fixtures include modern, minimalist luminaires and circular pendants. In the crew conference room,

**Left:** At the Kansas City International Airport’s new terminal, luminaires in the exterior canopy are custom-designed to match interior fixtures to create design continuity. **Bottom:** Daylight zones at the perimeter of the terminal deploy photosensors and automatic controls for daylight harvesting.



Lucas Blair Simpson © SOM





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### PROJECT CREDITS

Public Works, City of Prairie Village, Kan.  
 Architect & lighting designer: Clark & Enersen

long, rectilinear pendants — the Slot 2 by Mark Architectural Lighting — provide diffuse illumination over the length of the seating area. Small, cylindrical fixtures — the High Center Beam Pendant Stem Cylinder from Gotham Lighting’s Incito line — provide direct light in other areas.

The mechanic shop used for maintaining the city fleet, including its snowplows, allowed the facility to utilize several industrial fixtures. Its high ceiling features JEBL LED High Bay pendant fixtures from Lithonia Lighting, with black die-cast aluminum housings.

Per a LEED requirement for interior lighting quality, at least 70% of the fixtures needed a color-rendering index at or above 80, Adams said, but all project fixtures met this bar. “That’s an easy one to beat with good, high-quality LED fixtures nowadays.” He said that achievement was less a reason for the

**Top:** The construction of the 22,000-square-foot Prairie Village Public Works facility was greenlit with the caveat that it strive for LEED Platinum certification. **Right:** Circular pendants in varying sizes adorn the facility lobby with understated contemporary style.



© Tom Kessler Photography



© Tom Kessler Photography

Top: Slot 2 rectilinear pendants by Mark Architectural Lighting provide comfortable, diffuse light with a minimalist aesthetic in the conference room. Bottom: Industrial JEBL High Bays from Lithonia Lighting illuminate the bustling mechanic shop.

team to brag, but more a “testament to the industry” and the significant advances of LEDs in the past decade. That LEED credit also requires a rated life of 24,000 hours, another easy check box for LEDs.

The city had stringent exterior lighting requirements to avoid light trespass: zero horizontal foot-candles at the property line and tight restrictions on the vertical plane. Adams believes those specifications would have been impossible to meet were it not for modern LED fixtures. “We reduced the amount of lighting in the parking lot ... so that we could be good neighbors,” Prenger said.

To illuminate the facility’s outdoor flagpole at night, the team avoided spotlights, which typically point up, contributing to light pollution. Instead, they found a pole-top fixture that illuminates



© Tom Kessler Photography

down 360 degrees, the American Star-Gazer by Concord American Flagpole.

The dimmability and controllability of LEDs also helped the design meet its energy mandate. The interior lighting system is controlled on the Acuity nLight platform, which Adams said uses low-voltage power via Category 5e cable that connects switches, dimmers, vacancy and occupancy sensors, and

photocells to a power pack relay. Exterior lighting is controlled via timeclock and photocell. Adams added that when the fixtures’ integral sensors detect an occupant, the lighting “dims up” from 50% lumen output to full brightness.

Ultimately, the new public works facility earned an impressive 83 LEED points, sliding past the required 80 points required for Platinum certification.

# What's new in rebates for 2023

**CRAIG DILOUIE** examines the trends that are driving more rebates in controls and lighting and potentially fewer future opportunities in replacement lamps, based on research by rebate fulfillment provider BriteSwitch.

The outlook for commercial lighting rebates is strong this year, with substantial incentives available for owners planning to invest in energy-efficient lighting and controls for existing buildings. Active commercial lighting rebate programs cover nearly 80% of the U.S., with the largest programs occurring in the Northeast and the Northwest. This is one finding among research by rebate fulfillment provider BriteSwitch, based in Kingston, N.J., which shared topline data from its 2023 rebate database with the Lighting Controls Association.

This article will dissect this and the following trends identified by BriteSwitch: Average LED and lighting control rebate dollar amounts remain stable; select LED replacement lamp rebates are in jeopardy; horticultural lighting and networked lighting control rebates continue to grow in availability; and substantial rebates for electric vehicle (EV) charging stations are being offered by utilities and governments.

Energy efficiency rebates are funds invested by utilities and organizations to avoid the higher cost of building new power generation infrastructure. For

*CRAIG DILOUIE is education director for the Lighting Controls Association, a council of the National Electrical Manufacturers Association that educates the public about lighting control technology and applications.*

lighting practitioners, the rebates are a mechanism by which they can reduce initial cost and incentivize owners of existing buildings to invest in energy-efficient lighting and controls.

The rebate may be prescriptive (downstream), meaning it offers a financial reward for each qualifying product installed in an approved project; this is the most popular rebate type and fairly straightforward to execute beyond an administrative process. Point-of-sale (midstream) rebates are instant rebates realized at the point of purchase. They are typically limited in availability and focused on common lamp types and luminaires. The third type of rebate is custom, typically applicable for innovative projects that push the boundaries of prescriptive rebates.

## Rebates home in on LED solutions

Commercial lighting rebates track changes in technology and costs. Currently, LED is the main lighting technology promoted by prescriptive rebates, which include popular product categories. Owners of existing buildings in a rebate territory are eligible to receive the rebates.

Table 1 lists popular LED rebates and average dollar amounts across North American 2023 rebate programs in



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the BriteSwitch database. Interestingly, after years of decline in value due to falling product costs, rebates have stabilized over the past three years. The cause may be a combination of market stabilization and reduced demand during the COVID pandemic. This year, average rebates modestly increased, most likely because of inflation.

An interesting takeaway from Table 1 is the big increase in average rebate dollars for LEDs designed to replace traditional general-service lamps. This is likely a final push to promote these

LED products before the conventional lamps they replace are phased out by the Energy Independence and Security Act’s backstop energy standards, which take effect in July. As a result of the expectation that many traditional general-service lamps will be removed from the market, many rebate programs for LED replacements will end, according to BriteSwitch.

The growing reliability of rebates for horticultural lighting is another compelling trend. Between 2021 and 2022, the number of rebates tripled, with many offered as prescriptive rebates rather than the custom approach historically used. In 2023, the number increased again, though more modestly, to 677 programs, with approximately 60% as prescriptive rebates averaging \$110 per product, according to BriteSwitch. This reflects growing interest in rebate programs to cultivate energy savings in this market with LED options that the program operators see as viable.

**Lighting control rebates**

While rebates for lighting controls have remained substantial and relatively stable over the past 15 years, networked lighting controls continue to grow as a key subcategory, according to BriteSwitch data. Table 2 shows the most popular rebates for common automatic lighting controls this year. (Networked lighting control rebates are not shown because approaches remain unstandardized.) Overall, these rebates can make common occupancy and daylight-responsive controls an attractive upfront add-on for an LED retrofit.

Of additional interest to this category is that a majority of programs qualify products as eligible for rebate by requiring their inclusion in the DesignLights Consortium Solid-State Lighting Qualified Products List (DLC SSL QPL). Listed products must satisfy certain technical requirements. Version 5.1 of the SSL QPL

**TABLE 1. Popular LED categories featured in prescriptive and midstream commercial lighting rebate programs in 2023.**

Type of LED Solution	2023	% Change vs. 2022
Replacement lamps (A19, PAR, MR)	\$8	71%
Linear tube replacement lamps	\$4	1%
Pin-based (CFL-ni replacement)	\$6	-11%
Downlights	\$28	-2%
Troffers/panels	\$34	1%
Retrofit kits (1×4, 2×2, 2×4)	\$38	10%
Accent/track lighting	\$50	-2%
Screw-in HID (corncob) LED lamps	\$58	4%
Outdoor wall-mount luminaires	\$98	4%
Parking garage luminaires	\$101	4%
Outdoor pole/arm mount	\$106	3%
High-bay luminaires	\$127	4%

Average rebate amounts per product for programs in the U.S. and Canada. All numbers rounded to the nearest integer. Source: BriteSwitch RebatePro North American rebate database, February 2023.

**TABLE 2. Popular standard lighting controls featured in prescriptive commercial lighting rebate programs in 2023.**

Lighting Control	2023	% Change vs. 2022
Remote-mounted occupancy sensors	\$27	0%
Wall-box occupancy sensors	\$23	0%
Photocells	\$20	7%
Luminaire-mounted occupancy sensors	\$22	2%
Daylight dimming systems	\$26	3%

Average rebate amounts per product for programs in the U.S. and Canada. All numbers rounded to the nearest integer. Source: BriteSwitch RebatePro North American rebate database, February 2023.

requires dimming controllability for a range of products and continuous dimming for most indoor luminaires and retrofit kits.

Note that DLC listing is not required for standard lighting controls, though prescriptive rebate programs often require it for networked lighting controls. In 2016, the DLC launched a QPL for Networked Lighting Controls to support the category, as its research demonstrated significant energy savings for this technology. In 2023, the number of rebate programs promoting networked lighting controls increased 16%, bringing the total to more than a quarter of all prescriptive rebate programs, according to BriteSwitch. If a prescriptive rebate is not available, the installation may be eligible for custom rebates.

Rebate programs are experimenting with how best to promote networked controls, with some basing their message on energy reductions, power savings, controlled wattage, or controlled luminaires. Many programs have adopted to incentivizing it as a rebate adder per luminaire connected to a qualifying networked lighting control system. According to BriteSwitch, the average rebate per LED luminaire installed with and controlled by a networked control system is \$204.

**EV charging stations**

Admittedly separate from the lighting industry, the availability of substantial rebates incentivizing electric vehicle charging stations presents a new and rapidly expanding market for electrical contractors and distributors. According to BriteSwitch, 53% of the U.S. has a rebate for residential applications and 65% for commercial/public/fleet use.

**Rebate outlook**

Lighting remains the most promoted category in utility prescriptive rebate programs, presenting a potentially substantial avenue for reducing the initial cost of advanced lighting and controls and increasing their adoption. To learn more about rebates, owners can contact local utility programs where available, a rebate fulfillment firm, or manufacturers that offer marketing support. Research each applicable program, as they generally pose different requirements for preapproval, product qualification, and inspection.

**EXPANDED TEXT:** [ledsmagazine.com/14291236](https://ledsmagazine.com/14291236)

# Finelite R&D executive says DfD is ‘a lot of work’ but it also expands potential for innovation

In an interview with **CARRIE MEADOWS**, Finelite vice president of R&D **AARON SMITH** explains how the company puts design for disassembly concepts into practice and how end users can inspire change across the lighting manufacturing and supply chain.

**LEDs Magazine:** Finelite, as a company, and you, as an R&D leader in the industry, have been vocal about design for disassembly — what that means and what to consider in terms of materials and processes. Can you run through some industry-facing initiatives and resources for design for disassembly (DfD) inspiration?

**Aaron Smith:** Finelite is part of some of the ongoing LCA [life cycle analysis] research projects. We’re working with Pacific Northwest National Laboratory on life cycle analysis — developing tools to try and make LCA easier for the lighting industry and less expensive — and data collection; and with the GreenLight Alliance, a conglomerate of manufacturers trying to set a bar for the industry in terms of LCA for lighting fixtures across different types of product platforms. Through some of those forums, and through presenting at events like LEDucation and LightFair, we’ve received feedback that what we’ve discussed with the marketplace about DfD has value across industry and company borders.

No one organization can make an impact by itself. It takes a collective effort. We’re sharing our pain points with each other and these third parties. Sometimes it means talking through a solution to a specific engineering problem or the type of supply chain that we’re trying to set up so that we can get more sustainable materials. We can all leverage that knowledge.

Lighting is relatively small compared to other industries, and those other industries are moving ahead to new ways

of doing things. I follow mechanical engineering blogs to see what new materials companies are coming out with, and now, more than ever, people are building whole factories around sustainable materials. One example is collecting ocean plastics and turning them into polymers that can

a materials list. We’re going to make a fixture that will be easy to disassemble. We’re going to try to limit the amount of composite materials that we’re using, so at the end of life, we can recycle those materials or reuse components somehow.



“Lighting is relatively small compared to some other industries [that] are moving ahead to new ways of doing things.”

be added to virgin material to offset the carbon footprint. We’re looking into those types of materials. There are smart people out there working to solve material issues, not just in the lighting industry. So many places to find inspiration.

**LEDs:** What changes or obstacles do lighting companies need to identify and understand in order to engage in DfD?

**Smith:** Incorporating DfD into the culture of your product development cycle is important. You have to actively consider components early in the design phase, so that you can factor in disassembly questions and needs during the design process and educate your team. Establishing clear principles to follow going into the design process is a start.

For example, when we begin product development, we’re going to make

Another key is pushing those ideas down to your supply chain. If we’re working with driver manufacturers, how can we help them understand the need to have materials transparency for those components? That’s a big pain point, trying to get material details nailed down. We ran into an issue where a potential design called for a washer and a hanging clip, and some manufacturers can’t give us specifics on the materials that go into those simple components — metal and steel — because they don’t have traceability all the way back [to the source].

We have to work with them to understand what our need is at a basic level; and then we may even have to switch suppliers to somebody who can get us that documentation.

But knowing that right in the beginning of the project, we can narrow down our options to those suppliers who can and will provide that information — examples like whether there is a composite material involved. Is it recyclable material? And so on.

**LEDs:** If you're trying to design a product for disassembly at end of usable life, what happens to components that need to be removed from the system because they can't be utilized?

**Smith:** We need more research about what happens at the end of life in a building. My experience is that it's very regional, depending on the code, the building process, or who the contractor is. There are certainly folks who have their own green initiatives; when they decommission lighting or electrical equipment, they'll separate out the components into different bins and try to get down as much as they can to the recyclable parts, especially things like copper wiring and components that are easy to separate.

Of course, there are still situations when fixtures are just getting thrown out, and you don't know what happens at the waste management facility. Are they actually separating those out, shredding them, and getting those materials out of the way? Ideally, we'd have a way of disassembling everything and being able to separate those materials so people know what they are. That's still something we need more clarity on — and this isn't unique to lighting. It's happening everywhere.

**LEDs:** How do materials sourcing and content factors influence design execution and supply-chain relationships?

**Smith:** This is a lot of work. Even though a material may look the same, a lot of things happened in the background to make sure that it would be suitable for our product. For example, we're looking at aluminum that has 75% recycled content versus virgin aluminum. There are tests; we have to make a new tool; and we've got to push a new extrusion with this new material and validate that it doesn't have any kind of mechanical defects, because we have to think about earthquake safety, mechanical safety,

**Declare.**

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Aluminum.Luminaires -RLD  
Finelite, Inc.

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**Life Expectancy:** 10 Year(s)  
**End of Life Options:** Recyclable (100%)  
EU CoC Screened: Contains

**Ingredients:**  
Aluminum; Steel; Small Electrical Component; Polyester fiber; 2-Propenoic acid, 2-methyl-, methyl ester, polymer with ethyl 2-propenoate; Poly(epsilon-caprolactone); Poly(epsilon-caprolactone-co-1,6-hexanediol); 2-Propenoic acid, 2-methyl-, 2-propenoic acid, 2-methyl-, methyl ester, polymer with butyl 2-propenoate and ethylbenzene; 2-Propenoic acid, 2-methyl-, methyl ester, polymer with ethylbenzene; 2-Propenoic acid, 2-methyl-, methyl ester, polymer with diethybenzene and ethylbenzene; Hexamine cyanurate; 1,3-Benzenedicarboxylic acid, polymer with 1,4-benzenedicarboxylic acid; 2,2-dimethyl-1,3-propanediol; 1,2-ethanediol and benzoic acid; Titanium dioxide; Barium sulfate; Phenol; 4-(4-(1-methylethylidene)bis(4-phenyl)imino)ethylene)bis(oxirane); Polymethyl methacrylate; Polyvinyl chloride; Methyl methacrylate; 2-Propenoic acid, 2-methyl-, Cl2-16-branched and linear alkyl esters, polymers with acryl methacrylate, He methacrylate, polyethylene glycol methacrylate branched triethyl ether and styryl methacrylate; Aluminum hydroxide; 1,5-hexadiene; Hexamethylenediamine; Octadecanamide; NN-1,2-ethanedithiol; Ethyl acrylate; Polyethylene.

**ULC Temp Exception RL-002 - Small Electrical Components**  
REACH SVHC present > 100ppm  
RoHS List present > 100ppm

**Living Building Challenge Criteria:**

**H-13 Red List:**  
 LBC Red List Free      % Disclosed: 100% at 100ppm  
 LBC Red List Approved      VOC Content: Not Applicable  
 Declared

**H-10 Interior Performance:** Not Applicable  
**H-14 Responsible Sourcing:** Not Applicable

FIN-0004  
EXP: 01 AUG 2023  
SCREENED: 02 AUG 2022  
Original Issue Date: 2020

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### A sample Declare label for Finelite luminaires shows the materials listed as part of transparency initiatives.

International Living Future Institute

and so on. Whenever you have long spans of fixtures, especially linear, if you don't use the right material, it can sag. So you have to make sure that everything is structurally sound.

There's usually a year or two of development ahead of us being able to use that component or material in manufacturing and then deliver finished product.

Once you find a product or material, then you ask, how do I actually get it to my supplier so that they can use it? Do I need to change suppliers? There are very commercial and practical steps that have to be addressed to be able to

use a new product. Identifying the component is step one. I'm excited about it. But then funneling it to the supplier and getting them to use it, that's the next step. We have also set goals about making sure that the products are Red List Free [of specific hazardous materials and chemicals]. So, do you have all that transparency information ahead of time?

It's definitely challenging, but it's doable. The more we do it, the more this process is ingrained into us that this is the way forward — it becomes part of our culture.

Always start small. Find something that's within your scope of ability to do, start working on that, and then expand from there. We didn't start with saying, "We're going to transform the whole company, every product that we make is sustainable." We're going to keep layering and building.

**LEDs:** Everyone asks about cost eventually. How does the transition to more sustainable materials and processes impact cost, and how has that been received by the marketplace?

**Smith:** Ideally it would be even — there wouldn't be a markup on a sustainable fixture. That's what we're striving toward. We have to build it into our design philosophy. When we are going out to suppliers and looking for different materials, we still need sustainable materials to come in at a very similar price to what we have now, because the market can't bear to pay more for it just because it's sustainable.

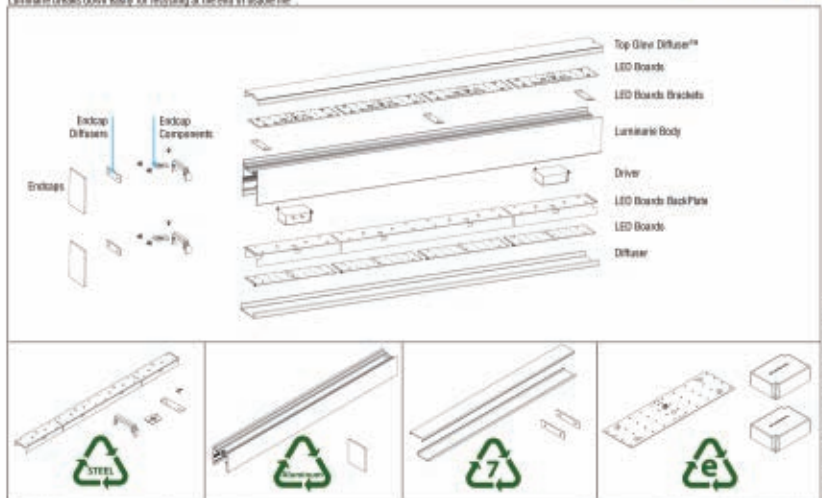
Our goal is to try to make [a sustainable fixture] as affordable as possible. Designing for disassembly has the potential to make a lighting fixture that's easier to produce, has fewer components, and has the ability to be recycled at the end of life. These simple things also make a positive impact on your manufacturing process over time. You're not spending as much time building the fixture, so you're actually lowering your costs. Those innovations in savings could be passed along to the customer, and allow you to be more profitable and in turn have more resources to consider other sustainable processes.

**HP-4 Indirect/Direct and Regressed**

HP-4 ID & ID RG Recycling Luminaire Breakdown



Luminaire breaks down easily for recycling at the end of useful life.



Recycling information is based on current practices. Please contact your local recycling authority for more information. © 2013 Finelite, Inc. All rights reserved. FINELITE IS A REGISTERED TRADEMARK OF FINELITE, INC. PHOTO: PHOTOFEST

Yes, some materials cost more, but processes like DfD can help offset those costs. Can you combine those [concepts] together to create something

that comes in at the right price at the right time? There are customers who are very engaged in sustainability efforts

End-of-life disassembly instructions provide guidance on which components can be broken down and recycled through appropriate waste management services. Finelite

— designers and architects. Outside influences are causing them to choose more sustainable products; they know that these products might be more expensive, but they see value in those choices like having Declare labels [that identify product “ingredients”], reducing volatile chemicals in furnishings and fixtures, and they’re willing to figure out how to get those things into the project. The more they ask for it, those prices will generally start to come down.

*This interview has been condensed and edited for clarity.*

**EXPANDED TEXT:** ledsmagazine.com/14291935



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# Centralized DC power bolsters CEA facility performance

**JAMES EAVES** details safety, efficiency, and resilience benefits of centralized DC power for indoor grower operations.

**A** growing number of architects and engineers are advocating for indoor farm and greenhouse designs that use centralized direct current (DC) power, because it greatly expands a farmer's ability to optimize energy efficiency, operational flexibility, production quality, and the physical design of a farm.

In this article, I begin by discussing the advantages of centralized DC power with a specific focus on horticulture LEDs because they use by far the most

power in an indoor farm. I also explain why centralized DC power design hasn't yet been widely adopted, despite the advantages. Lastly, I explain why this will change because of a new development in power distribution technology that makes centralized DC power practical and creates even more benefits.

## What is centralized DC power?

With a centralized DC power design, AC power is converted to DC power in one

central location, like an electrical room, instead of at each device. For example, in a traditional AC installation each LED fixture employs an individual driver. In a centralized DC power architecture, the DC power is converted from the AC power source in the electrical room to DC, and then distributed to driverless LEDs in the grow space. The change is subtle, but it removes constraints to unlock optimization opportunities. With more and more devices running on DC power in a modern farm, the centralized DC model can help optimize farm performance.

## Advantages of centralized DC power

**Increased reliability and resiliency.** AC-based designs require hundreds or thousands of power supplies installed in the worst place for active electronics — wet grow spaces that experience extreme temperature fluctuations. Centralized DC power moves the power supplies into spaces designed for housing electrical components, thereby increasing power-supply lifetime while dramatically reducing the total number of components.

Greenseal Cannabis in Ontario, Canada, was one of the earliest adopters of centralized DC power. Its facility design replaced thousands of small LED power supplies with a few large devices in the electrical room, resulting

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JAMES EAVES, PhD, is the director of indoor agriculture at VoltServer, the creator of Digital Electricity. He is focused on finding ways to address what he believes are the biggest problems facing CEA today: building costs and energy use.



in approximately 70% fewer electrical components than a traditional design. Since the LED power supply is the single most common point of failure, the reduction in system components significantly improved reliability and resiliency. Moreover, software can be deployed to diagnose any problem and immediately notify an in-house technician to fix it without entering the grow space. In a conventional AC design, someone must first see a dead LED fixture before calling in an electrician to enter the production space to diagnose and repair or replace the grow light; this not only disrupts production but increases biosecurity risk.

**Improved ability to integrate renewables.** Centralized DC power also affords operators the ability to integrate renewable energy sources more easily. Most renewable energy sources — such as solar panels, wind turbines, and batteries — deliver DC power. Using centralized DC power, buildings can directly connect to these sources without an AC-DC converter. By avoiding the conversion process, more energy from the renewable sources can be used directly by the building for a more sustainable and cost-effective site.

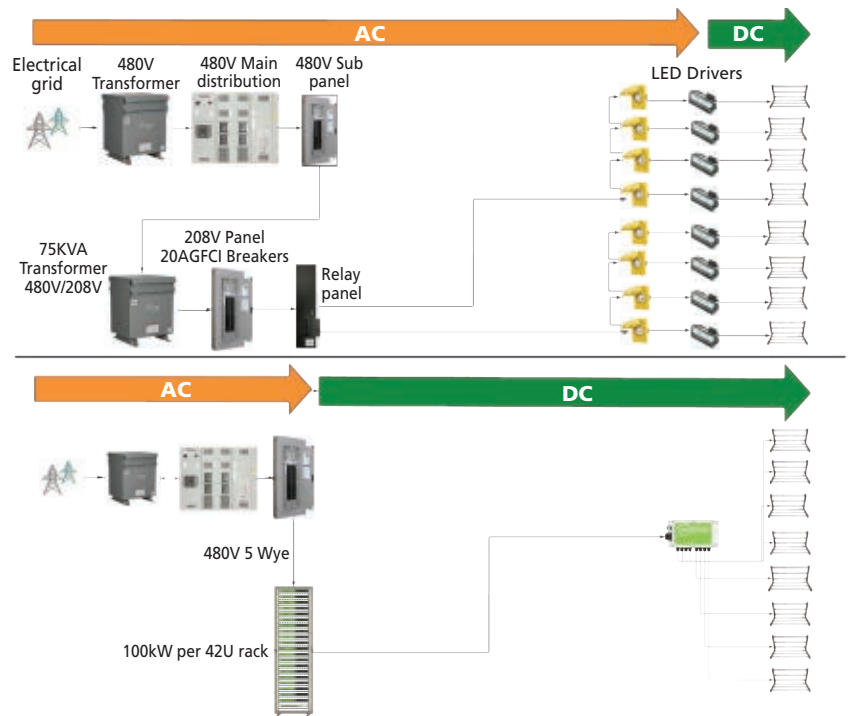
**Improved growing conditions.** From a physical layout perspective, power supplies disturb and restrict airflow inside grow spaces, increasing the number of small pockets of different temperatures and humidity — called microclimates — and making it harder to achieve consistent product quality. Each power supply also generates heat, which makes cooling the space more expensive. Moreover, when power supplies are near the LEDs, placing fixtures in the best location for the plants to receive optimal light for photosynthesis can be harder. Removing power supplies makes creating a consistent climate and providing good light distribution for plants easier and less expensive.

**Easier washdowns.** A significant challenge facing indoor farms is how pathogen populations grow and impact crop quality. If every part of the grow room isn't regularly and thoroughly washed, the population of harmful microorganisms will increase. This will eventually cause declines in yields and quality.

However, placing LED power supplies and other electrical components around plants makes it difficult to carry out a thorough washdown. Again, since centralized DC power removes most of these components, conducting a full washdown of the grow room becomes easier.

In the future, the design standard for indoor farms must include rooms that

For example, the National Electrical Code requires ground-fault circuit interrupters (GFCIs) for LED lights installed in grow spaces. However, getting GFCIs for high-voltage DC is tough. So growers would need to hardwire their LEDs, contributing to delays and the higher cost of hiring an electrician to repair any issues that arise. These operational constraints



**A sample traditional farm power distribution scheme (top) compared with a fault-managed power system distribution enabled with Digital Electricity (bottom) shows that the FMPS approach streamlines system components needed within the greenhouse environment.** VoltServer

can be fully washed down to prevent pathogen buildup.

### Obstacles to centralized DC design

Until recently, the only way for indoor and greenhouse farmers to centralize DC power was to install traditional bulk AC-DC power supplies in an electrical room and then distribute the high-voltage DC power to LEDs. However, distributing power from traditional bulk power supplies requires specialized equipment including DC-rated breakers, relays, and other components, which cost more to install and maintain than traditional AC systems; they also can be difficult to find.

and the need for specialized equipment have made using traditional bulk power supplies less appealing for growers.

These constraints have led to a new solution to centralize DC power in a simpler, more cost-effective manner for indoor and greenhouse operations.

### Fault-managed power paves the way

A new technology called “fault managed power” streamlines the distribution of high-voltage DC power without specialized safety equipment and wiring methods required for traditional AC-DC power supplies. Benefits include reduced initial and ongoing costs as well



Receivers like these in the Hardee Fresh facility safely distribute the DC power to LED fixtures and other hardware in the humid growing environment. VoltServer

as improved electrical efficiency, device control, and safety compared to traditional AC systems.

Simply put, fault-managed power uses intelligence to manage the amount of power that is released into a fault. It protects people and equipment by using sensors and software to identify faults, such as a person touching an exposed wire. When such a condition is detected, the system quickly shuts off power, releasing only a tiny amount of power that is not enough to injure a person.

Digital Electricity, a technology invented by VoltServer, is a high-voltage power distribution product with these advanced safety features. It is classified as a Limited Power Source (LPS) under the National Electric Code, which means it can be installed using the same wiring methods used for Ethernet cables, eliminating the need for complex, expensive electrical equipment and wiring methods.

The top panel of the illustration on page 31 demonstrates a traditional AC power distribution scheme for a grow room's LEDs. The farm's 480VAC feed is stepped down since GFCIs are more readily available for 208VAC. The

stepped-down power is then distributed through a relay to receptacles in the grow space that deliver power to AC-DC supplies. Power supplies, receptacles, and other electrical components (not shown in the figure) must be installed in the grow room or greenhouse.

The bottom panel of the figure shows how Digital Electricity can simplify the design. A high-voltage AC feed is converted into high-voltage DC using devices called transmitters. The DC power is then pulsed 500 times per second with a short pause after each pulse. This pause allows the system to check for faults, and if there are no issues, the next pulse is sent. If a fault is detected, the system stops sending power to limit shock and fire hazards. The safety checks are what allow the system to be classified as an LPS, enabling farmers to distribute high-voltage DC directly to driverless LEDs using 75% less equipment and labor compared to traditional AC systems.

### Energy, flexibility, and safety benefits

With Digital Electricity employed in CEA power schemes, higher voltage levels mean less electricity is lost during

distribution, thereby improving energy efficiency. Managing heat generated by LED power supplies in a dry room also requires less energy from HVAC systems than in the humid growing environment. Finally, larger power supplies can be less expensive and more efficient than many smaller devices.

Operational flexibility has increased, according to user testimonials. The system safety feature allows growers to control, monitor, and schedule individual 600W LED groups, which would be far more expensive with traditional AC design. Halton Peters, president at certified organic vertical farm Hardee Fresh, Wauchula, Fla., explained that using remote DC power enabled with Digital Electricity "provides a superior opportunity to have control of our lights and our other IT infrastructure . . . It's the most energy-efficient way to manage large numbers of lights."

A high level of flexibility is especially important in an emerging market like indoor farming because sales and marketing professionals still do not have good models for predicting consumer demand. Operators frequently and rapidly change

the crop and inputs, increasing the value of using a fault managed power system.

According to Jamie Schurmans, who led farm construction and design teams at both Canopy Growth and InFarms and is now a principal at EFI Engineering in Ontario, “Indoor cultivation, especially when considering different crops and environmental requirements, necessitates constant adjustment to the physical and environmental growing conditions. Fault managed power provides a low-cost and reliable solution that is washdown compliant and reduces localized heat sources. Our clients find the inherently safe design easy to manipulate and rearrange using their own inhouse labor.”

Ontario-based GreenSeal Cannabis facility manager Chris Murray explained, “Not having all these rigid conduits and high-voltage power in there ... we’re able to do a semi-permanent installation with VoltServer that can change at a moment’s notice,” which also improves the company’s speed to market.

Safety is the most important feature of a fault managed power system when handling high levels of electricity in complex, wet locations. With many new entrants to controlled environment agriculture, the risks of electrical shock are not always widely considered. Although the U.S. Bureau of Labor Statistics



**Transmitters convert the high-voltage AC power fed to the electrical room into high-voltage DC power, conveyed using Digital Electricity that pulses the power to limit shock and fire risks.** VoltServer

doesn’t report statistics for each industry, a total of 1,940 electrical injuries and 160 deaths occurred in the United States in 2020. That same year, an employee in an Ontario greenhouse was killed by electrocution. “Keeping AC out of the grow space gives us good peace of mind,” said Clint Hunnicutt, general manager at Hardee Fresh. “We use thousands and thousands of gallons of water through our building every day. If it does end up on equipment, we’re confident that our employees and equipment are safe.”

Centralized DC distribution, through fault managed power systems employing Digital Electricity, can significantly impact a grower’s bottom line and its viability for the long term with reduced equipment maintenance, greater energy efficiency, and a higher level of safety. It also has the ability to replace traditional AC methods of power distribution now and in the future.

*Digital Electricity is a trademark of VoltServer, which provides power distribution systems such as those described in this article.*



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# Are cubic InGaN, red micro LEDs on your roadmap?

AR/VR applications will prompt the next phase of micro LED technology development, says **MARTIN LAMB**, but new materials solutions that can be manufactured with existing methods are required to amplify color emitter performance.

Exploding interest in augmented reality (AR) and virtual reality (VR) applications has already triggered development activity in the markets for the key enabling hardware, components, and materials. The potential to deliver a cost-effective, head-mounted display with leading-edge user experience is central to success in AR/VR applications, so the acceleration of foundational technology investments in recent years is unsurprising.

Technologies under examination include liquid-crystal displays (LCDs), organic light-emitting diodes (OLEDs), and mini and micro LEDs. Research and Markets' 2021 forecast suggests that the opportunity for micro LEDs driven by AR/VR applications could hit \$21 billion by 2027 with a CAGR of 81%. Still, the market remains in its infancy and micro LEDs are currently confined to a few high-end applications.

Performance improvements from miniaturizing devices may be dwindling. A radical approach may be required — one that delivers advantages over existing device-level technology, but can also be dropped into existing manufacturing lines. If the micro LED approach can scale to a full commercial level, it offers the optimal combination of attributes for the AR/VR application. Anyone who manages to overcome the technology stumbling blocks in micro LEDs stands to control the AR/VR displays market.

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*Based in Milton Keynes, U.K., MARTIN LAMB is chairman of Kubos Semiconductors. He has 40 years' experience in the compound semiconductor materials industry.*

This article examines a potential solution based on fabricating LEDs from the cubic form of gallium nitride (GaN) rather than the hexagonal phase typically used, with improvements in efficiency and performance of small-form color emitters.

### Efficiency challenges of small-form LEDs

A primary pain point for micro LED display developers is the lower efficiency of small-form LEDs. First, a few definitions. A micro LED is an emitter smaller than 100  $\mu\text{m}$ ; a mini LED would be between 100 and 300  $\mu\text{m}$ , and conventional or large-area LEDs vary from 300 to 1,000  $\mu\text{m}$  in size.

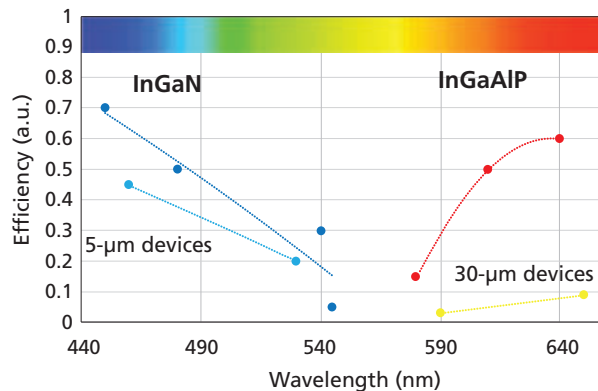
Typical high-efficiency, large-area LEDs are usually constructed from two material systems. Blue and green emitters are generally produced using diode structures fabricated from multiple layers of hexagonal crystalline indium and gallium nitride (h-InGaN) alloys. The red devices are made from structures comprising multiple layers of cubic crystalline aluminum, indium, and gallium phosphide (AlInGaP) alloys.

Larger-scale blue and red devices exhibit high internal efficiency — around 90% and 60%, respectively — while the efficiency for green emitters is approximately 20–30%. This efficiency deteriorates significantly when the size of the devices falls to around 5  $\mu\text{m}$ : Blue emitter efficiency falls to about 40%, which is adequate, but that for green and red drops to a few percent at best. In fact, current state-of-the-art, small-form red emitters deliver efficiencies of approximately 1–2%. These limitations are represented in Fig. 1.

Increased efficiency would improve configuration and minimize concerns over power requirements for head-mounted displays. The amount of light emission required for a display to function properly will determine its battery size requirements and lifetime. Moreover, if significant energy is lost as heat, larger heat sinks will restrict form factor reductions of AR/VR displays. Therefore, addressing the loss of efficiency in small-form green and red LEDs would unlock the AR/VR opportunity for aspiring market participants.

### Differences between micro LED manufacturing systems

For a full-color display, then red, green, and blue micro LEDs should be reasonably matched with respect to the spectral sensitivity of the human eye and have usable efficiency. There are two initial considerations:



**FIG. 1.** Efficiency versus wavelength of nitride and phosphide LEDs.

All images courtesy of Kubos Semiconductors.

1. Select a material system and device design capable of delivering an LED with an acceptable underlying efficiency in the various regions of the spectrum.
2. Understand and manage the impact of the device size reduction on that efficiency to produce the required small-form emitters.

Producing blue LEDs with very high efficiency is possible in the conventional h-InGaN material system. The size reduction impacts emitter efficiency, but with suitable mitigations, one can produce blue micro LEDs with workable efficiency — around 5–10% for early versions.

Physical effects that arise in the devices are driven by changes in material composition required to access longer wavelengths. The fundamental properties of the hexagonal crystal structure are also a contributing factor. While the h-InGaN system can, in principle, be engineered to produce emitters across the whole visible spectrum, more work is required to wring sufficient efficiency out of LEDs of all sizes fabricated via h-InGaN for longer visible wavelengths.

Turning to the AlInGaP system, producing highly efficient, large-scale red and amber LEDs in this material is

possible. However, when the emission wavelength falls into the green region, the efficiency collapses due to fundamental physical limitations in material properties. For the same reason, coverage of the blue end of the spectrum is impossible. Although using two different material systems to address the range of

colors required for a display is not ideal, the AlInGaP system does have potential for dealing with red devices. That said, in this material, managing the impact of size to produce small-form LEDs is a more difficult proposition than in the h-InGaN system.

While overcoming this challenge is possible, experience suggests that the high efficiency exhibited by large AlInGaP devices collapses to a few percent as the device shrinks. Again, the production of red micro LEDs based on AlInGaP remains a work in progress. Even if the efficiency challenges can be overcome, integrating different material systems into a single display is a suboptimal solution.

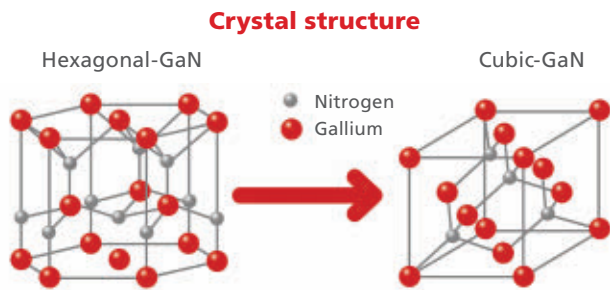
### Current methods

Most of the work on micro LEDs has focused on h-InGaN since it has delivered rapid improvements in LED performance over its 30-year lifetime.

As mentioned earlier, the reasons behind the deterioration in h-InGaN LED efficiency at longer wavelengths are well understood by materials scientists and LED developers. A large, internal electric field arises from the asymmetry of the hexagonal crystal structure in certain directions. The field extends across the quantum wells (QWs) that form the

active region of the LED, irrespective of device size. The electric field tends to separate the electrons and holes in the QWs and reduce the rate of radiative recombination, a process that is fundamental to the emission of light. This situation is exacerbated by increasing the indium content of the QWs, a necessity if longer wavelength emissions are desired, such as green, amber, and red. Worse still, these internal electric fields limit the width of the QWs that can be employed, further constraining the tools that device designers can use to access longer wavelengths.

Much of the work aimed at bypassing this roadblock has focused on trying to move the electric field in a direction that does not interfere with the radiative recombination process in the QWs by rotating the crystal structure with respect to the device. The structure is grown on a substrate with its surface cut parallel to a crystal plane at a significant angle to that usually employed for h-InGaN LED layers.



**FIG. 2.** Comparison of hexagonal and cubic GaN crystalline structures.

Unfortunately, while this rotation technique helps with the internal electric fields, it also results in the need to manage defects that appear in the grown layers, which generally do not appear in the traditional growth direction. Managing this trade-off is tricky and these approaches have yielded little more than a few incremental improvements in efficiency of green, amber, and red h-InGaN LEDs. A more fundamental change in approach is essential for a market breakthrough.

**Is a cubic structure the answer?**

Materials scientists and LED developers have long understood that the InGaN alloys forming the basis of the LED structure can also crystallize in a cubic structure (c-InGaN). The structures are compared in Fig. 2.

The cubic structure offers potential benefits over the usual hexagonal crystalline form:

- The internal electric fields that cause the collapse in efficiency with increasing wavelength in h-InGaN LEDs are completely absent in c-InGaN due to the higher symmetry of the cubic structure. This makes the use of wider QWs to access longer wavelengths possible, something precluded in h-InGaN devices. It is also expected to reduce spectral drift with increased drive currents.
- The bandgap of c-GaN is 3.2eV compared to 3.4eV for h-GaN, meaning that the baseline emission from a device employing that material will be at a longer wavelength even before the

**Key properties of h-GaN and c-GaN\*.**

Property	h-GaN	c-GaN
Internal electric fields	Yes	No
Band gap	3.4eV	3.2eV
Thermodynamically stable at STP	Yes	No

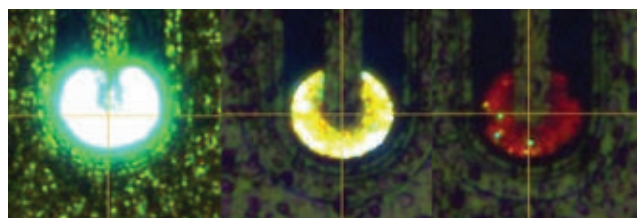
\*The smaller bandgap for c-GaN devices is critical to improving efficiency at longer wavelengths. Courtesy of Kubos Semiconductors.

addition of indium. So lower indium content will be required to access a given wavelength when compared with h-InGaN devices. The ability to employ wider QWs in this material system is a further benefit (see table).

- The hole mobility and maximum hole concentration achievable are materially higher in c-GaN than in h-GaN. The ability to produce highly conductive p-type layers is vital to successful LED operation at high current densities.

Until recently, the c-InGaN system has gone relatively unnoticed due to the rapid progress made in h-InGaN applications and historic difficulties around reliably producing, manufacturing, and scaling pure c-InGaN layers. With progress in h-InGaN reaching a plateau, interest in the cubic system has been rekindled.

Kubos Semiconductors, a spinoff from the University of Cambridge, in the U.K., has established a reliable and scalable manufacturing route for c-InGaN structures. It utilizes industry-standard metalorganic chemical vapor disposition (MOCVD) equipment and silicon substrates. Growth on 150-mm-diameter substrates has been achieved (see Fig. 3), and early results support the predicted promise of using c-InGaN to fabricate more efficient, longer-wavelength LEDs. This in turn raises the prospect of producing red, green, and blue micro LEDs from one material system and in the same MOCVD reactor. In doing so, it provides a roadmap to monolithic c-InGaN RGB pixel arrays.



**FIG. 3.** Kubos cubic-InGaN LEDs produced using MOCVD and demonstrating emission spectra in green, amber, and red.

Although work remains to optimize QW emission efficiency, compelling evidence exists supporting the consideration of a cubic InGaN system to produce LEDs with adequate underlying efficiency in the green, amber, and red parts of the spectrum. Furthermore, if the robustness of h-InGaN LEDs to the reduction in device area can be maintained in the cubic form, this material could be the breakthrough for red micro LEDs that unlocks the AR/VR display market.

*The author represents Kubos Semiconductors, which has established a fabrication technique for LEDs as described in this article.*



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# Increase the service life of lighting products for greater overall benefit

**RUAIRIDH MCGLYNN** of Stoane Lighting believes that lighting manufacturers should launch a circular economy process that eases supply chain challenges, addresses waste reduction, and enables a new service model.

From the initial lighting product design phase, circular economy principles can maximize the service life of luminaires, maintaining their materials' value for as long as possible via reuse and refurbishment. Beyond extending luminaire lifespan, embracing a circular economy model will result in less waste and less reliance on the extraction of raw materials, which will enable water and energy savings while supporting biodiversity. Lower emissions during the materials extraction, transportation, and manufacturing stages will lower overall greenhouse gas emissions and the accompanying climate impact.

With a few initial steps, manufacturers can ensure product circularity and maximize luminaire lifetime for customers, while increasing supply-chain stability and speed to market.

**Make it modular.** Modular design is key to reusing components and extending service life. If common components are deployed across a product range, or across multiple ranges, then the likelihood of being able to reuse components increases.

Take, for example, a surface-mount fixture installed in a retail space for several years. Perhaps a rebrand takes place and track spotlighting is now required. The existing fixtures can be remanufactured simply by replacing their surface-mounted canopy with a track adapter. Surface-mount components that have been removed are almost certainly reusable due to their durability; they can then be returned to the factory.

Modularity doesn't end with the form factor, mount, or housing. Specifying optics, light sources, and drivers that can be upgraded or repaired extends the reuse of luminaire components. Typically, the power electronics and possibly the light sources will be the first components to fail within a luminaire. As a result, designs should ensure that those parts can be removed with ease via standard tools. Integrating multiple fixing points to the heatsink component can also facilitate LED and optics selections at the beginning and end of service life.

## **Simplify materials.**

Additional design tactics include reducing the number of required components and reviewing manufacturing processes to minimize material waste and volume; for instance, choose an extruded profile over one machined from a solid bar of material.

Using high-quality materials in the product manufacturing process can also significantly increase lifespan, as the former will resist degradation over time and perform better under various environmental conditions. For example, durable materials such as aluminum — with its high strength-to-weight ratio — can be anodized and powder-coated for greater resilience. Use recycled materials wherever possible and consider end-of-life recycling so materials can be repurposed into new product.

**Stand by serviceability.** Manufacturers should also provide a duty of care

service beyond the standard manufacturer's warranty to support products and projects for the long term. Design and manufacture replacement parts in-house whenever possible.

Manufacturers should also provide access to disassembly information via a unique identifier on a product, such as a serial number (see page 27). Equip end users with resources on spare part listings, required tools, skill level information, and material identification, so the proper personnel can repair or upgrade a luminaire without returning it to the original manufacturer.

Luminaire manufacturers might consider a mobile repair and upgrade service for customers who cannot return large or bespoke fixtures, or in cases where the customer must minimize any facility closures, such as at a museum or gallery.

Increasing the service life of lighting products and advancing low-impact luminaires into the market requires a multifaceted approach. However, designing for durability, educating users, offering incentives, and engaging with the lighting community can enhance repeat business and drive sustainability goals into reality for the long term. ◀

*Interested in learning more? Download a white paper in which Stoane Lighting describes how it employed circular principles in designing a lighting product range.*



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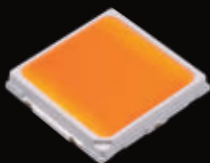
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