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# LED professional

BY LUGER RESEARCH

Review

LpR 103

May/June 2024

## INTERVIEW WITH DR. JENNIFER VEITCH, PRESIDENT OF CIE

ENVIRONMENTAL IMPACT OF LED LUMINAIRES

THE FUTURE OF SCAN-TO-BIM IN LIGHTING DESIGN

The Global Information Hub for Lighting Technologies and Design

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**Highlights**
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- Stable CTR over whole temperature range
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## Horticulture-specific beam shapes that improve light uniformity

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**Product info: cree-led.com/horizon**

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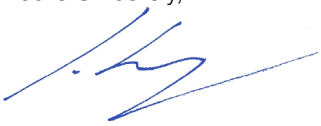
# Navigating the Future of Lighting with Science and Innovation

In this edition of our magazine, we delve into a range of compelling topics within the lighting industry, emphasizing technological innovation, health impacts, and environmental sustainability. The issue features an exploration of advanced micro-optics technologies that enhance the precision and efficiency of lighting systems, crucial for applications in mobility and consumer electronics. The transformative potential of Scan-to-BIM technology, facilitated by smartphones equipped with LiDAR sensors, is highlighted for its role in revolutionizing architectural and lighting design through efficient 3D data acquisition and model creation. An interview with Dr. Jennifer Veitch, President of the CIE, provides insights into her career and the strategic direction of the organization, emphasizing the integration of scientific research with global sustainability goals. Professor Dr. Manuel Spitschan discusses the significant non-visual effects of light on human health, advocating for advancements in standardized light exposure measurements. Additionally, an analysis by Dr. Sebastian Knoche and Dipl.-Ing. Marina Proske addresses the environmental impacts of LED luminaires, focusing on sustainable product design and improved recycling processes. The vibrant lighting market in Asia is examined for its growth and innovation, reflecting the region's unique challenges. Lastly, Adam Lilien from UL Solutions discusses the development of circadian tools that enhance the circadian performance of lighting products, aiming to design healthier indoor environments. Each article contributes unique perspectives on the current trends and future directions in lighting, highlighting the industry's commitment to enhancing both human well-being and environmental stewardship.

Enjoy your read!

Yours Sincerely,



Siegfried Luger

Luger Research e.U., Founder & CEO
LED professional, Trends in Lighting, LpS Digital & Global Lighting Directory
International Solid-State Lighting Alliance (ISA), Member of the Board of Advisors
Member of the Good Light Group and the European Photonics Industry Consortium

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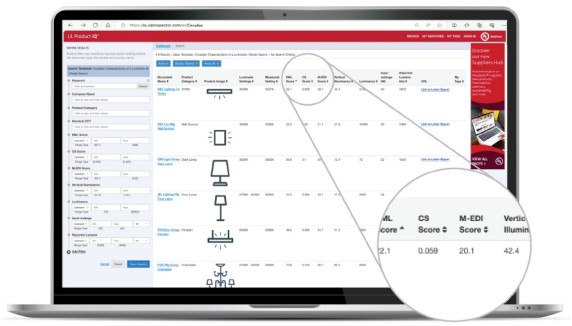
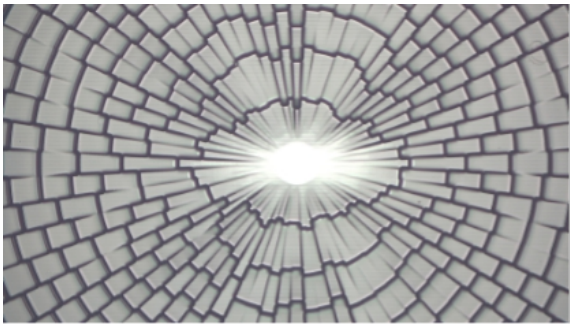




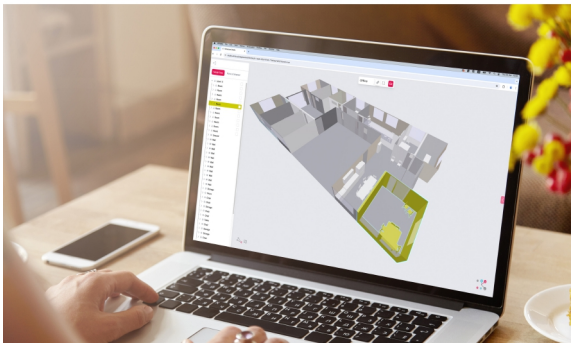
## MICRO-OPTICS





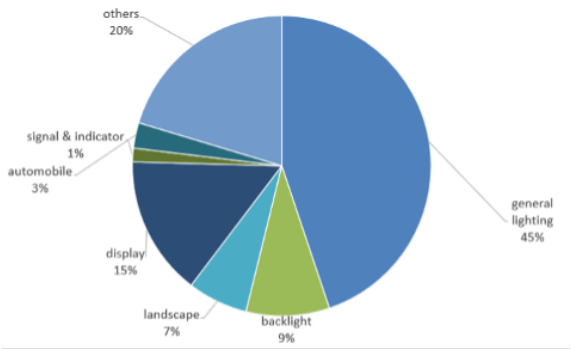
## LIGHTING DESIGN





## MARKET REPORT






## LPS DIGITAL TALKS







## ADVERTISING INDEX


## Prof. Dr. Manuel SPITSCHAN

Prof. Dr. Manuel Spitschan is the Rudolf Mössbauer Assistant Professor for Chronobiology and Health at the Technical University of Munich and a Max Planck Research Group Leader at the Max Planck Institute for Biological Cybernetics. After studies in psychology at the University of St Andrews, Prof. Spitschan received his PhD on melanopsin sensitivity in the human brain from the University of Pennsylvania. He completed post-doctoral training at Stanford University, the University of Oxford and the University of Basel. He is currently the Speaker of the Daylight Academy Steering Committee, and Chair of the CIE Joint Technical Committee 20.

www.tscnlab.org


# A Roadmap for Light and Health

In 1980, Al Lewy and his team discovered that light exposure at night suppresses the production of the endogenous hormone melatonin. About 20 years later, two teams at Thomas Jefferson University, led by George “Bud” Brainard, and at the University of Surrey, led by Debra Skene, characterized the wavelength dependence of melatonin suppression by light, identifying a signature for a non-rod, non-cone photoreceptor underlying melatonin suppression. Almost at the same time, the photopigment melanopsin and its expression in a subset of nerve cells in the retina was discovered. Another 20 years later, a team around Andrew Phillips and Sean Cain characterized significant individual differences in melatonin suppression in people.

These fundamental discoveries in neuroscience have revolutionized how light is used, conceptualized, and measured in the built environment. In addition to the assessment of light exposure in terms of photometry, $\alpha$-opic radiometry (standardized by the CIE in the International Standard CIE S 026/E:2018) allows us to estimate just how the photoreceptors in the retina are affected by environmental light. These standardized “physiologically relevant” quantities, particularly the melanopic equivalent daylight illuminance (melanopic EDI) are essential for any lighting engineering and design approaches putting human responses at the centre.

What should the following years of research on the non-visual effects of light look like? There are several key emerging approaches and technologies that will move the needle in making the science count in the “real world”.

The first one concerns the use of wearable light loggers that allow for measuring light exposure in the field. In the EURAMET-funded MeLiDos project[a], a novel framework for characterization and calibration of these light loggers is developed, and feeds into a currently active CIE committee (CIE JTC20). In addition to the technical aspects of this work, more data sets measuring light exposure in diverse populations across the globe will need to be characterized to derive baseline measurements of light exposure. Such a global measurement campaign necessarily needs some harmonization of approaches, but only through ’big data’ will the field be able to understand just how much light people receive – and what opportunities for improving their light exposure for optimizing health outcomes.

A second direction concerns the appreciation of individual differences in the non-visual effects of light, and further, understanding which biological, genetic and behavioral mechanisms drive these differences. Similarly, large-scale coordinated efforts are needed to create an evidence base that reflects those who can benefit from optimal light exposure – and that is all of us.

A third area of work that is of high priority is the development of effective communications strategies for various stakeholders – the general public, and also professional groups that can use knowledge of the non-visual effects of light. My team has recently started the podcast Light O’Clock[b], and in a recent meeting I chaired in Ladenburg, a group of international experts agreed on developing effective communications strategies and wrote a White Paper[c] about it, which will see implementation over the next year.

The following 20 years of research on the influence of light on health will allow us to move the needle – and make the neuroscience count. ■

M.S.

[a] https://melidos.eu/
[b] https://tscnlab.org/podcast
[c] https://doi.org/10.17605/osf.io/rxa35

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## New Managing Director at Instrument Systems

https://www.instrumentsystems.com

On 2 April 2024 the position of the Managing Director passed from Yasumasa Kuboyama to Dr. Yuta Yamanoi, who together with CEO Dr. Markus Ehbrecht form the new Instrument Systems management team.

Dr. Yuta Yamanoi has distinguished himself through more than two decades of professional experience in the field of color and light measurement technology. After eight years in the development department at Konica Minolta Sensing in Japan, in 2016 he transferred to Konica Minolta Sensing Americas Inc. as Business Development Manager. In this capacity he also took over the support of key account customers in the IT segment. Most recently, he was Senior Manager for Strategic Planning in Light & Display and Color & Appearance division of Konica Minolta Sensing Business Unit in Japan. As a scientist with a PhD in "Earth and Space Sciences" he thus disposes of extensive and highly relevant know-how in the business area of the wholly-owned Konica Minolta subsidiary Instrument Systems.

In his new role, over the next few years he will continue to promote the cooperation between the Konica Minolta subsidiaries of the Sensing Business Unit with their Light & Display and Color & Appearance division, which also includes Instrument Systems. Dr. Markus Ehbrecht welcomes Dr. Yuta Yamanoi to his new position. In the course of the regular change in the double leadership he is looking forward to strengthening the company together with Dr. Yuta Yamanoi for the volatile market situation, creating new added value for the customers.

The departing Yasumasa Kuboyama has been Managing Director of Instrument Systems in Germany since April 2023 and is now taking over a new department in Konica Minolta Sensing business unit in Japan.

Instrument Systems GmbH
Instrument Systems GmbH, founded in Munich in 1986, develops and produces high-end light measurement technology that is indispensable for the manufacturers of consumer electronics, (AR/VR) displays, mLED wafers, VCSEL/laser systems, automotive lighting and LED/SSL modules. All solutions benefit from our CAS series of high-precision spectroradiometers that are recognized and in use all over the world. In combination with 2D imaging colorimeters, integrating spheres and goniometer systems, they enable high-precision and accurate measurements in the entire range from UV to IR, traceable to PTB or NIST. Today, Instrument Systems is one of the world's leading manufacturers of light measurement technology. At its Berlin facility, the "Optronik Line" of products is developed and marketed for the automotive industry and traffic technology. Our subsidiary in Korea supplements the product portfolio with the "Kimsoptec Line" for the Korean light & display market. Instrument Systems has been a wholly-owned subsidiary of the Konica Minolta Group since 2012. ■

## Thorsten Cramer new CEO of Ansorg GmbH – Shaping the Future Direction

https://ansorg.com

Ansorg GmbH announced that Thorsten Cramer has been leading the company as the new CEO since March 1, 2024. With extensive leadership experience in the lighting industry at international companies, Mr. Cramer brings comprehensive expertise to the management.


As a key cornerstone of its long-term strategy, Ansorg GmbH aims to establish a future-oriented management structure. This includes gradually transferring responsibility to a new leadership team composed of experienced professionals in sales, finance, and operations. The first phase of this new management structure was successfully initiated in 2022, appointing key positions in operations and finance with experienced executives. Thorsten Cramer's appointment as CEO marks another step in this development. This measure strengthens the leadership structure of Ansorg GmbH and supports the targeted further development of corporate management.

Ansorg GmbH will continue to focus on providing innovative and outstanding lighting solutions for the retail industry. "I look forward to continuing Ansorg's success story," said Thorsten Cramer. The current managing directors, Rudolf Pütz and Manfred Meier, will continue to actively support the transition and remain with the company as shareholders in advisory roles. ■

## DOE Releases First Ever Federal Blueprint to Decarbonize America's Buildings Sector

www.energy.gov/eere/buildings/building-technologies-office

First Comprehensive Federal Strategy Outlines Pathways to Reduce Emissions 90% in Buildings Sector by 2050, Reinforcing President Biden's Investing in America Agenda to Lower Energy Costs, Improve Resilience, and Tackle the Climate Crisis.


The Biden-Harris Administration released Decarbonizing the U.S. Economy by 2050: A National Blueprint for the Buildings Sector, a comprehensive plan to reduce greenhouse-gas (GHG) emissions from buildings by 65% by 2035 and 90% by 2050. The U.S. Department of Energy (DOE) led the Blueprint's development in collaboration with the Department of Housing and Urban Development (HUD), the Environmental Protection Agency (EPA), and other federal agencies. The Blueprint is the first sector-wide strategy for building decarbonization developed by the federal government, underscoring President Biden's whole-of-government approach to cutting harmful carbon emissions and achieving the nation's ambitious clean energy and climate goals.

"America's building sector accounts for more than a third of the harmful emissions jeopardizing our air and health, but the Biden-Harris Administration has developed a forward-looking strategy to slash these pollutants from buildings across the nation," said U.S. Secretary of Energy Jennifer M. Granholm. "As part of a whole-of-government approach, DOE is outlining for the first time ever a comprehensive federal plan to reduce energy in our homes, schools, and workplaces—lowering utility bills and creating healthier communities while combating the climate crisis."

Buildings account for more than one third of domestic climate pollution and $370 billion in

annual energy costs. Reducing GHG emissions from buildings is essential to reaching the Biden-Harris Administration's goal of achieving net-zero emissions by 2050.The Blueprint projects reductions of 90% of total GHG emissions from the buildings sector, which will save consumers more than $100 billion in annual energy costs and avoid $17 billion in annual health costs.

One in five Americans lives in a household that is at least one month behind on its energy bills, according to the U.S. Census Bureau Household Pulse Survey. Economically disadvantaged communities are more likely to face energy insecurity due to high energy costs. They are also more likely to suffer from the effects of substandard building conditions and health-harming pollution. To address these inequities, the Blueprint emphasizes affordability through reduced energy and technology costs, as well as measures that would help make communities more resilient to power outages and climate change-fueled extreme weather events.

Four strategic objectives:

- Increasing building energy efficiency
- Accelerating onsite emissions reductions
- Transforming the interactions between buildings and the electricity grid
- Minimizing the emissions from producing, transporting, installing, and disposing of building materials

Each objective has specific performance targets and market, policy, and technology milestones to reach by 2035 and 2050. Meeting these targets will require accelerated deployment of a wide range of decarbonization and energy efficiency technologies. The Blueprint outlines coordinated federal actions that can increase the speed and scale with which these solutions are deployed. Those actions include funding research and development to develop lower-cost technologies, expanding markets for low-carbon technologies, providing direct funding and financing, and supporting the development and implementation of emissions-reducing building codes and appliance standards. In line with the Biden-Harris Administration's efforts to help ensure the benefits of the clean energy transition flow directly to impacted communities, the Blueprint also outlines ways that federal agencies can support state, local, and Tribal decarbonization objectives.

To achieve these goals, DOE is focused on building innovations in three pivotal areas: building upgrades, efficient electrification, and smart controls. DOE's approach strives to advance scalable technologies and installation solutions for affordable-housing residents while expanding workforce capabilities at the state and local levels.

DOE's Affordable Home Energy Shot™, which aims to reduce the upfront cost of upgrading a home by at least 50% and reduce energy bills by 20% within a decade, will accelerate progress toward the emissions-reduction targets established in the Blueprint. To learn more about DOE's efforts to improve the efficiency and affordability of America's building stock, visit the Building Technologies Office homepage. ■

## DOE Launches Final Phase of Its L-Prize Lighting Competition on Manufacturing & Installation

https://americanmadechallenges.org/challenges/lprize

The U.S. Department of Energy (DOE) launched the third and final phase of its Lighting Prize (L-Prize®) competition, a DOE American-Made Challenge designed to spur groundbreaking innovation, local manufacturing, and the benefits of an inclusive, clean-energy economy for next-generation lighting in commercial buildings. Phase 3, called Manufacturing & Installation (M&I), will unfold over 16 months and reward production and installation of products that meet L-Prize technical requirements in real-world buildings. Up to four competitors earning the most points based on technical and design innovation,

U.S. content, production, and installation will share an award of $10 million.

"This final phase of the L-Prize is primed to showcase next-generation lighting solutions that combine high efficacy with exceptional lighting quality, data-driven control, and sustainable design and construction in real buildings," said Mandy Mahoney, DOE Building Technologies Office director. "What makes this prize different from many others is that it will showcase both the products' innovative features, and also their potential to scale. And it rewards competitors for thinking creatively about how to make them in America."


The L-Prize advances the state-of-the-art in LED lighting, encouraging innovators to develop advanced luminaires and lighting systems that lead to transformative designs, products, and impacts. In addition to its technical innovation goals, the L-Prize prioritizes equity, affordability, and resilience-related innovations that will support the broad deployment of winning solutions to all communities, particularly those with limited resources.

"I'm excited about the approach to equity in this phase of the L-Prize. It meets the commitment DOE has made to the Justice40 Initiative, so that 40 percent of the overall benefits of certain federal climate, clean energy, affordable and sustainable housing, and other investments flow to disadvantaged communities where they're needed most," added Mahoney.

The M&I Phase will recognize teams that are able to translate innovations inspired by the L-Prize to market availability and installation. The M&I Phase has two separate tracks: the Luminaire Track and the Connected Systems Track. Competitors may submit to the Luminaire Track, the Connected Systems Track, or separately to both tracks. DOE will evaluate each track's submissions independently. All entries must meet the minimum technical requirements and be fully commercially available and physically installed in real-world applications. Entries must demonstrate benefits ranging from energy efficiency and lighting quality to connectivity and sustainability. The M&I Phase also includes evaluation criteria unique to this phase, including U.S. manufacturing content, installation, and deployment strategy.

How to Participate in the L-Prize's M&I Phase: Visit the L-Prize website to view the complete competition requirements and timeline. Forms to express interest in the competition are due October 1, 2024. ■

## New Working Group to Collaborate and Advise on Horticultural Lighting Controls

https://www.designlights.org/our-work/horticultural-lighting/technical-requirements/hort-v3-0/

Lighting and controls manufacturers, engineering and design consultants, non-profits, researchers, and indoor cultivators are among stakeholders recently appointed help the DLC accelerate the horticultural lighting industry's adoption of networked lighting solutions that advance both crop production and energy efficiency.


"The controlled environment agriculture industry has grown steadily since the DLC created its first horticultural lighting technical requirements and Qualified Products List in 2018," DLC Executive Director and CEO Tina Halfpenny said. "We look forward to collaborating with these industry experts as we take the DLC's horticultural program to the next step, expanding the role of connected and integrated lighting solutions that will enhance both energy use and crop production."

Representing the interests of their respective industries rather than individual companies and organizations, members of the Horticultural Lighting Controls Technical Working Group include:

- Mikhail Sagal, TSRgrow
- Erik Runkle, Michigan State University – College of Agriculture & Natural Resources
- Gretchen Schimelpfenig; Greenhouse Lighting & Systems Engineering (GLASE) Consortium
- Eric Eisele, GrowFlux
- Mark Blonquist, Apogee Instruments
- Cristin Dziekonski, Fluence
- Ihor Lys, Agnetix
- Francois R.-Moisan, Sollum Technologies
- Emmanuel W J L Oomen, Hawthorne Gardening Company

The nine-member panel will provide input on DLC horticultural lighting program updates, creation of resources, and related activities. Moreover, as the DLC continues to improve the efficacy and quality of horticultural lighting eligible for utility incentives and rebates, the working group will provide technical and strategic feedback and input on activities such as:

- Mapping opportunities for horticultural lighting controls and integrated controls solutions that save energy and/or optimize crop production;
- Addressing challenges and risks to the advancement of energy-saving and/or production-improving connected solutions; and
- Reviewing and developing resources that support the DLC's mission, DLC efficiency program member objectives, and grower needs, including case studies, grower education and guidance, and program implementation.

The Horticultural Lighting Controls Technical Working Group is expected to meet quarterly. Explore the DLC website for more information about horticultural lighting and the Horticultural Lighting Technical Requirements, and to search for and view hundreds of products on the Hort QPL. ■

## ams OSRAM Sells Passive Optical Components Assets to Focuslight Technologies

www.focuslight.com/

ams OSRAM (SIX: AMS) sells relevant Passive Optical Components assets to Focuslight Technologies Inc. for EUR 45 million in cash.


"With our strategic efficiency program 'Re-establish the Base', we have promised as one key element to exit the non-core portfolio in our semiconductor business. Now we deliver another important step and announce the sale of relevant Passive Optical Components assets to Focuslight Technologies Inc., who is an excellent home for them. ams OSRAM continues executing its 'Re-establish the Base' program according to plan," said Aldo Kamper, CEO of ams OSRAM.

**Executing the 'Re-establish-the-Base' Program**
On July 27th, 2023, the company announced its 'Re-establish the Base' program, focusing on its profitable core as a new base for sustainable, profitable growth.

In terms of portfolio measures aimed at exiting certain non-core businesses in the semiconductor portfolio, the company had prioritized the carve-out of the Passive Optical Components business.

ams OSRAM signed an agreement with Focuslight Technologies Inc. (Focuslight – Never Stop Exploring), a fast-growing company in optical technologies, headquartered in Xi'an (China) and listed on the stock exchange in Shanghai (China), for the sale of relevant assets of its Passive Optical Components business. Focuslight Technologies Inc. agreed to acquire those assets for EUR 45 million in cash. The transaction is subject to closing conditions which include approvals by the shareholders of Focuslight Technologies Inc. and Chinese regulatory authorities. It is expected to close in the third quarter 2024.

The existing business in optical components for Consumer applications, generating around EUR 50 million of revenues in 2023 and phasing out in 2024, is not part of the transaction. ■

## Lumileds to Sell its Lamps and Accessories Business to First Brands Group

https://lumileds.com

Lumileds, LLC, one of the world's leading LED manufacturers and solution providers for the global automotive, illumination, display, and flash markets and First Brands Group, LLC ("First Brands"), a global automotive parts manufacturer that serves the worldwide automotive aftermarket, have entered into an agreement for First Brands to acquire the Lamps and Accessories business of Lumileds for $238M. Under First Brands, the Lamps and Accessories business will continue to expand its global offerings and position its products and leading brands in the automotive accessories sector.


"The automotive OEM lighting go-to-market synergies and conditions that made the union of Lumileds and Philips automotive lighting business so compelling nearly a decade ago have changed as transportation manufacturers have adopted LEDs as their standard light source and traditional automotive light sources have transitioned to primarily an automotive aftermarket business," said Steve Barlow, Lumileds CEO. "Our Lamps and Accessories and our LED businesses are industry leaders in their respective markets and will be free to focus on the ongoing growth of their unique brands, channels, and customers."

The sale is expected to close in the 2nd calendar quarter of 2024.

As part of the acquisition, Lumileds automotive lamps factories in China, Germany, and Poland will transfer with the Lamps and Accessories business. Lumileds will retain its factories and sites in The Netherlands, United States, Malaysia, Singapore, Germany and Jiaxing China.

Citi acted as financial advisor and DLA Piper acted as legal advisor to Lumileds.

About Lumileds: Lumileds is a global leader in OEM and aftermarket automotive lighting and accessories, camera flash for mobile devices, MicroLED, and light sources for general illumination, horticulture, and human-centric lighting. Our approximately 5,500 employees operate in over 30 countries and partner with our customers to deliver never before possible solutions for lighting, safety, and well-being. Learn more at https://lumileds.com.

About First Brands: First Brands™ is a global automotive parts company that develops, markets and sells premium products through a portfolio of market-leading brands that offer best-in-class technology, industry-leading engineering and manufacturing capabilities, and superior customer service. ■

## Signify Introduces Ambitious Net Zero Emissions Reduction Targets, Validated by SBTi

www.signify.com/global/sustainability/our-program

Signify announced that it is expanding its climate action with ambitious new Net Zero emissions reduction targets. The company has introduced a 2040 net-zero target and a commitment to reduce absolute scope 1, 2 and 3 greenhouse gas (GHG) emissions by 90% without the use of carbon credits. These targets have been reviewed and validated by the Science Based Targets initiative (SBTi).

"Absolute emissions reduction has always been the backbone of our climate action. We have reduced more than 75% of our operational carbon footprint since 2010. Through the combination of radical improvements in the efficiency of our products and hundreds of initiatives implemented in factories, offices, and across our operations, we have reduced our full scope greenhouse gas emissions by half since 2019."

*"We believe we have an important role to play in the transformation toward a low-carbon economy. Our dedication to sustainable innovation has enabled us to continuously break through energy efficiency technology barriers with our LED products and connected systems."*
–Maurice Loosschilder, Global Head of Sustainability at Signify

In 2019, Signify became one of the first 30 companies worldwide to have its carbon emissions reduction targets validated by the SBTi to be aligned with the 1.5°C pathway. Having surpassed its 2025 targets, Signify has set further near- and long-term reduction targets and will be introducing a detailed Climate Transition Plan in 2024. The following climate goals have been reviewed and validated as science-based net-zero targets:

- Overall Net-Zero Target: Signify commits to reach net-zero greenhouse gas emissions across the value chain by 2040. Near-Term Targets: Signify commits to reduce absolute scope 1 and 2 GHG emissions 50% by 2030 from a 2019 base year.
- Signify also commits to reduce absolute scope 3 GHG emissions 50% within the same timeframe.
- Long-Term Targets: Signify commits to reduce absolute scope 1 and 2 GHG emissions 90% by 2040 from a 2019 base year. Signify also commits to reduce absolute scope 3 GHG emissions 90% within the same timeframe.

Signify has halved its greenhouse gas emissions since 2019, with a cumulative reduction of 334 million tons $CO_2e$ in excess of the requirements of the Paris agreement's 1.5-degree pathway.

Signify's sustainability program Brighter Lives, Better World 2025 set out to double the pace of decarbonization required by the Paris Agreement's 1.5°C scenario by the end of 2025. The company is proactive in reducing emissions across its supply chain, participating in the CDP Supply Chain program and encouraging suppliers to commit to science-based targets.

"We are proud to be part of the global movement for ambitious corporate decarbonization. This validation of our targets sets an example our peers and the broader industry must follow as we redouble our efforts to reduce emissions across the value chain in line with the Paris agreement's 1.5-degree pathway," said Loosschilder.

**About the Science Based Target initiative**
The Science Based Targets initiative (SBTi) is a collaboration between the Carbon Disclosure Project (CDP), the United Nations Global Compact, World Resources Institute (WRI) and the World Wide Fund for Nature (WWF). Launched in 2015, SBTi defines and promotes best practice in science-based target setting and independently assesses companies' targets. ■

## Signify Introduces New UltraEfficient and 3D Printed Innovations, Supporting the Transition to Energy-efficient, Sustainable Workspaces

www.signify.com/global/innovation/3d-printing

Signify has introduced cutting-edge solutions that effectively illuminate workspaces, support productivity and accelerate the transition to energy-efficient, sustainable buildings.

**UltraEfficient luminaires drive energy efficiency**

Signify continues to expand its UltraEfficient (UE) range, with new panels, recessed luminaires, and downlights that help businesses lower their carbon emissions, while delivering substantial cost savings over time:

Philips UltraEfficient TrueBlend is a recessed fitting, suitable for a wide variety of ceiling types that can simplify the process of switching to LEDs. Its modular design makes it possible to fit TrueBlend luminaires in the same cutout as existing fittings, delivering time and cost savings for the customer.

Philips PowerBalance UE recessed luminaires and Philips LuxSpace UE downlights come with an ultra-high efficacy (up to 174 lm/W and 160 lm/W resp.), tunable white option, and a lifetime of 50,000 hrs at L90. With these UltraEfficient luminaires, users can yield energy savings of up to 21.7% compared to other comparable LED luminaires. With a similar look, feel and light distribution, they allow for an easy replacement of current luminaires. They also meet Signify's strict Lighting for Circularity criteria, with parts that are serviceable, reusable, refurbishable and recyclable.

The UltraEfficient range will be further extended with the Philips UltraEfficient CoreLine panel in May 2024.

*"Signify is setting the standard for office lighting, investing in understanding and anticipating our customers' needs, and developing product that fit. With buildings responsible for 40% of energy consumption and 36% of greenhouse gas emissions in the EU, there is an urgent need for businesses to transition to energy efficient sustainable workspaces. We are driving down energy use with our UltraEfficient range, saving installation time and cost for our customers, while minimizing the use of materials with our 3D-printed Essentials and Grand range, and reducing the amount of plastics in our trade packaging by 70%."*
–Sophie Breton, Professional Business Leader for Europe at Signify

**Remarkable, customizable and sustainably printed connected lighting from Philips MyCreation**

Developed to transform offices into inspiring places to work, the Philips MyCreation range is 3D-printed using bio-circular materials, offering unparalleled functionality and customization, with a wide range of color, texture, and designs to choose from. All MyCreation products are printed-to-order, reducing waste as no excess products are produced.

The MyCreation Essential downlighter is made from at least 55% bio-circular plastics. Integrated emergency lighting is available now, with wall-mounted lighting coming in May. The MyCreation Grand Pendant, also made with 55% bio-circular printed parts, offers stylish, and functional lighting design, with the ability to connect to different lighting systems.

The GreenSpace PerfectFit is available in many sizes to fit any space in the ceiling. With housings and trims made with at least 65% post-industrial recycled polycarbonate, it is 3D-printed to order, making it an ideal solution for renovation projects. ■

## Zumtobel Introduces the EXTONA Explosion-proof Luminaire

www.zumtobel.com

Zumtobel's new moisture-proof luminaire EXTONA is ideal for use in hazardous areas and harsh industrial conditions. Certified for

use in ATEX 2/22 zones, this explosion-proof luminaire is particularly resilient thanks to its robust design and is also protected against the most challenging conditions, such as significant dust formation or powerful jets of water. It also features impact-resistant housing and an emergency light function.

Harsh environmental conditions, for example in industrial spaces and halls, demand a lot from the technical equipment in them – the lighting in particular. That's why Zumtobel is launching a new lighting solution that meets all the requirements of challenging environments: the new EXTONA moisture-proof luminaire, which offers reliable light output to certified standards even in the most difficult conditions. This includes effective protection against explosions in accordance with the ATEX guidelines (ATmosphères EXplosives), which relate to environments that could have an explosive atmosphere on an ongoing or short-term basis. A potential source of ignition, such as a luminaire, could trigger a detonation in this type of environment, but that is not the case with EXTONA: as an ATEX-certified moisture-proof luminaire with a maximum surface temperature of 80°C, EXTONA is permitted for use in 2/22 zones. What's more, vapors, gases and dusts in the atmosphere won't affect the luminaire's light quality: with a reduction in luminous flux of L85 after 100,000 hours of use, EXTONA is demonstrably durable and robust, helping to save on costs.

Thanks to its reliable explosion protection, EXTONA is a safe lighting solution that is suitable for all industrial applications and sectors with these types of potential hazards. This includes areas in the automotive industry where petrol is stored or where scrap metal is pressed, where bodywork is painted or where lithium batteries are manufactured. EXTONA also plays to its strengths in power stations – for example in engine rooms and biogas plants, petrol and pellet stores, or wood chip production plants. The metalworking industry is another sector where this luminaire is a perfect match – in any areas where welding, soldering, blasting, sanding or painting take place. The woodworking industry can also benefit from its high degree of explosion protection, for example in areas around saw mills, chippers or paint shops. Last but not least, EXTONA is ideal for the textile and paper processing industries, offering ample explosion-proof light output for the recycling, grinding and shredding of fabric and paper, for example.

**Maximum protection against impacts, dust and water**

As well as its high level of explosion protection, the luminaire also offers outstanding resilience. EXTONA can withstand even heavy impacts and significant mechanical forces, and an IK10 rating means it has the highest possible level of impact resistance. Thanks to its IP66 protection class, this moisture-proof luminaire is also reliably protected against challenging environmental conditions such as penetrating dust or powerful jets of water. In addition, the housing is made from durable polycarbonate with UV stabilization to prevent discoloration. EXTONA can cope with a wide range of temperatures and works as well in cold conditions of up to -20°C as it does in extreme heat of up to 60°C.

As another benefit, the luminaire offers cleverly designed safety features for emergencies and is fitted with an emergency light function as standard, with a single-battery power supply that provides for an operating time of three hours. This means that a reliable light source is guaranteed, even when the unexpected happens, so that enough time and light are available to evacuate a hazardous area in an emergency. Thanks to the DALI protocol, the emergency lighting supply can be seamlessly connected to building management software and can be regularly read out, tested and monitored. The DALI integration enables the luminaire to be controlled individually and in response to current needs within a dynamic digital lighting management system.

**Maximum efficiency paired with optimal luminous efficacy**

EXTONA combines ATEX-certified lighting with optimal luminous efficacy: the moisture-proof luminaire is available with six different luminous flux values from 1,200 lm to 11,000 lm as standard, but can also be upgraded to a version with up to 16,500 lm on customer request – with an efficiency of up to 166 lm/W. This reduces power consumption, lowers operating costs and minimizes $CO_2$ emissions, optimizing the environmental footprint of industrial plants. The luminaire is supplied with a neutral white light color at 4,000 K as standard and offers impressive color rendering of CR180, while the medium-beam light distribution provides optimal illuminance for industrial applications. EXTONA can also be installed in a variety of ways: whether it's mounted on the ceiling, a wall or a pole or suspended with a cable suspension cord or a chain, the luminaire can be optimally adapted for any context and space.

"With EXTONA, we've created a lighting solution that uniquely combines brilliant light quality, high standards of explosion protection, maximum durability and excellent energy efficiency. This means that even in challenging industrial environments we can achieve human-centered light that provides the highest degree of safety and usability as well as creating a pleasant atmosphere to work in. My thanks go to the project team, who have carried out really excellent work", says Felix Breuss, Product Manager for Protected Luminaires at Zumtobel Lighting. ■

## LUXEON HL4X for High Output Applications & Improved Efficiency

https://lumileds.com

Lumileds announced the release of its LUXEON HL4X power LED that delivers the lighting industry's highest output and efficacy; it furthers the ability for lighting manufacturers to standardize their designs around a common footprint and proves that meaningful LED efficacy gains are still possible.

LUXEON HL4X is designed specifically for outdoor and industrial applications such as stadium lights, streetlights, and high bay luminaires, as well as torches and rugged portable devices where the high lumen density, efficacy, robustness, and quality of light are critical. The high-power domed package delivers very high output, excellent

efficacy, color stability, and longevity regardless of the application or environment.

With typical output of 680 lm at 700 mA and typical efficacy exceeding 168 lm/W, LUXEON HL4X offers manufacturers a simple, seamless upgrade for virtually any existing application using a similar 3535 package. Engineers managed the optical design so that existing optics for solutions with 2 $mm^2$ work with the new LED.

**LUXEON HL4X at a Glance**

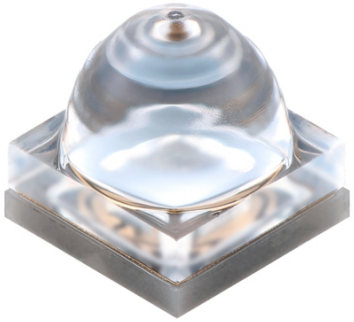
- Industry standard 3535 package with a 3-stripe footprint
- CCT options of 3000K, 4000K, 5000K, 5700K, and 6500K
- CRI options of 70, 80, and 90
- 4A maximum drive current
- Optimized intensity distribution for higher system optical efficiency (no loss of light output below the horizon)
- Unique dome design is optimized to maximize light output within ±130°
- Large thermal pad allows high drive currents and close-packed LEDs

"The features of LUXEON HL4X make it ideal for high-lumen applications such as industrial and stadium lighting," said Noman Rangwala, Head of Product Marketing and Management (L1) at Lumileds, "However, the optical compatibility with many existing 3535 optics makes it possible to replace lower-performing LEDs directly and improve system efficiency by 10 lm/W or more. This will be a game changer." ■

## Toyoda Gosei Develops UV-C LED with World-Class Light Output

www.toyoda-gosei.com

Toyoda Gosei Co., Ltd. has developed deep ultraviolet (UV-C) LEDs with light output that is among the highest in the world. UV-C is used in disinfection as it destroys viral and bacterial DNA structures and inhibits their replication. As an alternative light source for mercury lamps used for disinfection, improved performance of UV-C LEDs has been expected. Sample sales of Toyoda Gosei's high performance LEDs will started internationally in April 2024, to promote their wider use for disinfecting water, air and surface.



Compared with mercury lamps, UV-C LEDs are environmentally-friendly as it is mercury-free, more compact, and have a longer life. These advantages promoted their wide use in devices for disinfecting air and surfaces during the Covid-19 pandemic. Since they differ from lighting LEDs in composition, however, light output has been still limited. For water purification plants and other situations where high disinfection performance is needed, mercury lamps are still used.

Toyoda Gosei has leveraged its expertise in crystallization and design of blue LEDs for lighting, and successfully developed UV-C LEDs that achieve light output at the level of 200 milliwatts with a single chip when driven by a current of 350 milliamperes. Improvement of the LED structure and composition quadrupled the amount of light that can be extracted. Enhanced LED performance including disinfecting capability of about three times higher will expand their applicable areas including a future alternative to mercury lamps, contributing to more hygienic and safer living. ■

## DALI Alliance Launch Test and Certification Specifications for DALI+

www.dali-alliance.org

The DALI Alliance, recognized as the international authority in lighting technology standardization, has unveiled much-anticipated certification details for its wireless specification: DALI+ over Thread.


As lighting specifications increasingly seek smarter, sustainable, and interoperable solutions, DALI+ emerges as a crucial enabler of standardized wireless or IP-based lighting systems. The alliance's collaboration with partners such as Thread Group has resulted in the integration of enhanced security and encryption solutions, ensuring the integrity and confidentiality of data transmission within DALI+ networks.

Key features of DALI+ with Thread include:

- Wireless Mesh Network: Thread creates an Internet Protocol version 6 (IPv6) based wireless mesh network. Off-the-shelf Thread border routers can also be used to connect multiple Thread networks through IP technologies, such as Ethernet or Wi-Fi, allowing a highly scalable lighting control system.
- Extended Addressing: In addition to the standard 64 control gear and 64 control device addresses, DALI+ with Thread IPv6 routing allows almost unlimited addressing capability. The usual DALI broadcast, group and short-addressing methods are included together with IP unicast and multicast capability.
- Interoperability: DALI+ certification includes all the benefits of the existing DALI-2 and D4i certification programs with extensive testing, independent verification, and listing of every certified product in a publicly searchable product database to ensure a high level of product interoperability. Furthermore, DALI+ bridge devices will allow DALI-2 wired devices or systems to connect with and operate with the products in a DALI+ wireless system.
- Device Support: DALI+ supports a wide array of control devices, including occupancy sensors, light sensors, switches, sliders, rotaries, and pushbuttons. Control gear support currently includes LED drivers with the three optional data parts: luminaire data, power and energy, and diagnostics data.

Paul Drosihn, General Manager of the DALI Alliance, expressed enthusiasm about the launch, stating, "This represents a significant advancement in DALI-enabled technology. Our members and users will experience the benefits of enhanced wireless interoperability and strengthened sustainability credentials." Drosihn continues, "Moreover, this milestone underscores our steadfast commitment to driving innovation and nurturing eco-conscious solutions within the industry. By leveraging the potential of DALI technology, we are not only revolutionizing lighting controls but also laying the groundwork for a more sustainable future for generations to come."

Commenting on the collaboration, Klaus Waechter, VP Commercial Buildings at Thread, said, "We are proud to collaborate with the DALI Alliance in utilizing Thread technology in the DALI+ specification. This

partnership underscores our commitment to advancing wireless connectivity and interoperability for commercial grade markets and the lighting industry in general." ■

## Nordic Power Converters Launches Two Versatile Products for LED Lighting

www.npc.lighting

Nordic Power Converters is thrilled to announce two significant additions to our product portfolio: the InviTrack Casambi Gateway and the InviTrack LED Driver with Manual Dimming. Recently showcased at Light + Building 2024 in Frankfurt, these products underscore our commitment to providing smart, efficient lighting solutions that cater to both advanced wireless control systems and desires for simplistic yet high-quality manual lighting control.

InviTrack Casambi Gateway: Advanced Wireless Lighting Control:
The InviTrack Casambi Gateway sets a new standard in lighting control technology, facilitating seamless integration with Casambi wireless systems. This powerful gateway can manage up to 64 DALI devices in up to 8 groups, offering high flexibility and control. Moreover, the gateway simplifies the DALI addressing process, making it easier than ever to configure and customize lighting settings to suit any environment. Being part of the InviTrack family, the InviTrack Casambi gateway is fully integrated into 3-phase track systems from Global, Stucchi, Eutrac, and PowerGear.

Key Features:

- Integrates smoothly with Casambi wireless systems, offering expansive control over lighting settings.
- Controls up to 64 DALI devices in up to 8 groups, enabling comprehensive management of diverse lighting environments.
- Simplifies the DALI addressing process, allowing for easy customization and configuration through the gateway itself.
- Fits all major European 3-phase track systems

InviTrack LED Driver with Manual Dimming: Where Simplicity Meets Excellence
Showcasing our dedication to intuitive lighting solutions, the InviTrack LED Driver with Manual Dimming delivers uncomplicated and direct manual control. This driver simplifies the process of achieving the ideal lighting ambiance, enabling adjustments that are both immediate and precise without relying on digital controllers. Its straightforward operation makes it an excellent choice for settings where simplicity and tactile responsiveness are paramount.

It is an ideal choice for environments like museums and galleries where lighting precision is crucial, but may also find uses in residential or other applications where simple and straightforward lighting control is desired. Finally, the InviTrack LED Driver with Manual Dimming boasts the high-quality performance features of the InviTrack LED driver family, such as a very wide output window, low inrush current, flicker-free light, and smooth dimming capabilities down to 0.1%.

Key Features:

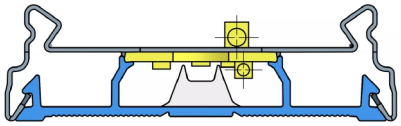
- Manual dimming functionality for easy, intuitive control over lighting levels.
- Ideal for settings requiring precise lighting adjustments, enhancing visual experiences without the need for digital devices.
- Delivers high performance with a wide output window, low inrush current, flicker-free operation, and smooth dimming down to 0.1%.

With these latest product launches, Nordic Power Converters continues to lead in the development of innovative lighting solutions that meet and exceed the expectations of our customers. Whether for specialized applications or broader lighting projects, the InviTrack Casambi Gateway and InviTrack LED Driver with Manual Dimming are designed to transform the way lighting is controlled and experienced. ■

## Optical Components with a Lower Carbon Footprint

www.plexiglas-polymers.com

BWF Profiles uses PLEXIGLAS® proTerra M5 containing recycled material for high-quality optical components in luminaires.



Sustainable luminaire design is a multifaceted standard which can be broken down to the manufacturing process of every single luminaire. Although the use of recycled material is a resource-efficient option, it reaches its limits for lenses and light covers as these require recycled materials with flawless optical properties. One such material is PLEXIGLAS® proTerra M5, a molding compound from Röhm containing recycled polymethyl methacrylate (PMMA).

By making an optical component for the lighting manufacturer RIDI using this material, BWF Profiles, a leading manufacturer of high-quality plastic profiles for the lighting industry, has proven that it is practical for parts such as this. BWF Profiles uses PLEXIGLAS® proTerra M5 to produce a continuous-row lighting system for a concept study on the RIDI LINIA EVO system, which was presented at the leading trade fair Light+ Building 2024 as an example of sustainability.

**Sustainable molding compound with recycled material**
"Our PLEXIGLAS® proTerra M5 molding compound contains up to 30 percent mechanically recycled PMMA from post-industrial sources, which is mixed with new PLEXIGLAS® in a controlled manner. This reduces the material's carbon footprint by 30 percent compared to new material," explained Christian Bitsch, Senior Market Tech Consulting Manager in the Molding Compounds business unit at Röhm GmbH.

**Decision in favor of the circular economy**
Lighting manufacturers and their suppliers strive to produce in an environmentally and climate-friendly manner, as sustainability has become an established market demand. "At BWF Profiles, the processed materials alone account for nearly 80 percent of the company's carbon footprint," says Nico Sonntag, Materials Development Engineer at BWF Profiles. That's why the company places such a lot of value on using resource-efficient materials and handling them sparingly – for example, by wasting as little material as possible when starting the extruder and by returning production waste directly to the internal recycling process.

Florian Bisle, Director Innovation & Development at BWF Profiles, added: "We had discussed possible approaches for the sustainable production of light covers. We rejected the option of procuring mass-balanced material, and instead, devised a solution based on a direct circular economy, which meant that we had to test various recompounded materials." In this case, this refers to reprocessed materials containing post-industrial recycled material.

**"PLEXIGLAS® proTerra M5 impressed us with its optical purity"**
"The prerequisite was that we obtained recycled materials without any inclusions or unwanted black specks. PLEXIGLAS® proTerra M5 convinced us with its high purity," said Bisle. The high-quality PMMA plastic provides ideal conditions for the circular economy because it can be completely recycled time and again while maintaining virtually identical material properties. Its exceptional optical properties are also retained.

"We need a reliable partner that can guarantee consistently high quality. In this respect, we are in good hands with Röhm," Bisle emphasized. "We share a partnership that goes back many years. Many decades ago, BWF Profiles was the first company that processed PLEXIGLAS® molding compounds in its extrusion business. And even today we relish being a pioneer for new projects with the new and sustainable PLEXIGLAS® proTerra."

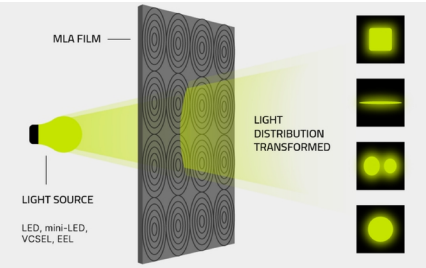
**Coextruded profile with tailored properties**
The optical components for the concept study on the RIDI LINIA EVO continuous-row lighting system contain around 78 percent PLEXIGLAS® proTerra M5. In order to achieve the light and production-related properties that RIDI was looking for, BWF Profiles coextruded the 60-millimeter-wide profile with two PMMA products from Röhm: The centrally positioned TIR lens consists entirely of PLEXIGLAS® proTerra M5. As with other crystal-clear PLEXIGLAS® molding compounds, it possesses exceptionally high light transmission with virtually no absorption of visible light in the material. The profile base, the crosspieces that hold the circuit board in place and the lateral snap-in hooks must withstand high mechanical stresses. Therefore, PLEXIGLAS® Resist with a higher impact resistance is added to the PLEXIGLAS® proTerra M5 used in this segment.

**Strong partnership for innovative, sustainable lighting technology**
The optical quality also impressed the CEO of RIDI Leuchten GmbH, Manfred Diez, and Product Manager Edwin Baran: "The optical components with recycled material meet our stringent quality demands for a sustainable lighting solution. In collaboration with BWF Profiles, our aim is always to produce as sustainably as possible with the highest degree of energy efficiency. Starting from the very first discussions, we focus on designing products that meet the demands of the circular economy." ■

## BrightView's New Display Film Boosts Brightness up to 30%

www.brightviewtechnologies.com

BrightView Technologies, a leading global supplier of Visual Intelligence™ solutions, has announced the launch of its new Polycarbonate Brightness Enhancing Films (BEFs), engineered to increase brightness up to 30% for high-performance display designs. An ideal solution for desktop monitors, laptops, tablets and other custom displays, the unique film stack helps engineering teams achieve advanced optics while ensuring efficiency.




"Innovation in AI chips and other technologies are leading to exciting breakthroughs across many applications, but design engineers must balance these advancements with objectives for optics and power management," said Jennifer Aspell, CEO of BrightView. "BrightView's new BEFs extend our full portfolio of display film solutions designed to support innovators at the forefront of cutting-edge technology development, empowering them to take advantage of the latest solutions with an advanced, efficient display film for optimized visual intelligence."

BrightView's BEFs leverage a high-quality polycarbonate substrate, combined with premiere edge-lit and mini-LED micro lens array (MLA) stacks, to maximize brightness and efficiency. The two-film solution helps increase output from the backlight and minimize power consumption of the display – making it a valuable resource for optical deployment across emerging automotive, augmented reality, virtual reality and aerospace applications, among others. ■

## Nichia Automotive Innovation Center in Germany

www.nichia.co.jp/en/

In a significant move to spearhead the future of automotive lighting design and functions, the world's leading LED manufacturer Nichia announced the launch of the Nichia Automotive Innovation Center located in Aachen, Germany. The newly inaugurated facility marks a pivotal step in the company's ongoing commitment to innovate and deliver enhanced support to customers that have rapidly evolving requirements.

Nichia Automotive Innovation Center's mission is to develop advanced and sustainable lighting solutions such as improvement of road safety, visual comfort and energy efficiency, as well as enhancing the aesthetic appeal and functionality of vehicles by utilizing and combining Nichia's latest technologies. In close partnership with industry leaders, together with the R&D team at Nichia's headquarters in Japan, the Center will accelerate the development of technology breakthroughs and achieve quicker market entry, while consistently prioritizing advances in the quality of light. To support the next generation of automotive lighting solutions, Nichia Automotive Innovation Center contains a wide array of laboratory tools for testing, modeling, monitoring, analysis, and rapid prototyping, among others.

Dr. Ulf Meiners, Managing Director, Nichia Automotive Innovation Center, explains: "The key to unlocking the full potential of automotive lighting lies in collaboration. By working closely with business partners and academia, we will bring groundbreaking solutions to the market faster and more efficiently than ever before. As a result, the Center can rapidly accelerate the pace of innovation. Industry leaders that are ready to redefine automotive lighting standards need to connect with us with great urgency to truly shape the future." ■

DALI® Alliance

# DALI+ with Thread

DALI lighting control plus wireless and IP-based networking

DALI+ THREAD

Find out more about DALI+

www.dali-alliance.org/daliplus

# Lighting the Way Forward – A Comprehensive Look at the CIE's Strategic Vision for the Future of Lighting, Dr. Jennifer VEITCH, President of CIE

**Dr. Jennifer VEITCH**
"Light and lighting research can contribute to 12 of the UN Sustainable Development Goals. Few subject areas can claim such a broad reach."

Photo Credits: © National Research Council of Canada 2019.

In this enlightening interview, Jennifer VEITCH, president of the CIE, shares insights into her extensive career in the lighting industry, beginning from her academic pursuits in environmental psychology to her significant contributions at the National Research Council of Canada. She discusses her deep-rooted connection to lighting, fueled by both familial influences and her early professional engagements. Throughout the interview, she offers an in-depth exploration of the CIE's organizational structure, its pivotal role in advancing lighting science and standards, and the strategic objectives outlined in the recently published CIE Research Strategy. This document aims to enhance the integration of lighting research with global sustainability goals, demonstrating the critical impact of lighting on both human health and environmental well-being.

**https://cie.co.at**

LED professional: **Could you please share your professional journey with us? How did you enter the world of lighting, and ultimately become the President of the CIE?**

**Dr. Jennifer VEITCH:** Early in my university years I encountered environmental psychology, which seeks to understand how our physical surroundings affect us and, in turn, how we affect our physical world. At that same time I worked in the lab of a psychology professor who had an interest in lighting, and I became involved in his research. My father was an indirect influence – he was a professor of interior design, and taught lighting to his students. I'm sure that from him I learned, at an early age, how important lighting is to the spatial experience.

Like many people, once I was "bitten by the lighting bug" I stayed passionate about it. I was fortunate to find a professional home at the National Research Council of Canada right out of my doctoral studies (at the University of Victoria in British Columbia, Canada), and have worked there as a researcher ever since. The first CIE Session after I joined the NRC was 1995 in New Delhi, where I got to know many people who have since become friends and colleagues – and I was persuaded to join my first Technical Committee, TC 6-11. When its Chair had to step down a few years later, I took on that role and led the final work on what became the first consensus publication concerning the effects of light on health (CIE 158:2009), originally published in 2004.

These days, many organizations look to demonstrate the relevance of their research by looking to have it taken up by others, and I quickly came to see the CIE as an important body for translating my research into lighting guidance and recommendations – and equally, as the source of discussions and ideas for new research. I also found that by taking on increasing responsibilities as a leader in the CIE, I learned new skills that transferred back to my daily work. I've served as a TC member, TC Chair, Division Member (for Canada), Division Secretary, Division Director, Vice-President Technical, and now CIE President. Every step has taught me communication and management skills – and always, brought me into contact with interesting, lovely people who have become good friends.

LED professional: **Naturally, many people recognize the name CIE, but it's likely not everyone is aware of what the CIE does for the field of lighting and how the CIE is organized. Would you give us a closer look at the CIE as an organization?**

**Dr. Jennifer VEITCH:** Everyone who is deeply involved in lighting knows that it's a complex topic. Not surprisingly, the CIE is a complex organization. Broadly speaking we have two aspects: one as a collegial organization that promotes knowledge exchange about the science (and to a lesser extent, the art) of light and lighting, and one as an international standards-developing organization. We structure our work into six Divisions, each with responsibility for developing a work program in its scope: Vision and Color; Physical Measurement of Light and Radiation; Interior Environment and Lighting Design; Transportation and Exterior Applications; Photobiology and Photochemistry; Image Technology. Divisions manage the scientific workflow and propose Technical Committees that will develop a publication, usually a technical report or an international standard, that represents an international consensus on that topic. Following a rigorous review and approval process, which involves CIE National Committees spread over six continents, these documents are published by the CIE. CIE events, ranging from scientific conferences (held every two years) to expert symposia, workshops, and tutorials support the technical work by bringing people together to present and to discuss their research.

LED professional: **In this interview, we would like to delve into the recently published CIE Research Strategy and shed more light on this important document. What inspired you to contribute to the CIE Research Strategy, and how does your personal background or interest in lighting influence your work?**

**Dr. Jennifer VEITCH:** I think it's fair to say that light and lighting gets taken for granted among people who haven't yet found the lighting community (by which I mean everyone with a professional interest in light and lighting). Think of how you explain what you do to a neighbor from another industry – I'll bet they ex-

press surprise about our field's technical complexity! This leads many research funders not to prioritize lighting topics. Like all researchers, I've faced this problem and can see how if only our work were better appreciated, and better funded, we could accomplish so much more to improve the lit environment, improve human and ecological health and well-being, and reduce resource use.

About a decade ago, the CIE leadership recognized that we could help the research community by developing a tool to help them to articulate the importance of their research topics, and that in the process we could nudge researchers to focus on topics that our experts judged will support the next generations of lighting guidance and standards. The first CIE Research Strategy was published in 2015, and our program of providing Research Support letters launched not long after.

The latest revision of the Research Strategy, released in 2023, represents a major reorganization of the document, with its most outstanding feature being to connect the research themes with the ways in which the results can support the achievement of the UN Sustainable Development Goals (SDGs). There are 17 SDGs, and light and lighting research can contribute to 12 of them! Few subject areas can claim such a broad reach, and I find that very exciting. It's shaping how I think about my own future research and I hope it will do so for others.


There are 17 UN Sustainable Development Goals (SDGs), and light and lighting research can contribute to 12 of them.

**LED professional: What are the primary goals you aim to achieve with the CIE Research Strategy, and how do you envision these objectives advancing the fields of light and lighting over the next decade?**

**Dr. Jennifer VEITCH:** We hope to inspire researchers whose subject matter falls into our themes, so that they will develop research proposals that address those themes. Without reiterating the whole document here (it's available here: https://cie.co.at/research-strategy), we want the research community to take on projects that address the topics outlined so that we can get on with new and updated guidance. Then, we want research funders – by which I mean national funding agencies, charitable foundations, and industry – to support these projects so that they have the resources to provide us the knowledge we need. Furthermore, we believe that with this added support will come a greater appreciation of the importance of light to life, so that over time, the application of this research will result in better lighting for all.

**LED professional: In what ways do you foresee digitalization transforming metrology science and the lighting industry, and what are the potential challenges and opportunities associated with this transformation?**

**Dr. Jennifer VEITCH:** At the most basic level, making data FAIR (Findable, Accessible, Interoperable, and Reusable) can improve our ability to make use of the tremendous volume of data we can generate, especially as complex computations are the basis of decision-making. For lighting, having clear data-sharing protocols and standardized metadata and file formats for the next generations of simulation software can support lighting design and improve the final outcomes. This is especially important for physiological experiments with people, which are extremely complex and expensive. It is therefore important that these experiments are very well documented, with very detailed metadata, in order to guarantee scientific reproducibility and reusability.

Machine-readable standards could enable faster and more accurate determinations that proposed designs comply with the relevant documents, possibly based on the output of those more accurate simulations. We are in the early days of understanding all the steps needed to implement that vision.

There are lots of challenges to 'digitalization' in its many forms, but the one I see most clearly is in the need for consensus. Interoperability requires agreement among parties, and I have yet to see a machine that can quickly bring everyone to the same conclusion, especially if there might be a commercial interest involved.

**LED professional: Could you elaborate on the importance of inclusive and equitable lighting in today's global context? How does the CIE plan to address diversity, equity, and inclusion in lighting research and standards?**

**Dr. Jennifer VEITCH:** Most of the fundamental research on which present-day lighting is based was conducted using what psychologists call WEIRD samples: "White, Educated, Industrialized, Rich, and Democratic". This limits the generalizability of the results, because we lack information about most of the population. Furthermore, most researchers filter out the extreme scores (outliers) and focus on the average. As we start to explore more diverse samples we learn, for example, that there are inter-individual differences in the spectral sensitivity of the cone photoreceptors that our current models do not take into account, and these mean that determinations of color appearance and photometric quantities based on a single standard observer don't account well for the experiences of many people. When we lack good information, we can't develop guidance that will improve the quality of the lit environment for the people who are left out. That is why we have called in the Research Strategy for diversity and inclusion to be addressed as an overarching theme in all projects. This extends to the composition of research teams, wherever possible, because the evidence is clear that more diverse teams perform better.

**LED professional: How does the CIE Research Strategy align with environmental sustainability goals, particularly in reducing carbon emissions and minimizing light pollution?**

**Dr. Jennifer VEITCH:** Each theme in the Research Strategy is aligned with the UN SDGs, so I invite your readers to see the document for all the details. Our aim is to enable better use of light and lighting in support of the SDGs, and that means being able to deliver the right light in the right place and in the right amount at the right time to meet the user needs for that application without energy wastage and while respecting local ecological conditions. Obtrusive light, as the CIE calls it, is wasted energy as well as causing harm to flora and fauna and our appreciation of the night sky.

Carbon emissions, of course, depend in large part on the energy mix in a given place and time, and this is outside the CIE's scope. What we can do is to provide guidance that reduces lighting energy use, with reduced carbon emissions following from that.

**LED professional: With the decline in the use of incandescent sources and the rise of LED technology, what new challenges arise in the calibration of photometers and spectrometers, and how is the CIE addressing these challenges?**

**Dr. Jennifer VEITCH:** The CIE has published a new reference spectrum for LED photometry, with the intent that LED sources should be developed to realize it. These LED sources would then replace the old incandescent sources for calibration of photometers. Given that measurement error is higher when there is a spectral mismatch between the calibration source and the test source, the shift to the LED reference spectrum should increase measurement quality when the test source is an LED (as is increasingly the case today).

There still remains the problem, however, that LEDs can't presently replace incandescent sources for calibration of spectroradiometers, particularly outside the visible range (i.e. into the ultraviolet and infrared). Here it is important that the relevant research is driven forward, and I am pleased to say that the CIE research strategy has helped to initiate a major international research project (see https://www.ptb.de/epm2022/newstand/home). Sadly, however, with the technological shift towards LEDs, the know-how to manufacture metrological incandescent reference light sources is also declining.

**LED professional: What are the most significant recent discoveries about the impact of lighting on human health and well-being, and how might these findings influence future lighting design and standards?**

**Dr. Jennifer VEITCH:** There are several interesting developments, although it will be a while before they are firmly enough established to merit inclusion in guidance documents or standards. I am intrigued by the evidence that daytime bright light exposure can influence the quality of sleep on the night following. From a building science perspective the mounting evidence that we benefit from bright days points increasingly to the need for more and better daylighting in buildings. I am intrigued by evidence suggesting that although the near-infrared region of the spectrum is not a large contributor to brightness perception, it might have other influences on physiology and behaviour. If these early results hold up to closer scrutiny and replication, it could have a profound effect on light sources and on the quantities we use to describe their efficacy.

Practical examples of two rooms that combine daylight and electric light. Photo Credit: © National Research Council of Canada 2019.

**LED professional: How do you see the role of lighting evolving within the framework of smart cities? What are the key considerations for integrating lighting systems with other urban services?**

**Dr. Jennifer VEITCH:** Smart cities give the potential to understand how places are used, as opposed to how they were planned to be used. This allows designers and planners to better address the real needs of urban dwellers. It gives an understanding of the "life" of the city, how spaces come alive and go to sleep, and how they change throughout the day.

Adaptive spaces can sense occupancy and density of occupancy, adjusting to the needs of the people in the space while minimizing energy usage and reducing ecological impacts. It does, however, come with some risks. For example, a smart lighting system might follow people as they move through the streets, to reduce energy use and environmental consequences. Some individuals might perceive this as spotlighting, and could feel unsafe thinking that the government is controlling their conditions and drawing unwanted attention to them. Others might appreciate this because it draws attention to intruders or bad actors. Smart lighting needs to be implemented sensitively and with an understanding of how people feel within spaces, how they use and move within spaces, not just how they see, and not only to energy considerations.

The number and location of street lighting columns also requires careful attention for smart city lighting installations. The poles today are spaced and arranged to meet the lighting requirements, and smartness is an add-on. If they become smart access points that are spaced and arranged to meet the requirements for the smart city, and street lighting becomes an add-on, lighting design and the quality of our lit spaces will suffer.

**LED professional: The strategy emphasizes the importance of collaboration across various fields. Could you provide examples of interdisciplinary research efforts or partnerships that are crucial for advancing the CIE's strategic objectives?**

**Dr. Jennifer VEITCH:** To take one example, it's becoming clearer that our exterior lighting has unintended effects on other species and light exposure in the biological night isn't all that good for humans, either. However, in urban areas people rely on exterior lighting to travel safely on roads and to feel secure in their neighborhoods. We need to find the balance between these considerations, but to do this we need a better understanding from ecologists, photobiologists, vision scientists, psychologists, illuminating engineers so that light sources, lighting systems, controls, and the design guidance to use them wisely can all come together harmoniously.

**LED professional: What are the main challenges you face in conducting research and developing standards in the rapidly evolving field of lighting technology?**

**Dr. Jennifer VEITCH:** To use an age-old expression: "The more things change, the more things stay the same". As al-

ways, researchers struggle to fund their research. Industry may be doing lots of in-house research, but from the perspective of a non-industry researcher it can be a challenge to obtain the necessary funding for research and to support the time (and travel) to participate in standards development. Research also takes time, and I know that there has always been a disconnect between the speed of research and the desire for speedy standards development. This problem has become even more of a challenge given the rapid development of lighting technologies. Both of those things being said, the changing landscape of lighting together with the advances in understanding the effects of light on people and biological systems makes this a very exciting time, which makes the efforts to overcome these challenges worthwhile.

**LED professional: What advice would you offer to young researchers and professionals entering the field of lighting research? How can they contribute to the goals outlined in the CIE Research Strategy?**

**Dr. Jennifer VEITCH:** First, read the Research Strategy and be amazed and excited at the breadth and depth of a topic many take for granted. Then, choose research topics that derive from the Research Strategy! These are areas that the collective hive mind of the CIE Divisions have identified as fruitful areas. As your work evolves, take advantage of the CIE mechanisms to develop your ideas and obtain feedback. Present at CIE events, join a CIE Research Forum (for those topics that have one), and take part in discussions of your topic. Publish your work in journals where we can find it. As the knowledge of your topic builds, look for CIE technical committees where you can contribute your understanding to consensus reports, guidelines and standards. Finally, help us to make all of this work available to the world, so that light and lighting make their due contributions to the achievement of the UN SDGs.

**LED professional: Beyond the technical and scientific aspects, how do you hope the CIE Research Strategy will influence the broader societal understanding or appreciation of light and lighting?**

**Dr. Jennifer VEITCH:** Anyone reading this is on the inside of the lighting community, but there is work to be done to increase public awareness of how light and lighting contribute to all life on earth. Developing the Research Strategy 2023 revealed to us how strongly connected our work is to the UN SDGs, which are themselves a distillation of societal, even planetary, goals. We can use this to start the conversation with everyone from research funders to regulators, other standards developers, building and infrastructure professionals, public health agencies, and the public at large. As research findings come in, we can use the framework of the Research Strategy themes to deliver updated messages about progress. In turn, it's my hope that we will receive feedback from all of these engaged groups to inform the next edition of the Research Strategy, which we would expect to be in 2027.

**LED professional: Artificial intelligence now permeates many areas of life. How will AI influence the lighting sector, and is the CIE already addressing this topic?**

**Dr. Jennifer VEITCH:** The CIE is not yet addressing the use of AI in lighting. This is not in my personal area of expertise, but I would think that there is good potential for using machine learning approaches to optimize energy use and lighting system operation. I am aware that there are individual researchers or system developers engaged in exploring this possibility, and I have been told that there are algorithms that can be used to choose between luminaires, for example to optimize multiple design parameters. As we add parameters to our recommendations, such tools could help designers to manage the increasing complexity of the task. That said, care and sensitivity to user needs will remain paramount. Just as we have learned that AI training models for facial recognition have inbred biases, it is likely that without careful attention AI-based tools for lighting design will not fulfil the promise of delivering better lighting designs.

We also know that there are measurement devices which use forms of artificial intelligence such as machine learning, look-up databases, and reconstruction techniques to produce a synthesized measurement result. This has implications in terms of measurement uncertainty evaluation and measurement traceability, but also for the users: How do they know if such a device is measuring something "new" and effectively guessing the result? Blind trust in an AI model that has not earned it will not serve us well.

**LED professional: From a personal perspective, what is your vision for the future of lighting?**

**Dr. Jennifer VEITCH:** My vision is for more accessible high-quality lighting for all. The expert group of lighting designers can do great work, but many places do not benefit from their expertise, and almost no one has access to this expertise for lighting in their homes. We need to make it easier for everyone to experience high quality lighting, by which I mean lighting that meets their needs as users while respecting the architectural, environmental, and economic considerations of the context. The CIE can't remove all of the barriers, but we can convene the experts to develop guidance and we can communicate with our collective voices about how to apply it. ■

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For additional information, please visit https://cie.co.at.

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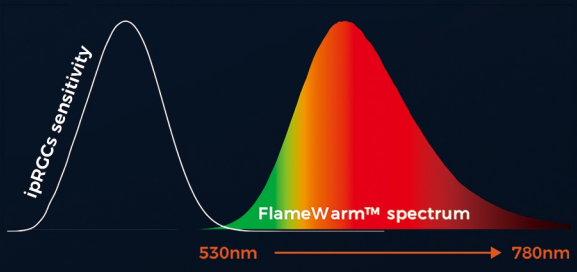


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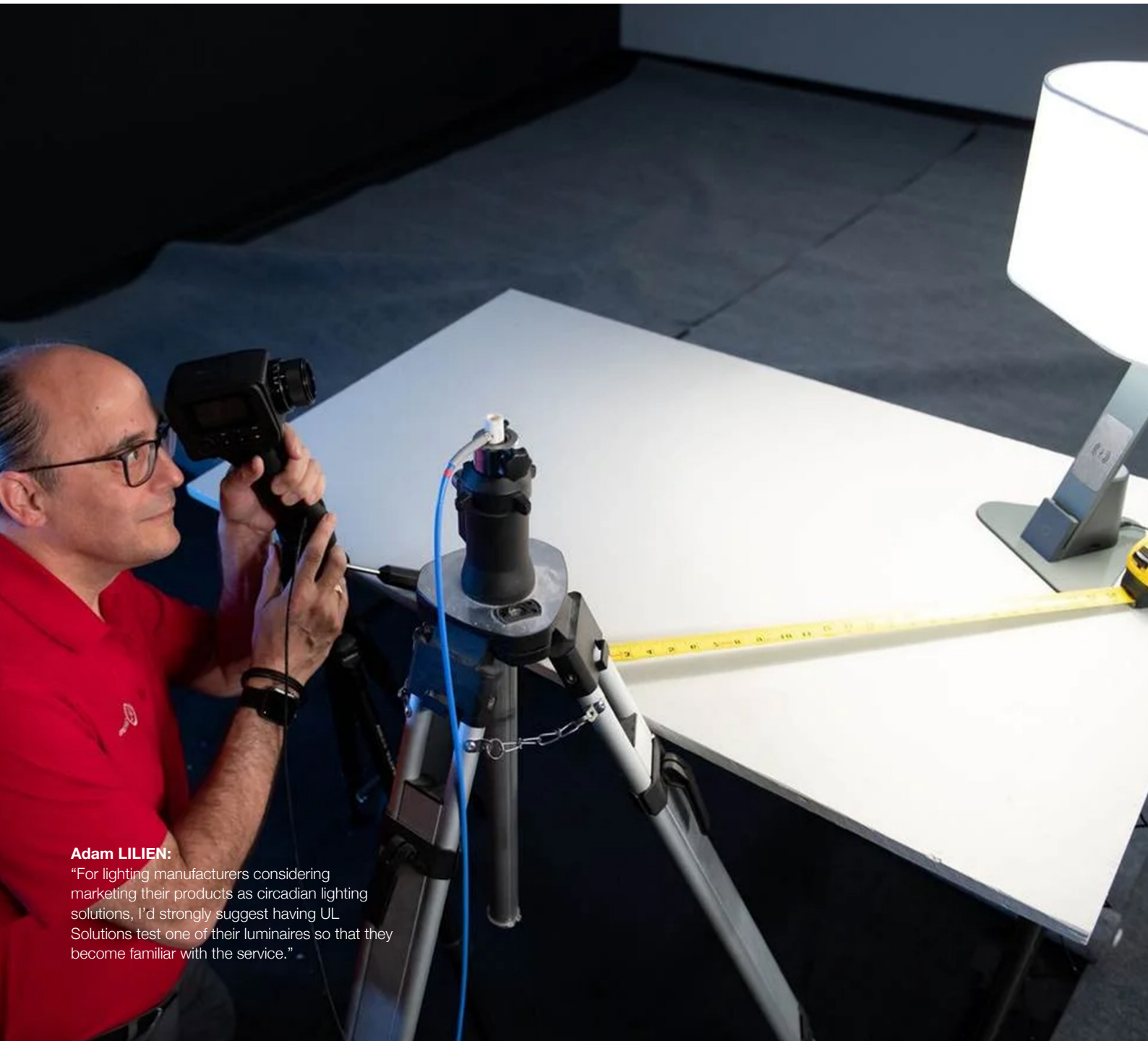
# Circadian Tools Advance the Health and Lighting Market – Adam LILIEN, Global Business Development Manager of Lighting at UL Solutions



**Adam LILIEN:**
"For lighting manufacturers considering marketing their products as circadian lighting solutions, I'd strongly suggest having UL Solutions test one of their luminaires so that they become familiar with the service."

Supporting health for building occupants through indoor lighting has been on the horizon for years. In 2015, industry experts told us that the circadian lighting market would be a multi-billion-dollar business by 2022. Still, there need to be more projects, given the upside of delivering better sleep to the people who live and work in buildings 90% of their lives. In this article, we'll look at what science says, what's required to improve our health, and what tools have been missing. For this purpose, we interviewed Adam Lilien, global business development manager of Lighting at UL Solutions, who has been working to resolve these issues.


LED professional: **We've seen "healthy lighting" as a goal for years, but it doesn't seem to be a movement yet. Why not?**

**Adam LILIEN:** Change takes time. We are moving relatively quickly in the lighting industry, especially in today's discussion. The challenge is that we are not moving as quickly as possible, negatively impacting people's health.

LED professional: **How has UL Solutions approached the issue of accelerating the impact of light on health?**

**Adam LILIEN:** In late 2019, we published the UL Design Guideline 24480 for Promoting Circadian Entrainment with Light for Day-Active People. That guideline gave lighting designers the "how to" for delivering healthy spaces. The document tells the lighting designer what to look for in a luminaire. For example, looking at the horizontal and vertical distributions is essential, as is the spectral power distribution (SPD). The document also explains the science behind these minimal requirements so that the lighting designer becomes aware of the laboratory and field studies behind the document. My participation in developing the document was to pull out and codify the six steps a lighting designer needs to follow to achieve the design goals. We called this the "Quick Guide." The document helped educate and answer all the lighting design community's questions.

We also spoke at conferences, provided webinars, published on social media, and provided details on our website. Then it was the industry's job to make the change. However, we kept hearing the same things: "Make this easy so we can use it." That's when we started to ask ourselves, "What's needed to make designing healthy spaces easier?"

It took some time, but in the end, we came up with several tools that we've launched to accelerate the adoption of healthy spaces in buildings.

LED professional: **You mentioned the tools that you've launched. Could you describe them and address who they are designed to help?**

**Adam LILIEN:** What UL Solutions developed is a service for lighting manufacturers to let the lighting designers know the circadian performance of their luminaires. We report the circadian score based on three published calculation methods:

- The WELL Building Standard, based on equivalent melanopic lux (EML)
- UL Design Guideline 24480, based on circadian stimulus (CS)
- DIN/TechSpec (TS) 67600, based on melanopic equivalent daylight illuminance (m-EDI)

As this score measures the "non-visual" performance of light hitting the vertical plane of the eye, it was totally different from anything that existed. With this score, the lighting designers start their design process knowing they have selected the right products. We call the laboratory results the circadian luminaire score.

The second is a service that informs the building owner of the current score of circadian lighting in their building. This is a service where UL Solutions comes to your facility, collects data, and produces a floor plan that tells the lighting designer and space planner where light is "delivering the desired design goal" and where the space is "below goal."

With this tool, information is available to understand the space and resolve the issues that are not visible. We call this the Circadian Field Measurement Service.

LED professional: **Can you share how the calculations are made for the circadian models?**

**Adam LILIEN:** Here is the most complicated calculation: the CS calculation that is part of UL DG 24480 and is found on page 46 of the document. The following equation defines CS:

$$CS = 0.7 * \left(1 - \frac{1}{1 + (\frac{CL_A}{355.7})^{1.1026}}\right)$$

Perhaps it's clear why the lighting designers asked us to make this "simple."

LED professional: **How do these services work? Are they available now?**

**Adam LILIEN:** Yes. In fact, both of these services launched, and we are providing test results for lighting manufacturers, lighting designers, property owners, and audiences we did not initially expect.

**LED professional: Let's discuss the first service. How does the Circadian Luminaire Score work?**

**Adam LILIEN:** For lighting manufacturers, our circadian luminaire laboratory in Allentown, Pennsylvania (USA), measures a single luminaire, capturing the photons entering the eye at the vertical plane. To make the data useful, we measure each luminaire type similarly. For example, each recessed ceiling troffer is placed in the same spot in the ceiling; each wall sconce is in the same location; and each desk lamp is measured. Over nine luminaire types are tested; we define more with every request. We then use the calculation methods published by the three working committees:

- WELL Building Standard V2, based on EML
- UL Design Guideline 24480, based on CS
- European DIN/TechSpec 67600, based on m-EDI

This generates the CS of the luminaire. We also captured the wattage draw the luminaire was using. The luminaire manufacturer receives their data in a UL Solutions letter report. After delivering the letter reports, the lighting manufacturers requested that we develop a way to promote their products to the lighting designer community. They felt an independent third party was better positioned to be the trusted messenger.

Fortunately, we have the answer and are developing a customized search template within UL Product iQ®. This online database currently serves as the point of reference for millions of users who need UL Certification information (see **Figure 1**).

With the new Circadian search template within Product iQ, which we developed in response to the manufacturer's request and is now launched, a lighting designer will come to the site and use our powerful parametric search tools to discover which product is suitable for their upcoming project. For example, first, they select the category of luminaire they are looking for, such as a troffer, pendant, wall sconce, floor lamp, desk lamp, or even a chandelier. Then, they sort the products with the high score at the top based on the parameters of their design goal; for example, EML if they are designing for WELL Building Standard points, m-EDI if their project requires the European lighting goal, or CS if the design requirements are seeking those goals. Access to view Product iQ requires the one-time setup of a complimentary account, with optional paid features available. Once the account is set up, customers can go directly to the circadian features at UL.com/CircadianiQ.

**LED professional: You said the Circadian Luminaire Score service has launched. What are you learning?**

**Adam LILIEN:** We've delivered circadian scores for numerous luminaires, and manufacturers can now start using the circadian search function on Product iQ. See **Figure 1**. We were also surprised, as one of the first customers was not a luminaire manufacturer but a manufacturer of a reflective surface in a building. Their products have different reflective scores, and they wanted to verify that the brighter surface increased the circadian score of the space. We are also discussing expanding the service to include other reflective surfaces such as paints, flooring, ceilings, and furniture.

**LED professional: Moving to the second service: How does the Circadian Field Measurement Service work?**

**Adam LILIEN:** We come to your facility anywhere in the world, collect the data and deliver a floor plan indicating the circadian scores for each space.

The reason we created this service is that we heard that, for larger spaces, the work needed to be simplified. Let me give you an example. If I'm a lighting designer asked to measure the current circadian score of a space for a customer — either because of a retrofit and we're keeping the lighting, or the project has just finished, and we want to know if we achieved the correct lighting levels — I can pull out my lux meter and take a few dozen readings. That's good for smaller spaces such as a small office or a conference room, but what about an ample office space, a school, or even a hospital complex?

Due to the complexity and the potential expense, UL Solutions developed a data collection method where we can capture thousands of readings in one or two hours. We provide the customer with a detailed floor plan, as illustrated in **Figure 2**, indicating the CS of each space, where:

- GREEN = above goal
- YELLOW = slightly below goal
- RED = significantly below goal

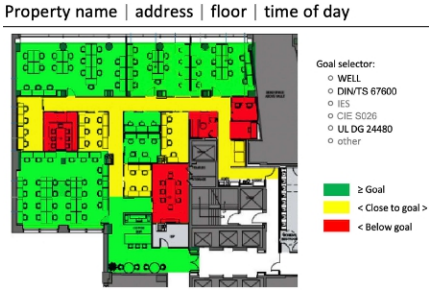



Figure 2: Circadian Field Measurement. After UL Solutions collects the data at the site, the lighting designer can select the desired calculation method: EML (WELL Building Standard), m-EDI (DIN/TS 67600), or CS (UL DG 24480).

A lighting designer and space planner will now know what they want to alter if anything. We also developed the Marketing Claim Verification about Verified Space for Promoting Circadian Entrainment with Light so that the property owner or the business occupying the space can communicate the results they achieved to the public. After UL Solutions provides the Circadian Field Measurement Service, the UL Mark reports the average space score, whether it's a conference room, a floor or a building (see below).


**LED professional: How is the market response? What are you seeing?**

**Adam LILIEN:** We've delivered this service to one of the largest real estate owners in the world and to a mid-sized architect in Ohio with global customers. In both cases, the customers have told us that this solves a problem they did not realize they had. Although they are leaders in delivering high-quality lighting for visual acuity and comfort at energy-conscious levels, they did not anticipate being able to rate an ample space for its circadian health score. Real estate owners want to offer circadian lighting to get

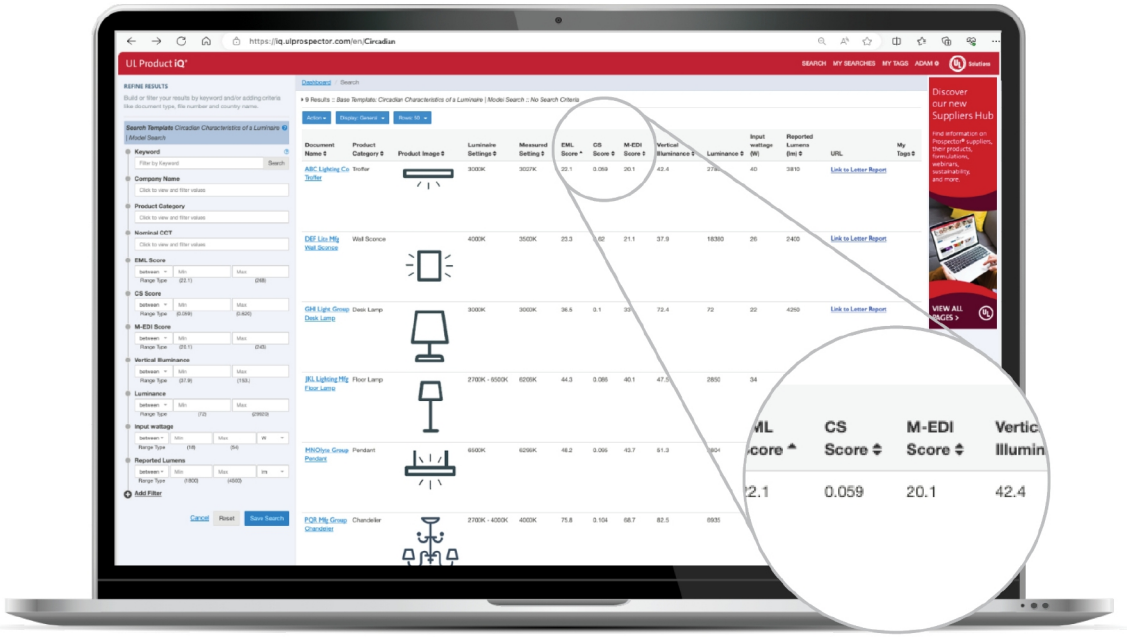



Figure 1: Circadian Product iQ®, UL Solutions' online search directory for products, including luminaires tested by UL Solutions for their circadian score.

businesses to sign a multi-year lease. By offering this solution as a tenant improvement, they don't even pay for the service, as the lighting and controls innovation is applied to the tenant improvement budget. The prospective tenant wants the circadian lighting improvement so that they can tell their employees that they work for a company that is attentive to occupants' health. They also use health improvements to recruit top-tier employees.

Architecture firms want to offer their customers science-based design that improves the health of the building occupants. While the building retrofit they designed may have delivered excellent results, we have discovered that workers in the space could undo the design. As in the example from a recent customer, some of the offices in RED scored significantly below the design goal of CS $\geq 0.3$, even though they were adjacent to GREEN offices that scored above the goal. Further analysis revealed that the lower score was due to the occupant dimming the lights, altering the sensitivity of the occupancy sensor, and closing the window blinds. As a result, they are considering UL Solutions to deliver education to the office workers so that they better understand how the office was designed to deliver the "bright day" signal that is necessary to entrain (synchronize) the 24.2-hour human circadian rhythm to the natural cycle of a day (24.0 hours). In essence, they are modifying their circadian lighting design.

**LED professional: What would you do next if you were the lighting manufacturer?**

**Adam LILIEN:** For a lighting manufacturer considering marketing their products as a circadian lighting solution, I'd strongly suggest having UL Solutions test one of their luminaires so that they become familiar with the service. Once tested, lighting designers can find the manufacturer's product with the score and consider specifying the product on their next project.

**LED professional: Is there any additional benefit for a manufacturer with a circadian lighting solution?**

**Adam LILIEN:** Imagine a manufacturer getting specified in a project. That project may be 6 months out, 12 months out, or even 18 months out. While all projects have a risk of the contractor "value engineering" the product at the last moment, when the project results are designed for a healthy outcome, value engineering won't be an option. Lighting manufacturers call this a "spec lock;" their product will be locked into the final solution.

**LED professional: How did UL Solutions get started on this adventure?**

**Adam LILIEN:** UL Solutions' involvement started back in 2018 when Mark Rea of the Lighting Research Center at Rensselaer Polytechnic Institute (New York, USA) came to us. He had the idea to explore a much-needed circadian approach considering a different set of parameters than the other methods.

With UL Standards & Engagement managing the process, the Industry Task Group worked for 18 months to define the goal, discuss the science, and write a paper.

The industry had a lot to say. UL Standards & Engagement published the proposed paper twice for public comment, and we even reached out to other countries to collect other scientific responses for consideration. Only after all 350 responses were addressed did UL Standards & Engagement consider publishing the paper. In November of 2019, the UL DG 24480 paper was published.

**LED professional: Why UL Solutions?**

**Adam LILIEN:** With our deep expertise in circadian-effective lighting, it makes sense that we continue on our mission to promote safer, more secure and sustainable living and working environments for people through the application of science. ■

For additional information, please visit **UL.com/circadian**.

# Environmental Impacts of LED Luminaires, Recycling Practices, and Recommendations for a More Sustainable Lighting Industry

RESEARCH PROJECT SUMATRA
Dr. Sebastian KNOCHE[1], Researcher at TRILUX and
Dipl.-Ing. Marina PROSKE[2], Researcher at Fraunhofer IZM

**We are surrounded by luminaires and artificial light almost everywhere. The costs are correspondingly high: 13% of the German electricity consumption is used for lighting. This is associated with high greenhouse gas emissions. And our life cycle assessments show that the resource consumption for luminaires is of similar relevance as the greenhouse gas emissions.**
**Life cycle assessments were conducted for a selection of LED luminaires. The results show the potential for making lighting quantitatively more sustainable. If the development of an LED luminaire is guided by life cycle assessments, this potential can be exploited in the best possible way.**
**We also investigated state-of-the-art recycling processes and assessed the realistic recyclability of luminaires. Here, too, we found potential for improvement. These cannot be exploited through improved product design alone, but require a coordinated approach between manufacturers and recyclers for the simultaneous improvement of product design and recycling processes.**

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## Introduction

"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs." This definition of sustainability by the United Nations dates back to 1987 [1]. In essence, this means to act in a way that we can continue doing, basically, forever.

In the research project SUMATRA (**Su**stainable **Mat**erials in Future Luminaire Designs – from **R**ecycling back to **A**pplication), the aim is to do things quantitatively, and not just have a qualitative discussion. To this end, we use environmental Life Cycle Assessments (LCAs). In a life cycle assessment, the environmental impacts that arise over the entire life cycle of a luminaire are measured in various environmental impact categories. This enables quantitative comparisons to be made between different product designs, so that it can be precisely stated whether variant A or variant B causes the lower environmental impact for providing the same benefit. However, it is not possible to make a statement on the absolute achievement of sustainability, as this would require a comparison of the determined environmental impacts of a luminaire with a maximum level that is considered acceptable. This maximum level, called "Safe Operating Space" in the scientific literature of Planetary Boundaries [2,3,4], is difficult to determine for a single luminaire.

## Background on Life Cycle Assessments

The following environmental impact categories are considered in our LCAs:

- **ADP elements** (Abiotic depletion potential of the elements): Utilization of resources (minerals, metal ores) that are limited on earth.
- **ADP fossil** (Abiotic depletion potential of the fossils): Consumption of fossil raw materials (oil, coal, gas), which are finite on earth.
- **GWP** (Global Warming Potential): Emission of greenhouse gases, measured in kg $CO_2$ equivalent.
- **Toxicities** (Fresh Water / Marine / Terrestrial / Human): Release of toxic substances.
- **AP** (Acidification potential): Emission of substances such as sulfur dioxide, which cause acid rain, for example.
- **EP** (Eutrophication Potential): Water bodies being enriched with nutrients (e.g. phosphates); which has adverse effects such as algal blooms, for example.
- **ODP** (Ozone Depletion Potential): Depletion of the ozone layer in the stratosphere (which is our natural UV-C blocker on earth).
- **POCP** (Photochemical Ozone Creation): Creation of ozone near the ground, which is highly reactive and has adverse health effects when inhaled.

**The SUMATRA Consortium**
The SUMATRA research consortium consisted of:

- TRILUX GmbH & Co. KG:
  Dr. Sebastian Knoche, Horst Rudolph, Sonja Beckmann, Gregor Grote-Schulte, Felix Bruchhage, Katrin Discher, Torben Tillmann
- Inventronics GmbH:
  Jürgen Schwarz, Markus Ziegler, Peter Kulf, Bernhard Orben, Markus Heckmann, Reinhard Lecheler
- Interzero Circular Solutions Germany GmbH:
  Carla Krätz, Torben Kabbe
- Fraunhofer-Institut für Zuverlässigkeit und Mikrointegration (IZM):
  Marina Proske, Jana Rückschloss, Otmar Deubzer
- Associated partner Kardorff Ingenieure Lichtplanung GmbH:
  Gabriele von Kardorff

The research project was conducted from June 2021 to September 2023 and received funding from the German Federal Ministry for Economic Affairs and Climate Action. The responsibility for the content of this publication lies with the authors.

Part of the Sumatra team: Klaus Röwekamp, Torben Kabbe, Marina Proske, Peter Kulf, Sonja Beckmann, Sebastian Knoche, Carla Krätz, Katrin Discher, Markus Ziegler, Gregor Groteschulte, Boris Safner, Bernhard Orben, and Jürgen Schwarz (left to right).

SUMATRA

Supported by:
Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

However, in the first indicative life cycle assessments, we found that most impact categories are very similarly distributed and about 95% of them originate from the electricity consumption in the use phase. It is therefore sufficient to select one representative for these impact categories. Our choice is to focus on the **Global Warming Potential (GWP)**. The GWP can be reduced directly by increasing energy efficiency.

A second metric that is in the focus of our considerations is the **Abiotic Depletion Potential of the elements (ADPe)**. In contrast to the GWP, large contributions occur in the production phase of the luminaire due to the materials used. The ADP is therefore related to **material efficiency**. This complements the aspect mentioned first, (GWP / energy efficiency) in a meaningful way.

## Climate Change

There is a broad consensus among scientists that climate change is extremely important for our life on earth, as the reports of the IPCC (Intergovernmental Panel on Climate Change) and their broad authorship show [5]. **Figure 1** shows the evolution of the global mean surface temperature over the past 24,000 years. Large differences are visible; but the last 10,000 years have been in a very stable condition with variances of just $\pm 0.5\,^{\circ}C$ [6]. This epoch in earth's history is called **Holocene**. Agriculture and advanced civilizations developed during this epoch, and it is considered the reference point of a desirable planet [3].

It is well known that global warming is mainly driven by human activities: emission of greenhouse gases, primarily $CO_2$ from the burning of fossil fuels [7]. Other greenhouse gases, like methane, also contribute. These other greenhouse gases are converted to their **$CO_2$ equivalent** [8], i.e. to the amount of $CO_2$ emissions that would give the same global warming effect. All greenhouse gas emissions are then aggregated in an LCA to determine the global warming potential, measured in kg $CO_2$ equivalent.

## Abiotic Resource Use

Humans extract raw materials (chemical elements and compounds) that are stored in the earth's crust, and use them to build things that have a function for them. This approach can be in conflict with the principle of sustainability, as resources are limited and non-renewable, i.e. they are not continuously produced in the earth.

In an LCA, the metric for measuring abiotic resource consumption is the **Abiotic**

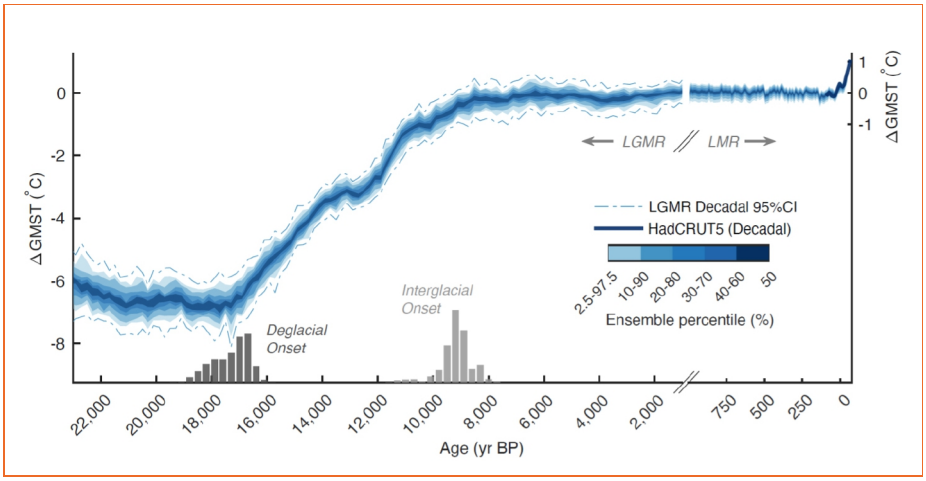


Figure 1: Global Mean Surface Temperature (GMST) change over the last 24,000 years, reconstructed from proxies (blue areas) and temperature measurements (line) [5].

**Depletion Potential of the Elements** [9,10,11]. All abiotic resources used during the life cycle of a product are assigned a weighting factor. This weighting factor describes the scarcity of a resource and is calculated from the total quantity *R* in the earth's crust ("ultimate reserve", in kg) and the current extraction rate *DR* (in kg/year).

For a resource $i$ it reads:

$$\mathrm{ADP}_i = \frac{DR_i/R_i^2}{DR_{\mathrm{ref}}/R_{\mathrm{ref}}^2} \qquad (1)$$

The reference element is antimony (chemical symbol Sb). Thus, the unit for the Abiotic Depletion Potential of the elements is **kg Sb equivalent**.

The weighting factors differ by many orders of magnitude. For example, aluminum, the third most common element in the earth's crust, has a weighting factor of $\mathrm{ADP}_{Al} = 1.09 \times 10^{-9}$ kg Sb–eq./kg. In contrast, gold has a weighting factor of $\mathrm{ADP}_{Au} = 52$ kg Sb–eq./kg, see reference [9].

## Life Cycle Assessment Results

We performed LCAs for eight luminaires of various types produced for professional applications. They have lifetimes (declared by the manufacturer) of 50,000–100,000 h, luminous fluxes between 2,200 lm and 26,700 lm and efficacies between 110 lm/W and 179 lm/W.

Some of them are dimmable and can be controlled by means of the DALI protocol. However, the use phase for all of them was modelled as a constant operation at 100% dimming level over the full lifetime. We calculated with a static electricity mix (Germany 2019).

Background data was taken from the Sphera LCA for experts® database.

Packaging, transport to the customer and the end-of-life treatment have been considered, and we found them to be of minor relevance. For the sake of clarity, they are omitted in the following presentation of the results and analysis of hotspots.

### Portfolio Overview

**Figure 2** shows the results of the life cycle assessment. Let us focus our attention on the absolute values (upper row of diagrams) first.

The global warming potential ranges between 470 kg and 5,000 kg $CO_2$-equivalent. Strikingly, the share of the production phase is very low, only between 1% and 5%. Included here is the complete supply chain up to the raw material mining. The vast majority of greenhouse gas emissions occurs during the use phase, i.e. in order to produce the electricity consumed by the luminaire.

In the diagram on the right hand side, it is discernible that the abiotic depletion potential is dominated by the production phase; more specifically by the electronic components (LED module, control gear, wiring). Optics (mostly made from transparent plastics like PMMA or PC) and housings (mostly steel or aluminum) have only small contributions. From the abiotic resource perspective, it seems that the large amounts of steel or aluminum in a housing have less impact than the small amounts of copper or tiny amounts of precious metals in the electronics. There is also a contribution of the use phase to the abiotic depletion potential. This comes from the electricity consumption, not from spare parts. Electricity generation also consumes abiotic resources, for building infrastructure, power plants, solar panels, and so on.

In both impact categories, the high-bay luminaire stands out in particular. In terms of global warming potential, this is mainly due to the high power and in terms of abiotic resource consumption due to the high number of LEDs. But that results in a lot of light (26,700 lm and 70,000 h lifetime).

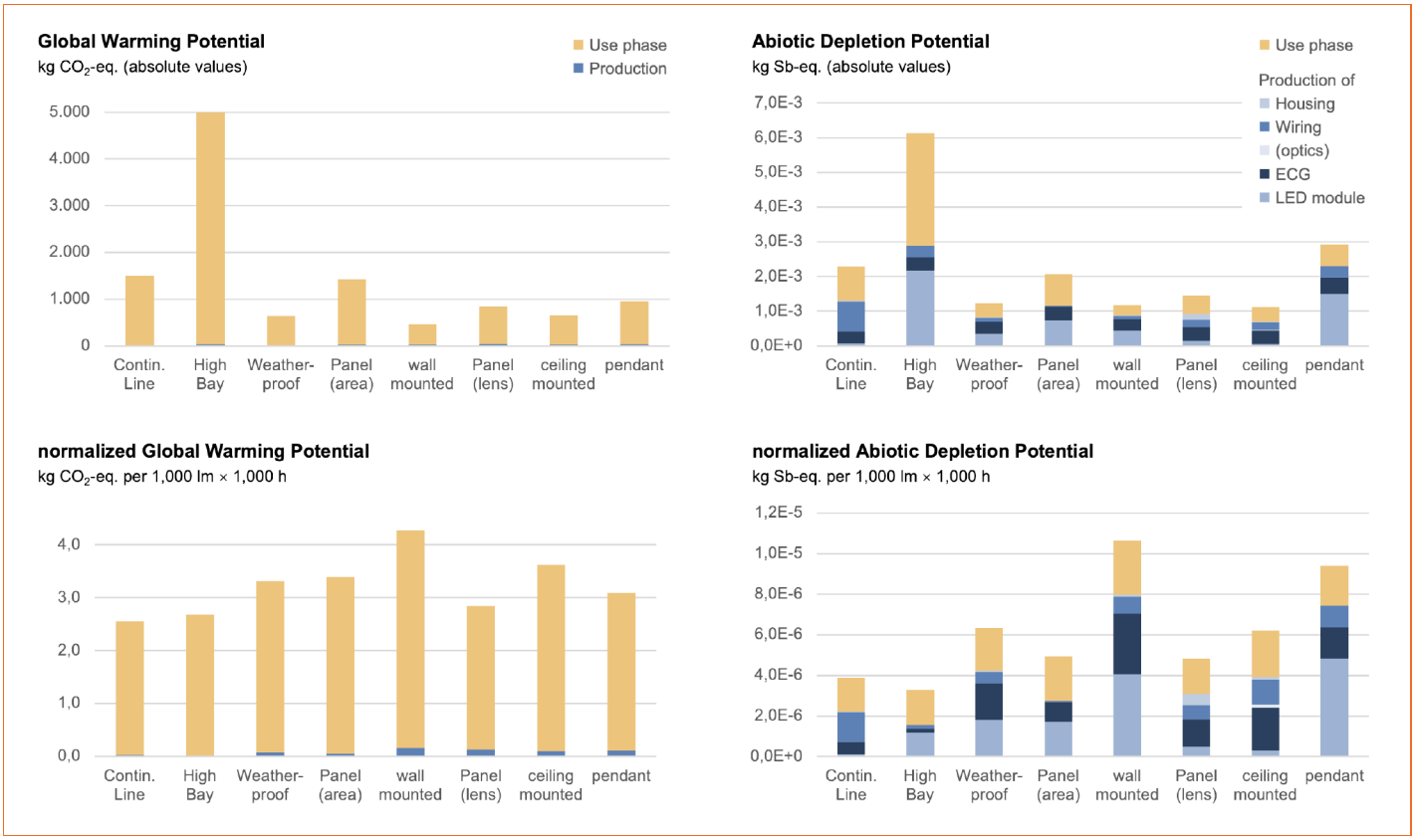


Figure 2: Overview of the Life Cycle Assessment results. The upper row shows the absolute values of the environmental impacts; the lower row shows the environmental impacts normalized to equal flux of 1,000 lm and equal use time of 1,000 h.


 

Therefore, in addition to the absolute representation, standardized representations for identical luminous flux and identical lifetime are also very useful. For this functional unit, we chose 1,000 lm and 1,000 h of operation. The results are shown in the lower row of **Figure 6**.

In this representation, the high-bay luminaire appears relatively sustainable compared with other luminaire architectures. Now the wall-mounted luminaire has the highest impacts in both categories. The wall-mounted luminaire consists of a large LED module (300 mm in diameter) and a big opal cover. Its luminous flux is relatively low (2,200 lm) and so is its luminous efficacy (110 lm/W). This explains the relatively large environmental impacts per 1,000 lm and 1,000 h.

It may be useful to deduce an "average" luminaire from the results, for example, to get a rough estimate of the environmental impacts of lighting in a complete building when no detailed data is available, or to start building an intuitive understanding of luminaire LCAs. As the selected luminaires are not representative of all existing LED luminaires, an exact calculation of the mean value makes little sense. In light of the unavoidable inaccuracy, the "smoothest" values possible are therefore selected, see **Table 1**.

| | |
|---|---|
| GWP | 3 kg $CO_2$–eq. |
| ADP | $6 \times 10^{-6}$ kg Sb–eq. |

Table 1: Estimated average environmental impacts of professional lighting per 1,000 lm · 1,000 h.

An average breakdown of the environmental impacts to the different phases and components is shown in **Figure 3**.

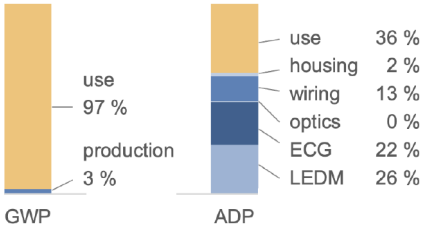


Figure 3: Average breakdown of global warming potential (left) and abiotic depletion potential (right) for a professional LED luminaire.

It is an intriguing question, whether the global warming potential or abiotic depletion potential caused by a luminaire is "more important". Obviously, both metrics use different units and cannot be compared directly. In fact, they describe completely different effects, and any comparison is always subjective. However, a comparison with normalization factors (NF) provides a first indication. The normalization factors are recommended by the Joint Research Centre (JRC) of the European Commission for the evaluation of environmental footprints and describe the global environmental impact of all human activities (determined for 2010), per capita **[12]**.

The comparison made in **Table 2** shows that the climate change potential of an LED luminaire has a higher share of the normalization factor (13%) than the abiotic resource consumption (3%). However, the proportions are of a similar order of magnitude – LCA results often show much more drastic differences. We therefore conclude that both environmental impact categories are equally relevant and that the eco-design of LED luminaires should aim to reduce both environmental impacts.

| | Luminaire | NF | Ratio |
|---|---|---|---|
| **GWP** [kg $CO_2$–eq.] | 1,000 | 7,550 | 13% |
| **ADP** [kg Sb–eq.] | 2 | 63.3 | 3% |

Table 2: Comparison of average environmental impacts for one luminaire with the normalization factor NF.

## Detail: LED-Module

As the portfolio overview (**Figure 2**) shows, the LED module can be the largest contribution to the abiotic depletion potential. The LCA of an LED module depends on three factors: The surface area of the printed circuit board (PCB), the type of LEDs, and their amount.

The results for exemplary LED modules are shown in **Figure 4**. A distinction is made between different LED types (flip chip / bond wire) and two PCB layouts either linear (71.9 cm x 2.3 cm, equipped with 96 LEDs) or large area (33.6 cm in diameter, equipped with 64 LEDs). The four possible combinations lead to significantly different environmental impacts.

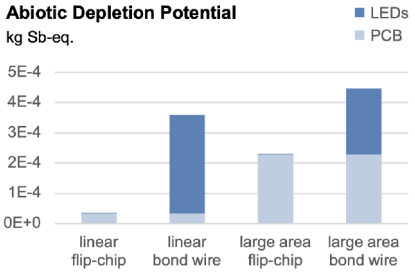


Figure 4: Abiotic Depletion Potential for LED modules of different geometry and with different LED type.

Thus the analysis includes two LED types that may require more explanation. In traditional LED architectures, bond wires, that are made from a gold alloy, are used to contact the emitter chip. More recently, LEDs with flip-chip technology have been introduced to the market. In them, the emitter chip is contacted by solder bumps from below, thus saving the gold for the bond wire. See **Figure 5** for a microscopy image of the two LED types.

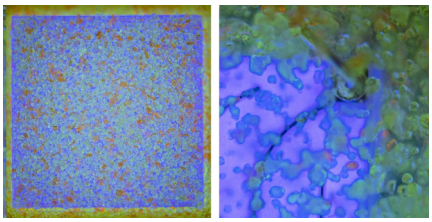

Figure 5: Flip-chip LED on the left and LED with bond wire on the right.

A comparison of the scenarios with and without bond wire in **Figure 4** shows that almost the entire abiotic resource consumption of LEDs is caused by the bond wire. Materials for the chip (e.g. gallium) or for the phosphors (e.g. rare earth elements) appear to play a minor role.

The following conclusion on sustainable LED module design can be drawn:

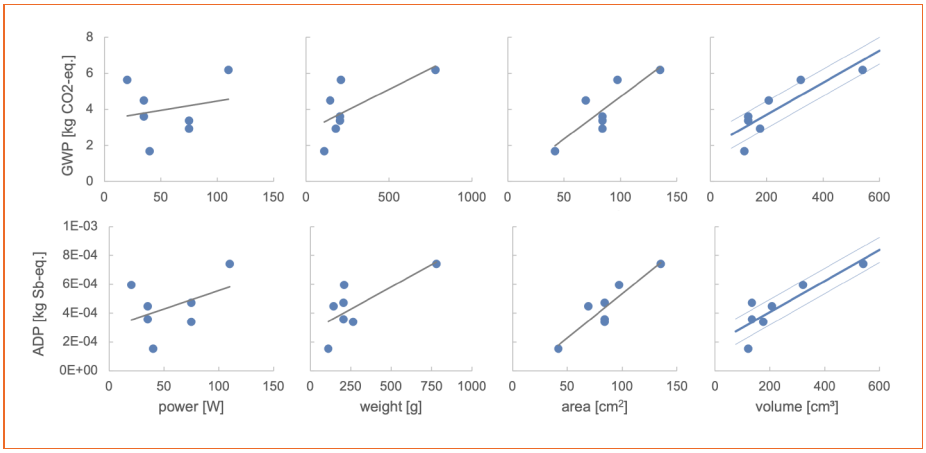


Figure 6: Correlation of the global warming potential (top row) and abiotic depletion potential (bottom row) for the production of an ECG with its power, weight, area and volume.

- Flip-chip LEDs have a significantly lower abiotic resource consumption than LEDs with bonding wire and are therefore preferable.
- The surface area of the LED module is relevant and should be kept as small as possible.

## Detail: Electronic Control Gear

The electronic control gear (ECG) of a luminaire has a complex structure and consists of a printed circuit board with a large number of electronic components. A proper life cycle assessment is only possible if the bill of materials is available. In the SUMATRA project, this was the case by the close collaboration of the consortium.

In the portfolio overview (**Figure 2**), we can see that the production of the ECG often has a major impact on the abiotic depletion potential. What are the driving factors behind this result?

**Figure 7** shows the result for different series of ECGs. Within the same series (connected by blue lines), we find that the ADP increases only slightly with increasing nominal output power. A comparison of a dimmable and a switchable ECG shows that the switchable ECG consumes around 30% less resources (▲ → △). We also assessed an ECG with safety extra low voltage (SELV). Due to the additional insulation stages in the internal structure, it has a slightly higher abiotic resource consumption than comparable non-SELV devices, the difference is approximately 25% (▲ → ◆).

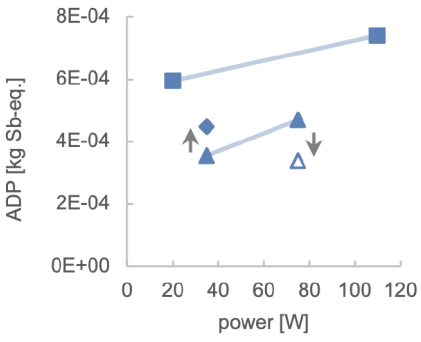


Figure 7: Abiotic depletion potential for the production of different ECGs. Outdoor devices (■), dimmable indoor devices with a linear form factor (▲), non-dimmable device (△) and a device with safety extra-low voltage (◆) were investigated.

Since the variance among commercially available ECGs is very large, a further generalization of the results is desirable in order to estimate the environmental impacts for the production of an unknown ECG. To this end, we analyzed whether the environmental impacts correlate with various parameters that are usually part of the data sheet. The results are shown in **Figure 6**.

It can be seen that the environmental impact does not correlate with the nominal output power; other factors appear to be more important. There is also no strong correlation with weight, as the ECG mass is driven by the housing, potting or heavy capacitors, whereas the environmental impacts are driven by the small, but complex, microelectronics components. The correlations with area and volume are reasonable and can be used for a simple linear model. For electronics, scaling with the base area is often chosen. In our case, however, we use volume as a parameter for the final model. For an otherwise unknown device, the values for GWP and ADP can be estimated based on the volume $V$ (in $\mathrm{cm}^3$) of the ECG as follows:

$$\mathrm{GWP} = V \cdot 0.0089\,\mathrm{kg\ CO_2{-}eq./cm^3} + 1.94\,\mathrm{kg\ CO_2{-}eq.} \quad (2)$$

$$\mathrm{ADP} = V \cdot 1.1 \times 10^{-6}\,\mathrm{kg\ Sb{-}eq./cm^3} + 1.9 \times 10^{-4}\,\mathrm{kg\ Sb{-}eq.} \quad (3)$$

This results in root-mean-square deviations of $\pm 0.5\,\mathrm{kg\ CO_2{-}eq.}$ and $\pm 8.8 \times 10^{-5}\,\mathrm{kg\ Sb{-}eq.}$ respectively, between the regression line and the data points (see thin lines in **Figure 6**).

## Detail: Use Phase

For the use phase of the luminaire, we consider an operation at 100% dimming level over the lifetime of the luminaire. Repair and maintenance are not taken into account, since all the luminaires are designed to work for their entire lifetime without any replacement of ECG or LED module.

Calculation of the baseline scenario of the use phase is straightforward: Take the total electrical energy consumed (in kWh), and multiply it by the emission factors (kg $CO_2$–eq. per kWh and kg Sb–eq. per kWh, respectively). Publicly available emission factors for the grid mix in Germany can be found in reference **[13]**, for example, but only for GWP. In the SUMATRA project, however, we stick to the values included in the Sphera® database, which we cannot disclose here.

Europe is in the middle of an energy transition towards renewables. The calculation of the use phase in such a scenario is more complex, because the emission factors vary over time. Based on a scenario for the energy transition in Germany, termed "KN50" in reference **[14]**, we calculated the annual emission factors, see **Figure 8**. The global warming potential per kWh of electricity decreases over the coming years due to the reduction of coal and gas-fired power plants. On the other hand, the abiotic depletion potential per kWh increases, which is particularly influenced by the increasing use of photovoltaics.

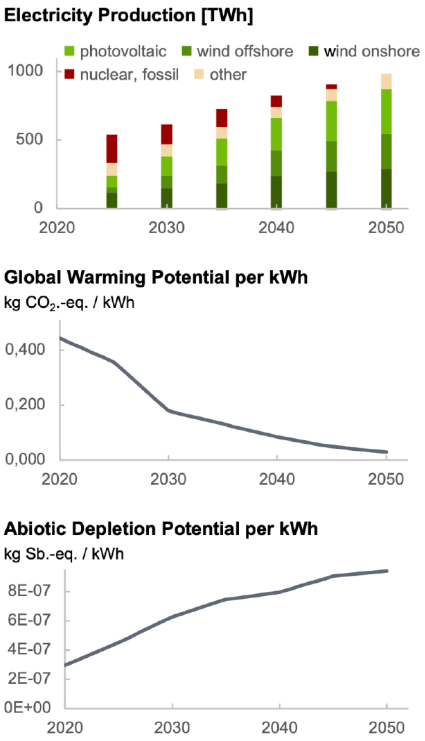


Figure 8: Energy transition scenario in Germany and its environmental impacts.

Calculation of the environmental impacts of the use phase in the energy transition scenario is now feasible: For each year, take the electrical energy consumed and multiply it by the emission factors valid for that year, and sum up all years of operation.

Obviously, the resulting totals will now also depend on the year when the luminaire was put into operation, the annual operating hours, and its usage time in the application.

This calculation process can be mapped to effective values for the emission factors. They are summarized in **Table 3** and correspond to an average over the period of use. The first section of **Table 3** defines four use scenarios with different annual operation hours **[15]**. In the second section, we demonstrate how long the period of use of a luminaire actually is: A luminaire with $100{,}000$ hours assigned lifetime could be used for 40 years in an office application – e.g. from year 2020 to year 2060. Finally, the third and fourth sections of **Table 3** present the effective emission factors. We can observe a high variance in the values, depending on the assigned lifetime and application scenario. For example, the global warming potential for the German electricity mix is currently a


 

little below 500 g $CO_2$–eq./kWh, see Reference **[13]**. For a luminaire with 50,000 h assigned lifetime, being put into a 24/7 operation in 2020, we have an effective emission factor of about 400 g $CO_2$–eq./kWh during the 5.7 years of use. In contrast, a luminaire with 100,000 h assigned lifetime, being put into an office application, will only use an effective emission factor of about 140 g $CO_2$–eq./kWh during its 40 years of use.

| Annual standard operation hours | | | | |
|---|---|---|---|---|
| | Office | Industry | Retail | 24/7 |
| | 2,500 h/a | 4,000 h/a | 5,000 h/a | 8,760 h/a |
| **Period of use (years)** | | | | |
| Assigned lifetime | 2,500 h/a | 4,000 h/a | 5,000 h/a | 8,760 h/a |
| 50,000 h | 20 a | 12.5 a | 10 a | 5.7 a |
| 70,000 h | 28 a | 17.5 a | 14 a | 8.0 a |
| 100,000 h | 40 a | 25.0 a | 20 a | 11.4 a |
| **Effective GWP [kg $CO_2$-eq./kWh]** | | | | |
| Assigned lifetime | 2,500 h/a | 4,000 h/a | 5,000 h/a | 8,760 h/a |
| 50,000 h | 0.241 | 0.312 | 0.347 | 0.402 |
| 70,000 h | 0.190 | 0.262 | 0.295 | 0.376 |
| 100,000 h | 0.142 | 0.207 | 0.241 | 0.326 |
| **Effective ADP [kg Sb-eq./kWh]** | | | | |
| Assigned lifetime | 2,500 h/a | 4,000 h/a | 5,000 h/a | 8,760 h/a |
| 50,000 h | 5.80e-7 | 4.82e-7 | 4.41e-7 | 3.71e-7 |
| 70,000 h | 6.62e-7 | 5.52e-7 | 5.04e-7 | 4.07e-7 |
| 100,000 h | 7.45e-7 | 6.32e-7 | 5.80e-7 | 4.65e-7 |

Table 3: Annual standard operation hours, period of use, and effective emission factors for global warming potential and abiotic depletion potential (luminaire being placed into operation in 2020).

### Discussion and Limitations

The most intensively discussed environmental impact is probably the global warming potential. We have shown that the use phase of a luminaire has the dominant influence. The value of the emitted $CO_2$-equivalents depends sensitively on the electricity grid mix. Both region and time influence the emission factors of the grid mix, which can vary to a great extent. When comparing the $CO_2$-footprints of two luminaires, careful consideration of the grid mixes is necessary.

When using same assumptions (like grid mixes), the results for the global warming potential are quite robust. However, we have experienced large uncertainties in the results for the abiotic depletion potential. ADP results are highly sensitive to even small amounts of precious metals, e.g. in electronics. Quantifying the exact content of noble metals is difficult, since the exact material composition of the electronics components are often not known by the luminaire manufacturer; and the suppliers are often interested in keeping this information confidential. Using established datasets for electronics components, like Sphera® or Ecoinvent®, is a feasible workaround, but leads to uncertainties. It can be shown, that the choice of life cycle inventory database can lead to different hotspots in the LCA, especially for other impact categories than GWP **[16,17]**.

Estimating the abiotic resource depletion by means of the ADP metric has even more fundamental challenges. For example, the values for *DR* and *R* are not fixed once-and-for-all, but are time dependent **[11]**. Moreover, it is questionable if all the different abiotic resources should be aggregated, as one depleted resource cannot necessarily be replaced by another one that is still available.

Another limitation of our analysis lies in the selection of environmental impact metrics. We focused on the global warming potential and the abiotic depletion potential. This choice was made after a screening of the results for 12 impact categories. However, there might still be relevant environmental impacts that were not within the scope of our first screening. A frequently asked question concerns the inclusion of the destruction of nature during material mining. This very direct impact on the planet, like in open-pit mining for metal ores, is neither included in the global warming potential, nor in the abiotic depletion potential. Further metrics on land-use or land-use change could be investigated to account for this. For other aspects like loss of biodiversity, there is not yet a widely established indicator.

## Recycling of Luminaires

Recycling is one specific form of waste treatment. A short explanation of the common terms seems to be appropriate to enable precise communication. **Waste** is a substance or object that the holder discards or intends or is required to discard. Waste can be sent to **recovery** operations, where it serves a useful purpose. One form is **energy recovery**, i.e. incineration or processing to fuels, another form is **material recovery**. The latter can be divided into (preparing for) **re-use**, **recycling** and **backfilling**. This defines recycling as a recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes, excluding energy recovery or backfilling **[18]**.

The term “recyclability” is even more difficult to grasp than the term “recycling”. In literature, a distinction is made between **[19]**:

- Theoretical recyclability (of the material itself)
- Technical recyclability (the material must also be able to be identified and separated)
- Realistic recyclability (collection systems and sorting facilities must be available, and actual pollution of the materials must be taken into account)

International standards **[18,20]** require manufacturers to report the realistic recyclability of their products as an environmental claim, not the purely theoretical recyclability.

### Reference End-of-Life Treatment Scenario

The central element of a realistic recyclability assessment is a reference end-of-life treatment scenario **[18]**. There is not yet a standardized reference scenario for luminaires. Based on the standard EN 45555 **[18]** and a publication that carries out the procedure for smartphones **[21]**, such a scenario was developed in the SUMATRA project, see **Figure 9**.

In our proposed scenario, luminaires are collected together with other small or large electrical appliances. The European WEEE Directive 2012/19/EU establishes some minimum requirements for the recycling, especially the selective treatment of **[22]**

- Printed circuit boards larger than 10 $cm^2$
- Plastics with brominated flame retardants
- Gas discharge lamps
- Batteries
- External electrical cables
- PCB-containing capacitors.

In practice, it appears that lamps, components containing harmful substances and batteries are removed manually before shredding. For most LED luminaires (without emergency lighting batteries, no PCB-containing capacitors), it can be assumed that they are shredded directly without manual treatment. The requirement for selective treatment is fulfilled by subsequent sorting.

**Figure 10** shows the result of shredding and sorting using the example of a weatherproof luminaire which was sent through the process. It can be seen that the ferrous and non-ferrous metals are sorted out well, the non-ferrous metal fraction containing printed circuit boards from the ECG and LED module. Only small quantities of plastics are separated into an own fraction. The largest proportion of plastics ends up in the residuals, which then only go to incineration, thus escaping material recovery.

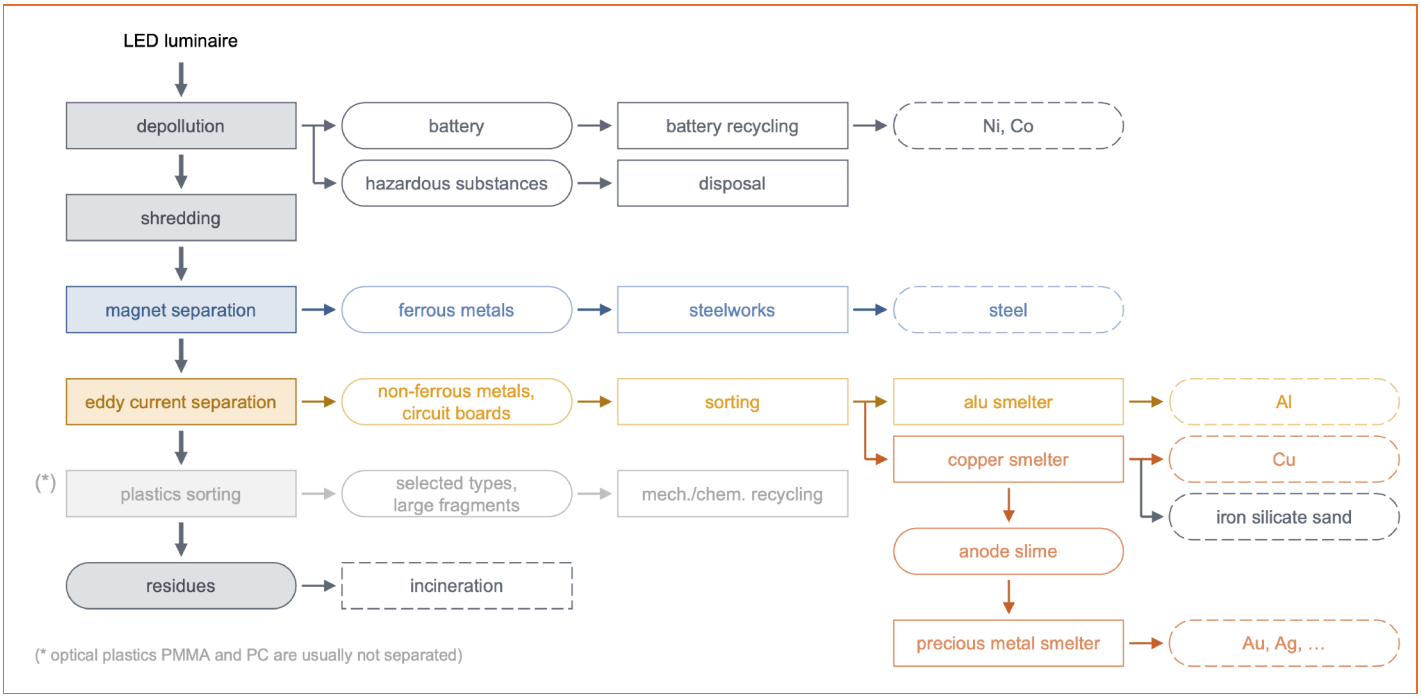


Figure 9: Proposed reference end-of-life treatment scenario for recyclability assessments of LED luminaires based on EN 45555.

There are two reasons for this loss. Firstly, the shredding processes materials like plastics (but also glass) into very small fragments that are almost impossible to sort out. Secondly, only certain types of plastics (target plastics) are sorted out. The polymers PC and PMMA, which are primarily used in the luminaires, are presumably no such target plastics, as they occur in insufficient quantities in the overall waste stream of small or large electric appliances.

These results confirm the data that was determined in IEC Technical Report 62635 back in 2012 [23]. Recycling rates for specific material groups are tabulated there. The data was collected in Europe between 2005 and 2008 and relates to the product groups of small and large household appliances, IT and telecommunications equipment and consumer electronics. Here, too, it can be seen that the plastics PC and PMMA, which are relevant for luminaires, are no longer recycled after shredding. Only the plastics ABS, PP, HIPS and PE are recycled after shredding.

## Recyclability Assessment

EN 45555 uses a mass-based approach to define the recyclability rate $R_{cyc}$ of a product [18]:

$$R_{cyc} = \frac{\sum m_k \cdot R_{cyc,k}}{m_{tot}} \qquad (4)$$

where $m_{tot}$ is the total product mass, the sum runs over all materials $k$, with $m_k$ being the mass of material $k$ and $R_{cyc,k}$ being its recyclability factor. The recyclability factors for each material shall include the efficiency of the steps of the reference end-of-life treatment scenario [18].

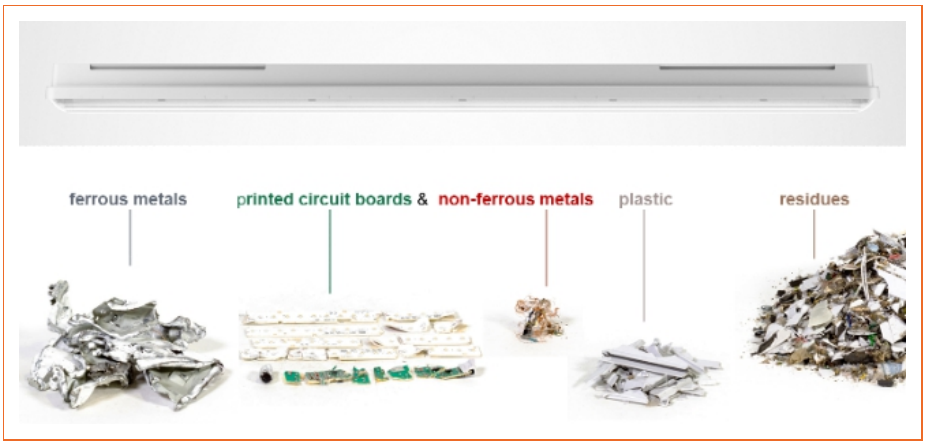


Figure 10: Output of the shredding and sorting process for one single weatherproof luminaire (length 1.2 m, weight 2.3 kg, housing made from grey polycarbonate and optics from clear polycarbonate.

As no more recent literature values for the recycling rates of specific material groups could be identified, the rates of IEC/TR 62635:2012 [23] are used for the recyclability factors. Material losses are taken into account: for example, steel is in theory completely recyclable, but due to losses to other fractions caused by imperfect sorting, an effective recycling rate of 94% is used.

The recyclability assessment requires a detailed bill of materials and weights of the luminaire. For many mechanical and optical parts, this is quite simple, as they consist of few materials. For ECGs and LED modules, on the other hand, it is quite challenging. Therefore, we studied the material composition of 2 LED modules and 4 ECGs in detail, to derive exemplary recyclability factors for these parts, see **Table 4**.

| Component | $R_{cyc,k}$ |
|---|---|
| LED module, epoxy resin substrate | 11% |
| LED module, aluminum substrate | 8% |
| ECG, outdoor application (potted) | 12% |
| ECG, plastic housing | 15% |
| ECG, metal housing | 55% |

Table 4: Recyclability factors (percentage by weight) of various electronic components of luminaires.

For LED modules, it was assumed that their final treatment step is the copper

smelter. The recycling rates in the copper smelter for the various metals (copper, precious metals, lead, tin, nickel, antimony) were taken from the literature [24]. The material composition of LED modules was determined with suppliers, but are not reproduced here for reasons of confidentiality. The recycling rates for LED modules range from 8% (for aluminum core PCBs) to 11% (for epoxy resin PCBs), which is even lower than the standard values for printed circuit boards classified as "poor" in IEC / TR62635:2012. The main recycling yield comes from copper and tin. Rare earths from the LEDs' phosphors are lost in the copper smelter, as is the PCB substrate (which makes up the largest proportion by weight). However, the metals recovered from the LED module are also the most "precious" materials and have the highest abiotic resource depletion potential.

For ECGs, we assume that the steel housing and printed circuit board are separated in the shredder, with the housing going to the steelworks and the circuit board to the copper smelter for the final recycling. The main contributions to the recyclability factor are the sheet metal housing and the copper from the PCB and larger components such as inductors. Potted ECGs, often found in outdoor applications, are critical, as they cannot be separated by shredding. We assume that these ECGs are sorted as "non-ferrous metals" despite the heavy potting compound and end up in the copper smelter, where copper and precious metals are recovered while the potting compound burns (i.e. contributes to energy recovery, not recycling).

An example of a complete luminaire assessment is shown in **Table 5**. In this case, the weatherproof luminaire obtains a recyclability of 37%. The main losses are the polycarbonate optics and housing. Though

| | | Mass [kg] | Final Treatment | $R_{cyc}$ | Yield [kg] | $R_{cyc}$ theoretical | Yield [kg] |
|---|---|---|---|---|---|---|---|
| Mechanics | Steel | 0.740 | Steelworks | 0.94 | 0.695 | 1.0 | 0.740 |
| | Stainless Ssteel | 0.014 | Steelworks | 0.94 | 0.013 | 1.0 | 0.014 |
| | PC | 0.720 | Therm. | | | 1.0 | 0.720 |
| | Other | 0.049 | | | | | |
| Wiring | Copper | 0.009 | Cu Smelter | 0.85 | 0.008 | 1.0 | 0.009 |
| | PVC | 0.009 | Therm. | | | 1.0 | 0.009 |
| | Other | 0.009 | | | | | |
| Optics | PC | 0.436 | Therm. | | | 1.0 | 0.436 |
| ECG | Metal Housing | 0.176 | | 0.55 | 0.097 | 0.55 | 0.097 |
| LED module | Resin Substrate | 0.084 | | 0.11 | 0.009 | 0.11 | 0.009 |
| Sum | | 2.246 | | 37% | 0.822 | 91% | 2.033 |

Table 5: Template for the recyclability assessment based on EN 45555, completed for a weatherproof luminaire. The central result is the value 37% in cell $R_{cyc}$/sum. The two columns on the right repeat the assessment for the theoretical best case.

theoretically recyclable, being a thermoplast, it is counted as 0% recycled in the reference end-of-life treatment scenario. This is due to the initial shredding in combination with the literature data of IEC / TR62635:2012 indicating that PC is not recycled after shredding.

To demonstrate the large potential that lies in optimizing the recycling processes, **Table 5** also shows the theoretical best case, based on the recyclability of the material itself. In this scenario, the recyclability of the weatherproof luminaire rises from 37% (realistic) to 91% (best case). This scenario could be reached e.g. by manual or robotic disassembly and sorting. In current recycling practices, this seems to be not viable for economic reasons.

We conducted assessments for ten luminaires. The results are summarized in **Figure 11**. The realistic recyclability varies between 22% and 84%, and is primarily influenced by the contents of plastics in the optics and mechanical structure. Other major losses in the recycling are glass sheets (e.g. in luminaire C). The rather low recyclability of LED modules and ECGs have an impact on the overall recyclability, especially for small luminaires like downlights (luminaire F) or when the LED module is relatively large and heavy (e.g. luminaire H).

## Discussion

We presented our method of the recyclability assessment in detail, because we want to enable the lighting community to harmonize this kind of assessment. This is necessary to make fair and comparable claims about the recyclability of luminaires. A very important part of the information lies within the method; not the reported value alone. Today, luminaire manufacturers are found to use different methods to define "their" notion of recyclability, and examples of environmental claims can be found that are even more euphemistic than the "theoretical best case" presented in **Table 5**.

The international standards agree that an assessment of the realistic recyclability of a product is required. However, a standardized reference end-of-life treatment scenario and material-specific recyclability

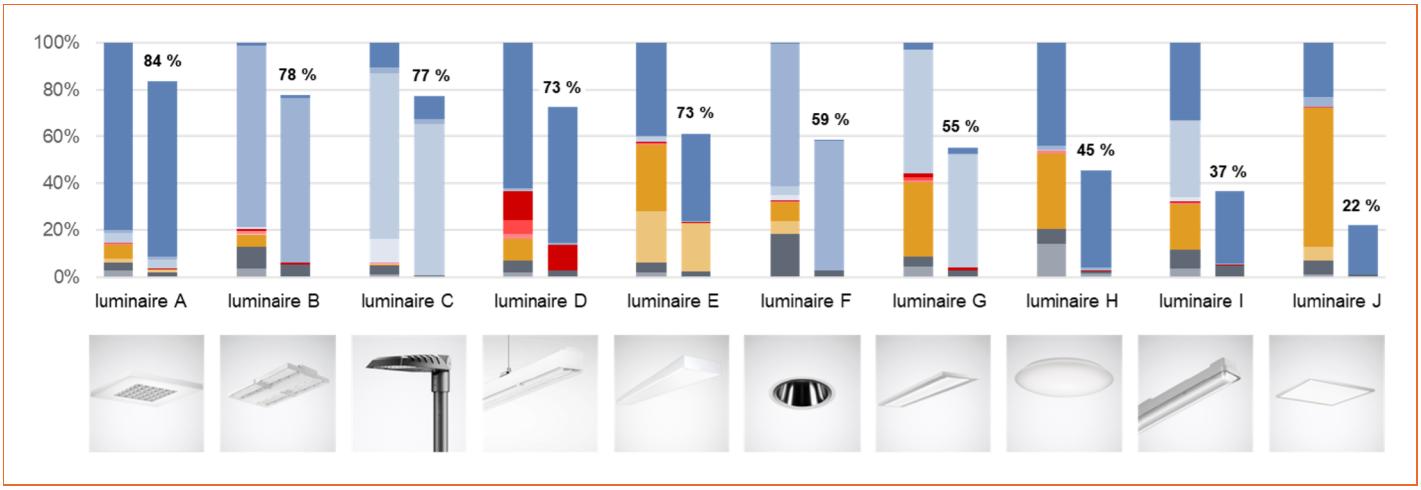


Figure 11: Realistic recyclability results for ten luminaires. The left column shows the masses of the luminaire components in its original state, and the right column shows the weight of materials recovered in the recycling process. Components belonging to the mechanical structure are blue (mostly metals), wiring red, optical components orange (mostly plastics), and electronics gray.

factors are not yet established for luminaires. The standard EN 45555 is, in fact, not to be applied directly for the recyclability assessment of products, but shall serve as a method for writing product or product-group standards [18]. In the SUMATRA research project, we took a short-cut, proposed an end-of-life treatment scenario, and performed the recyclability assessment directly.

## Conclusions

Luminaires and lighting do have significant environmental impacts. The relevance for the global warming potential is obvious from the statistics of energy usage: 13% of Germany's electricity is used for lighting [25]; and the energy sector is the major emitter of greenhouse gases in Germany [26]. Our life cycle assessment has shown that the abiotic resource depletion is of similar relevance as the global warming potential when compared to normalization factors, see **Table 2**. This finding might not correspond with our intuition because luminaires seem to be quite "simple" technology. And of course, smartphones, laptops, or electric vehicles contain certainly more precious materials than a luminaire. But think about how ubiquitous luminaires are in our built environment. How many luminaires, per person, are in our homes, at our workplaces, in the streets?

Light is a very common product, and needs careful consideration to make it as sustainable as possible. After years of close collaboration, the SUMATRA researchers agreed on 9 recommendations for lighting industry and policy makers presented in the **Recommendation Box** below. Some of the recommendations are concluded from research activities that were not presented in this article.

The recommendations include a call for more accurate life cycle assessment data, especially of electronics components like the LED modules. This data is difficult to obtain for a luminaire manufacturer, and should be communicated along the supply chain. Only then, reliable LCA results are achievable and informed decisions for more sustainable product designs are possible. Interest in this kind of data will increase, as more and more companies will be required to report their environmental impacts, including scope 3 (supply chain emissions and those associated with the use of their products).

One of the original goals of the SUMATRA project was to design a luminaire with its end-of-life in focus. However, there is little sense in optimizing a luminaire for the shredding process of today's recycling practices. Recycling, in its current form, seems to be one of the least favorable circularity options, it is rather the last resort than the first choice. We conclude our research on the recyclability of luminaires with a call that coordinated activities between manufacturers and recyclers are necessary to make real progress in this very relevant field.

In this article, we presented three facets of sustainability of luminaires in detail: The global warming potential, the abiotic depletion potential, and the recyclability. By using quantitative methods to assess these three aspects, different luminaire designs become comparable. However, we did not find a satisfactory solution for an "overall sustainability rating". This challenge is illustrated in the following example: Imagine two luminaire concepts, A and B, for the same lighting purpose. A may have an 8% lower global warming potential than B, because it reaches a higher luminous efficacy by employing more LEDs and a better heat sink. This leads to B having a 17% lower abiotic depletion potential than A. Furthermore, A surpasses B by 5 percentage points in recyclability. Which concept, A or B, deserves to be called "more sustainable"? We do not even dare to raise the question which luminaire would be justified to be claimed "sustainable" in absolute terms.

Though having made progress in quantifying, explaining and interpreting the environmental impacts, we still have to conclude that sustainability is not measurable. In view of this lack of certainty, we encourage further research and expanded efforts to move the lighting industry towards a more sustainable future, as expressed in our 9 recommendations. ■

## Recommendations for the Lighting Industry and Policy Makers

With these recommendations, we want to boost the efforts of turning the lighting business into a more sustainable future, even if some details are still unclear. The recommendations were agreed on by the SUMATRA researchers on their final meeting on 27 September 2023 in Arnsberg, after 28 months of research and intensive collaboration.

01 Light management systems offer great energy saving potentials, and the additional costs are low compared to a non-managed system. They should be employed according to the necessities of the application.

02 Life Cycle Assessments of LED luminaires should focus not only on energy efficiency, but also on resource efficiency.

03 The luminaire should be designed to enable replacement and upgrades of electronic components such as LED modules and electronic control gears (ECGs).

04 Spare parts for luminaires and components should be available in the long term.

05 All components should be designed to identical lifetimes, which should meet the lifetime requirement of the application.

06 Information that makes it easier to replace components should be found on the luminaire label, electronically in the luminaire, or via building information models (BIM).

07 Luminaires should be designed to be separated into uniform material fractions in the recycling process, in order to minimize material losses. At the same time, recycling processes should be optimized. This requires coordinated activities between manufacturers and recyclers.

08 Life Cycle Assessment data-sets for luminaire components, especially LED modules and ECGs, should be completed, standardized and communicated transparently.

09 Manufacturers are recommended to perform Life Cycle Assessments during product development to achieve a meaningful eco-design of their luminaires.


 

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**About Trilux:** TRILUX is one of the major international suppliers of professional light for many applications - from office to industry, from retail to outdoor. Ever since the company was founded in 1912, TRILUX luminaires have been setting new standards, for example with top values in energy efficiency, light quality and user-friendliness. The medium-sized family business has a total of 30 subsidiaries and exports its lighting solutions to 50 countries worldwide. The company's core values include quality, innovation, and sustainability.

www.trilux.com

**About Fraunhofer IZM:** Since 1993 Fraunhofer IZM has been one of the world's leading institutes for applied research and the development and system integration of robust and reliable electronics. For over 30 years, more than 450 employees have been finding technological solutions in cooperation with partners from industry and academia. Emerging challenges are addressed in branches such as automotive and industrial electronics, medical engineering, ICT and semiconductor technology.

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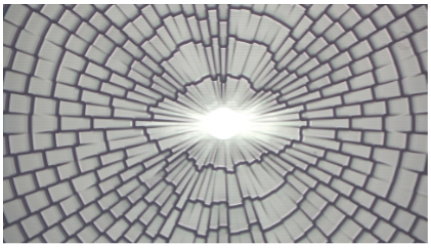
# The Promising Future of Free-form Micro-Optics in Mobility Interiors

Christian FORSTNER, Head of Sales at Seisenbacher

**Light not only illuminates a room, but also boosts the mood of those in it. It is therefore crucial that internal spaces are optimally lit. This applies not only to domestic living rooms but also to train compartments. That's why Seisenbacher GmbH, a manufacturer of rail vehicle interiors, is participating in a unique project: the EU-funded H2020 research project PHABULO$\mu$S, a project aiming to revolutionize the development of free-form micro-optics in Europe, providing new opportunities for lighting techniques.**

## What are Free-form Micro-Optics?

Free-form micro-optics (FMOs) are extremely small and complex optical elements that enable precise control over light distribution and intensity. These optics are designed with non-symmetric surfaces, allowing for greater flexibility in shaping the light output. In the context of lighting for mobility interiors, free-form micro-optics play a crucial role in creating innovative lighting designs, enhancing passenger comfort, and improving safety.



Closeup from a GSLL Master by Joanneum Research.

## Advantages of Free-form Micro-optics

FMOs offer several advantages over traditional optics technologies. Firstly, FMOs offer enhanced design flexibility as they enable precise control over light distribution, allowing for the creation of unique lighting designs and customized lighting effects tailored to specific requirements and design aesthetics.

Secondly, FMOs optimize light extraction and control, resulting in higher efficiency and reduced energy consumption. Thirdly, their small form factor makes them ideal for integration into compact mobility interior designs, enabling seamless and unobtrusive lighting solutions.

Finally, the precise control over light distribution provided by FMOs improves safety by facilitating easy navigation and emergency exit identification, and the ability to adjust brightness and color temperature enhances passenger comfort.

## The Manufacturing Process for Free-form Micro-Optics

The manufacturing process for FMOs differs from traditional optics production methods in several ways. While traditional optics typically involve grinding and polishing flat or symmetric surfaces, FMOs require advanced fabrication techniques such as lithography, additive manufacturing, or precision molding.

The manufacturing process for FMOs involves three stages. The process starts with the design phase where optical simulations and modelling tools are employed to optimize the shape, dimensions, and surface characteristics to achieve specific lighting objectives.

Simulation and modelling play a crucial role in the design and optimization of FMOs. By leveraging advanced software tools, engineers can simulate and analyze the behavior of light within the optics, allowing for the optimization of shape, surface characteristics, and optical properties.

Specifically, by simulating different design iterations, engineers can

- evaluate and compare the performance of various FMO configurations, enabling informed design decisions;
- analyze how light propagates and interacts with the optics, enabling the optimization of light distribution, minimizing losses, and achieving the desired lighting effects;
- identify design improvements that enhance efficiency, maximize light extraction and minimize unwanted light scattering or reflection; and
- predict and validate lighting characteristics, such as intensity, color temperature, and beam angles.

The second stage is fabrication: depending on the chosen manufacturing technique, the fabrication process may involve precision machining, etching, or 3D printing. The fabrication methods used are typically capable of producing intricate and non-

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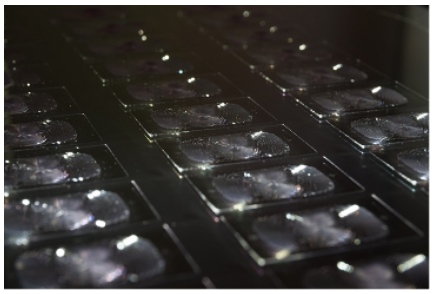
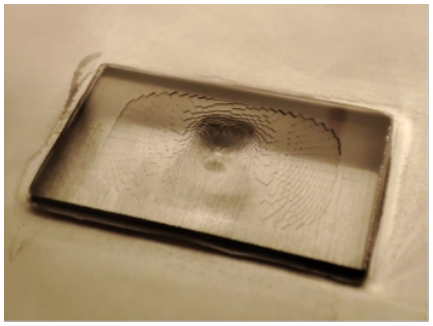
symmetric surface geometries required for free-form micro-optics.

The third stage is testing: to ensure the quality and performance of the fabricated optics, precise metrology tools are used to measure and verify the shape, surface roughness, and optical properties of the micro-optics.



Roll to Plate Replicas by Morphotonics.



Stamps used for S+R Up-scaling by Joanneum Research.

## Challenges in Integrating Free-form Micro-Optics into Existing Technology

Such smart transportation interior lighting, combined with micro-optics, can be utilized in various modes of transportation such as airplanes, trains, buses, and other vehicles. This is a significant gain for the entire industry, which, thanks to advanced LED technology, is also energy-efficient and environmentally friendly. However, integrating FMOs into existing technology still poses several challenges.

Firstly, because FMOs involve intricate designs and precise fabrication requirements, their integration into existing technology is frequently complex and challenging. Secondly, the mass production of FMOs with consistent quality can be challenging due to the complexity of fabrication techniques and the need for specialized equipment. Finally, the fabrication and integration of FMOs usually involve higher costs compared to traditional optics technologies, especially in the initial stages of adoption.

## The PHABULO$\mu$S Project

To overcome these challenges, collaboration between industry partners, research organizations, and technology providers becomes crucial. To this end, in 2020, the EU funded the PHABULO$\mu$S project, that was set up with the aim of developing robust manufacturing technologies via a pilot line that can deliver high-quality free-form micro-optics at scale and at lower costs and streamline the integration of FMOs into existing technology.

As a manufacturer of rail vehicle interiors, SEISENBACHER has been able to bring its considerable expertise in lighting solutions for mobility interiors to the PHABULO$\mu$S project. The project's emphasis on establishing a pilot line for the entire production cycle, from design to the finished application, has allowed us to contribute our expertise and shape the development of lighting solutions for mobility interiors. By leveraging the advancements in free-form micro-optics, our aim is to create new lighting designs and enhance the lighting experience for passengers.

Our experience of participating in the PHABULO$\mu$S Pilot Line project has been highly valuable and enriching - particularly the collaboration with renowned research organizations and industrial partners which has provided unique insights and opportunities for innovation.

Up-scaled Poly-Shims by Joanneum Research.

## The Future of Free-form Micro-Optics

The future of free-form micro-optics holds significant potential for advancements and innovations as FMOs are the only technology capable of satisfying the growing demand for compact and efficient lighting solutions.

Key potential advancements include increased miniaturization enabling their integration into increasingly compact and slim designs across various mobility interiors, as well as advanced functionality, such as sensors for occupancy detection and advanced gesture control. Ongoing research and development efforts will also focus on optimizing the optical efficiency of FMOs, resulting in improved light extraction, reduced energy consumption, and longer lifetimes.

Furthermore, FMOs will increasingly be integrated into smart systems, allowing for seamless integration with other technologies, such as Internet of Things (IoT) connectivity, to enable intelligent and adaptive lighting experiences. Similarly, greater design flexibility will enable lighting solutions that are not only functional but also aesthetically pleasing, enhancing the overall interior design of mobility spaces.

Finally, the ongoing collaborative efforts between industry and research organizations, as exemplified by initiatives like the PHABULO$\mu$S project, will continue to drive the advancements in free-form micro-optics and pave the way for their widespread adoption in the industry. ■

**Christian FORSTNER**
**Head of Sales, Seisenbacher**

Christian FORSTNER is Head of Sales at Seisenbacher GmbH, with extensive experience in the rolling stock industry. Having obtained a degree in Electrical Engineering, he embarked on a successful career that spans over 20 years in this specialized sector. Christian's expertise lies in the areas of design, engineering, and project management for rail vehicles. He has been involved in the development and implementation of innovative solutions, ensuring the highest quality and safety standards are met, and he remains an active participant in industry conferences and workshops.

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# The Future of Scan-to-BIM in Lighting Design

Martin HUBER[1], Co-Founder & CEO of Metaroom by Amrax

**Light planning is the art and science of strategically designing lighting systems to enhance the functionality, aesthetics, and ambiance of indoor and outdoor spaces. Whether it is a residential home, a commercial building, or a public space, effective light planning plays a crucial role in creating environments that are both visually pleasing and functional. At its core, light planning involves understanding the properties of light, such as intensity, color, direction, and distribution, and applying this knowledge in combination with computer-based simulation and analysis tools to achieve specific objectives, including visibility and safety, task performance, ambience and mood, and cost- and energy efficiency.**

**In this article, we focus on light planning inside buildings and how efficient and user-friendly 3D Scan-to-BIM solutions based on smartphone technology can simplify and even revolutionize the light planning process. We discuss the value of 3D data, building information modelling, standardization, AI, and smart building technology with respect to current and future potential for this field. As a practical example dedicated to the light planning industry, we provide an overview of Metaroom by Amrax®, a smartphone-based 3D Scan-to-BIM solution.**

## Is 3D Data All You Need?

To simulate and analyze the effect of light, an important criterion on top of the well-standardized properties of the light sources, is to obtain knowledge of the real world, i.e., the building for which the light simulation needs to be performed. For light planning, it is essential to understand both the light sources and the illuminated scene. Certainly, there exist simplified solutions based on 2D floor plans, or even more simplified information about the interior of buildings, e.g., based on the rooms' area only. For optimum results, however, 3D models of buildings are an essential prerequisite. Beyond geometry, particularly windows and materials (colors) are important properties strongly influencing the light simulation's output (**Figure 1**).

For example, the spatial (3D) position and geometry of a wall, in combination with the reflectance properties of the wall's surface material, influence how the emitting light is reflected inside the room. The exact vertical position of a window (which is potentially missing even in an accurate 2D-floor plan) strongly influences how the daylight enters the room. Any obstacles on top of the basic room geometry, which block and reflect the light, are often not modeled in simplified (e.g., 2D) models. Based on these examples and since the world is three-dimensional, it is obvious that light planning needs to be performed in three dimensions to achieve optimum accuracy.

From a technical perspective, a 3D model that includes all these relevant properties needs to be provided in any way that the light planning tool can read and interpret the data (**Figure 2**). Theoretically, this data is all you need and there are no requirements for a specific interface. However, well-defined standards are essential to enable seamless interaction between different tools and stakeholders. This is particularly the case since light planning is often one part of a larger project performed in parallel or sequence with other trades. Only interoperability facilitates the highest efficiency and circumvents the redundant generation, processing, and storage of asynchronous data.

## Building Information Modeling & IFC

Building Information Modeling (BIM) involves creating and managing digital representations of buildings' physical and functional characteristics. A BIM model is a digital representation of a building that includes geometric shapes and information about the project's components, such as materials, spatial relationships, quantities, and properties of building assets. The models provide the all-encompassing basis of information on which individual stakeholders extract the information relevant to them. This information is stored in a structured way, allowing each stakeholder to access and use it throughout the lifecycle of a project, from initial planning and design through construction, operation, and maintenance. In the beginning, due to missing standards, BIM software developers mainly created proprietary data structures in their software. Therefore, data and files created by one vendor's applications may not work in other vendor solutions, which, in turn, strongly limits the usability of software solutions. Open standards for sharing BIM data among different software applications have been developed to achieve interoperability between applications. BIM's evolution traces back to the 1970s, but it was not until the early 2000s that it gained worldwide recognition. Progress in open BIM standards has varied across nations. In 2013, the Industry Foundation Classes (IFCs) [4], crafted by buildingSMART [5], attained international standard status as ISO 16739 for the first time. The specified file format is also known as IFC4. Furthermore, the evolution of IFC to version 4.3 (2021) represents another significant mile-

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stone in the ongoing development of BIM technology and standards. Recent developments indicate that IFC4.3 is becoming increasingly widespread and important in the architecture, engineering, and construction (AEC) industry. For the near future, our expectation is a higher adoption rate of BIM and IFC in the lighting design industry.

## BuildingSMART

With the vision of enabling seamless interoperability, BuildingSMART [5] is an international organization that aims to improve the exchange of information between software applications used in the AEC industry. Beyond IFC, which is the standard for BIM data models, BuildingSMART has developed several other standards. For example, BuildingSMART has developed BIM Collaboration Format (BCF), another standard for exchanging comments and issueing tracking information between different software applications utilized in BIM workflows.

## Creating BIM is Laborious and Expensive

Nowadays, standardized BIM models are typically available for new buildings. However, light planning often needs to be performed in existing constructions due to high energy prices, outdated equipment, technological progress, and new regulatory requirements. For most of these buildings, up-to-date open BIM models are unavailable. This is partly because BIM models were not created. However, it can also be the case that a BIM model is available, but due to very recent establishments in standardizations, interoperability is often not given.

*"85% of EU buildings were built before 2000." [1]*

For that reason, the creation of BIM models from existing buildings is currently of high relevance in many fields related to AEC. This process, however, is typically laborious and expensive. One approach to digitizing buildings is based on manual measurement followed by the manual creation of BIM models based on dedicated CAD/software [1]. Despite powerful and elaborate software tools, this approach is highly time-consuming and error prone. Particularly in the case of special geometries and inaccurately built constructions (e.g., non-planar walls and inaccurate angles), manual measurement can be highly challenging, even for experts. Another approach relies on dedicated hardware including high-end sensor technology, such as laser sensors [2]. This hardware allows the capture of rooms, floors, and buildings by accurately scanning the interior with depth sensors in combination with cameras. Typically dedicated stationary hardware is placed at several distinct positions inside a building to accurately capture local point clouds at each position. Finally, these acquired local point clouds are merged to generate a single global point cloud representing a whole building or a part of a building. There are also portable hardware solutions, which facilitate acquisition while walking through a building. The strength of this high-end hardware technology is its extraordinarily high visual quality and highly resolved point cloud that can be automatically reconstructed based on the scan. However, experts and dedicated devices must be present on-site for scanning. Another disadvantage is the fact that often, a large point cloud is not needed and is even unwelcome in workflows. For modeling buildings, a slim & efficient parametric representation based on simple basic elements (e.g., planar walls, planar floors, planar ceilings) is not just smaller and easier to handle, but also more appropriate for computations and for interacting with the model. For that reason, point clouds are often manually converted into a simplified

Figure 1: Light planning is based on 3D building models and light simulation.

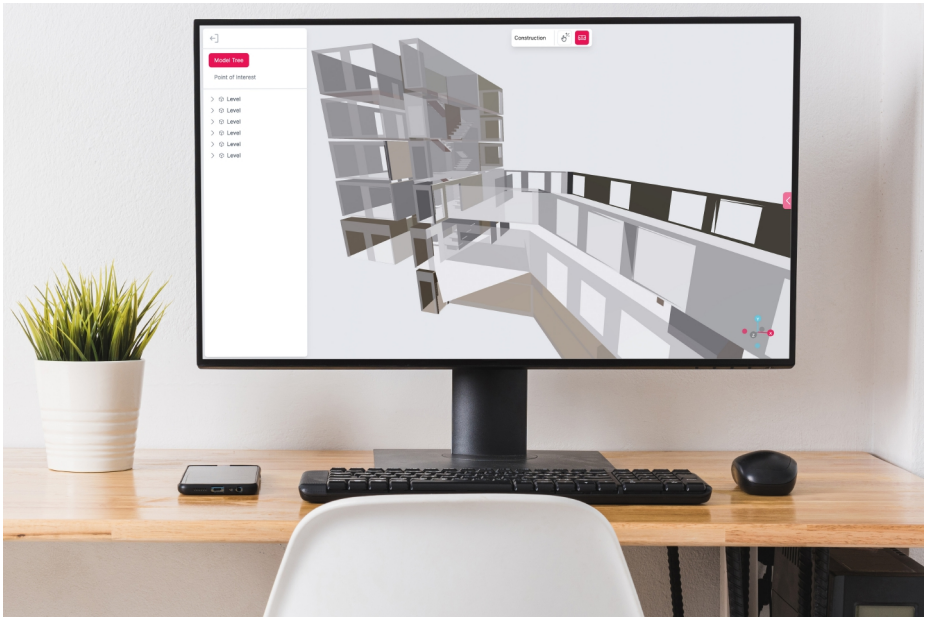

Figure 2: 3D Model of a building created with a smartphone solution.

parametric BIM model. Despite automated point cloud acquisition, the data acquisition and preparation process is still labor-intensive and thereby expensive. Scanning, as well as data post-processing, requires experts. The scanning process even requires experts on site. The costs for scanning and reconstruction range from about EUR 1.00 (for exceptionally large sites) to EUR 5.00 per square meter.

## Easy Scan-2-BIM: Smartphones as a Solution

Smartphones nowadays contain powerful cameras and hardware for efficiently processing computer vision and AI algorithms. Modern devices are also partly equipped with light detection and ranging (LiDAR) sensor technology. This allows the capture of depth information on top of an RGB camera signal, in turn enabling the acquisition of 3D (point cloud) data with small and portable consumer devices. The built-in sensors show higher deviations and a clearly lower spatial resolution than dedicated expert hardware. This can be a limitation if the fine structure should be accurately reconstructed. The geometry of buildings, however, is typically strongly constrained with planar walls, floors, and ceilings combined with (rectangular) corners and edges. This fact, along with modern AI and computer vision algorithms, enables smartphones to reconstruct the interior of buildings accurately despite being less accurate and having orders of magnitude cheaper sensor technology.

This technology eliminates all barriers, clearly reduces scanning costs, and enables Scan-2-BIM for anybody. As soon as interoperability (e.g., based on IFC) is ensured, anybody can perform a scan, data can be processed on the phone or in a cloud, and finally, a BIM model can be exported and imported to be used in diverse workflows.

## Metaroom by Amrax®: Scan-2-BIM++

Metaroom by Amrax® represents a pioneering Scan-2-BIM solution based on smartphone LiDAR technology. With the Metaroom app (**Figure 3**), a user scans a room while walking with a mobile phone or tablet in their hands through a room. The captured signal is enhanced based on real-time computer vision and AI technology, and several deep neural network algorithms are used to capture the geometry, doors, windows, 3D objects, and material properties. Instead of (highly resolved) point clouds, this technology allows the direct creation of slim parametric BIM models consisting of a few basic elements without any need for manual post-processing (**Figure 2**). Since the deep learning models directly run on the smartphone, instant feedback is provided to the user in the form of a 3D preview.

Metaroom allows additional functionality on top of pure scanning and AI-based 3D reconstruction. After finishing the scan, the user can view and modify the generated scene on a desktop or laptop PC using Metaroom Studio. The user can extract and modify room measures to ensure that the 3D model perfectly corresponds to the real room. Additional objects of interest can be manually or semi-automatically annotated in selected 2D frames with the help of cutting-edge AI algorithms [6] (**Figure 4**). Finally, all data can be visualized in 3D and 2D, and various data formats (such as IFC) can be exported. This allows easy integration in light planning workflows with diverse planning software like Relux and DIALux.

**"This partnership has the potential to revolutionize the way external field staff interact with their customers. The partnership between Amrax and Relux is an important step in the development of design and construction technologies."**
*– Markus HEGI, CEO of Relux Informatik AG*


Figure 3: A 3D model is generated based on a smartphone's scan.

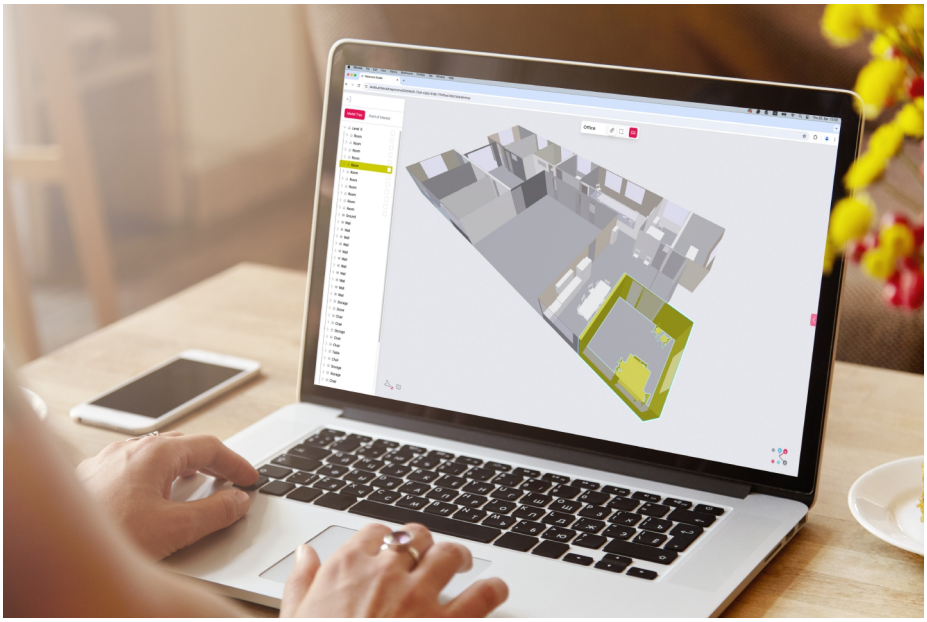

Figure 4: Semi-automated segmentation of any objects based on cutting-edge AI.


 

**"In Switzerland, the renovation and modernization of luminaires is a very important topic. Metaroom supports our sales force by creating the basis for planning in the shortest possible time. For luminaire manufacturers, light planning is an important element for client acquisition. Metaroom helps us to reduce costs, gain speed, and to be able to plan our projects more precisely."**
*– Ivo Huber, CEO of Tulux AG (Interview Light & Building)*

**"We provide state-of-the-art AI tools allowing the customers to detect and model 3D light sources based on a single mouse click on an object in a 2D frame."**
*– Luca DEBIASI, Chief Product Officer, Metaroom by Amrax®*

## Optimum Trade-off between Accuracy and Costs with Smartphones

Since any person can perform the scan without any expertise (**Figure 5**), the costs for digitization are approximately 90% lower with smartphone Scan-2-BIM solutions compared to competing solutions with dedicated hardware. On top of that, the flexibility is clearly higher since scans can be performed at any time without long lead times. Slight inaccuracies of this pipeline in the final 3D model created, do not considerably influence the accuracy of the light planning process. Instead, we obtain an optimum trade-off between accuracy, costs, and flexibility to improve the light planning workflow with this solution.

## The Future of Light Planning with AI & VR

Today, smartphone technology has already disrupted the market for 3D scanning of buildings due to the low costs combined with the high simplicity and flexibility. Due to continuous development and continuously enhanced smartphone technology, this novel approach can even revolutionize the future of light planning. AI, in combination with modern imaging sensors, has the potential to semantically capture all building details that are relevant for light planning in a fully automated way. For example, the reflectance properties of any material could be estimated and assigned to the 3D model to obtain even more accurate models for even more accurate simulations and planning. Improved LiDAR technology or enhanced AI training can incrementally enhance the geometric accuracy to come close to solutions based on dedicated hardware while keeping the cost advantage.

**"Deep learning technology is enormously powerful but typically inflexible since it requires large, labeled data sets for training models containing a fixed set of categories. We are currently establishing a method based on a deep large vision model developed by Meta AI in 2023. This will allow us to semantically capture any details of any object category based on one single example image of the object soon."**
*– Christoph HOFER, Chief Solutions Architect, Metaroom by Amrax®*

In combination with state-of-the-art virtual reality headsets, the highly realistic 3D model (**Figure 6**) can even be used to provide the customer with a realistic and cost-efficient preview of light-planned and furnished rooms or even of entirely equipped buildings. Scan-to-BIM solutions enable the capture and model of existing furniture. On top of that, based on interactive or automated AI tools, building models can be (re)furnished (semi) automatically. Theoretically, light planning could also be a part of a (semi) automated interior planning pipeline with realistic light simulation in combination with AI models generating recommendations.

Figure 5: Scanning with a smartphone is easy and can be performed without any expertise.

Figure 6: 3D Rendering of an industrial building based on a scan performed with Metaroom. Visualization is also possible with VR technology.

## Light Planning & Smart Buildings

Smart lighting systems offer enhanced energy efficiency through features like occupancy sensing, daylight harvesting, and adaptive lighting control, reducing electricity consumption and operational costs. They further provide flexibility and customization options, allowing users to adjust lighting levels, colors, and schedules according to preferences, occupancy patterns, and environmental conditions for improved comfort and productivity.

Light planning can be much more than a static simulation in such smart settings. Planning can incorporate the full potential of smart building features during the optimization of the infrastructure. However, BIM models and conventional light planning do not incorporate the time dimension and dynamical changes. To reach the next level, modeling based on digital twins will be needed.

## Digital Twins as the Next Level

Based on digital scans of buildings in combination with smart home technology, in the future, 3D BIM models can be translated into “alive” digital twins. A digital twin represents a dynamic model of a real entity with a bidirectional connection to the real-world counterpart allowing real-time synchronization between the twins. The digital twin can use smart-home control and IoT sensors, such as light sensors to capture the state of the real entity and perform synchronization.

Based on simulations and computations using the digital twin, for each situation (i.e., each point in time) an optimum setting can be calculated and assigned to the real entity (building). This enables us to combine light planning with real-time smart control of buildings to optimize the light situation depending on dynamic parameters. Incorporating the fourth (time) dimension, light planning can reach the next level, setting novel standards for comfort and energy efficiency. ■

**View the New Metaroom® Video**

https://bit.ly/metaroom-video

For more information, visit
**https://amrax.ai**

**About Amrax®**

Amrax® is a leading technology platform specializing in the digitization and design of spaces using 3D technology. Founded in 2020, the company offers fast, inspiring, and user-friendly solutions for space planning, interior design, lighting design, radio planning, and facility management through its innovative Metaroom® app. Amrax’s team of 25 experts in computer vision, AI, software development, and marketing use interdisciplinary collaboration and virtual reality to create groundbreaking innovations. Headquartered in Salzburg, Austria, Amrax® also operates in Vienna and the USA.

**Mission Statement**

In an era of numerous challenges, we have found computers and technology to be empowering tools, magnifying our human abilities and sharing them with the world. At Amrax®, we recognize the potential of these tools and strive to push their boundaries with our innovative product, Metaroom®. Metaroom goes beyond the conventional limitations, expanding our abilities and opening new doors of possibilities. We offer the ability not just to visualize but to reimagine these spaces with individual 3D visual support. It is a tool that cultivates creativity, allowing everyone to shape their environment according to their preferences and needs. Moreover, our technology upholds our collective responsibility towards the planet by promoting energy-saving solutions and driving efforts towards decarbonization in building design. What sets Amrax® apart is our team of some of the most dedicated and brilliant AI minds, globally. They are the driving force behind the development of this transformative superpower, making it accessible to everyone. Join us in embracing the future of spaces with Metaroom.

*– Martin HUBER, Co-Founder and CEO of Amrax®*

METAROOM by AMRAX

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Then use promo code **LED20** at checkout to receive a 20% discount on your annual subscription for the first 12 months. This offer expires on 31 July 2024.

**Martin HUBER, CEO of Metaroom by Amrax®**

Martin Huber is a seasoned leader in the tech and deep tech sectors with a solid product development and AI track record. As CEO and Co-founder of Amrax, he’s at the forefront of 3D modeling innovation. Before his role at Amrax, Martin was the CEO and Co-founder of the Dental Manufacturing Unit GmbH (DMU), and from September 2007 to April 2014, he served as CTO and Co-founder of CADstar. He played a vital role in technology development and management in this High-Tech healthcare company. His expertise is backed by a degree in Mechanical Engineering and studies in Computer Software Engineering. His comprehensive experience and educational qualifications make him a visionary leader and an authority in the intersection of technology and business.

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# In. Licht *pro*
# Lighting Fact sensor

Lighting Recipe Studio

Light data, all in your hands

- Lux
- CCT
- EML
- Visual Contrast
- Uniformity
- LRS Lighting Recipe™ Technology
- Monitoring circadian lighting



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## Recognizing the Excellence：
## In. Licht X Works with WELL in HCL

**Lighting Recipe Studio** (LRS) is a professional light research institute and also a leader in the development of forward-looking light products. It has the most advanced light environment monitoring technology, combined with life science research, to create various advanced algorithms to provide the highest light quality for human health.

### Game Changers to Reshape the Lighting Systems

Before, the researches of light & health were not well understood and applied without the regulations; recently, as we adapted light concept from the WELL standard, we discovered most of the lighting environments are not healthy enough for humans. Until now, with In. Licht portfolio, lighting data are visualised and able to interact with the dynamic lighting system, finally, we are able to build an adaptive lighting environment for a higher quality of health.

### People-Oriented Design plus Works with WELL

Combined with the WELL standard by the International WELL Building Institute (IWBI) for healthy buildings, the advanced life science research results from the LRS team in light, emotion and brain cognition, allows them to establish the premium professional-level light meter for light quality and HCL - **In. Licht Ultra** and **In. Licht pro**, the 1st and 2nd lighting fact sensor to be listed by IWBI "Works with WELL" program.

INTERNATIONAL WELL BUILDING INSTITUTE MEMBER CORNERSTONE

### From In. Licht pro to In. Licht Ultra

In. Licht pro is the most compact EML sensor by far recognized by Works with WELL and designed for better practical field application experience. In. Licht pro lighting sensor monitoring 5 key lighting indexes: Lux (Illuminance), EML (Equivalent Melanopic Lux), CCT(Correlated Colour Temperature), Visual Contrast, Uniformity

It provides real-time monitoring of light data in a super light-weight (40 g) device. Unlike any other light meters, In. Licht pro captures the key index of circadian rhythm, the Equivalent Melanopic Lux (EML), which can truly reassure residents in a healthy lighting environment. although In. Licht pro meets the needs of lighting industry personnel, but LRS is not satisfied just with this achievement.

### Laboratory-grade Spectrum Meter to be Reveal

In higher-end professional spectrum analysis, many experts have to work in the lab for their tasks. Some equipment that can perform spectral analysis in the field are bulky, heavy, and requires handholding. In response to the needs of professionals, the team has developed a lab-grade spectrometer that is hands-free (might be the world's lightest, again) and also Works with WELL certified.

**In. Licht Ultra** equipes with the best-in-class CMOS linear IC and Flicker sensor, provides 8 key modes to capture the light data:

- Spectrum
- Illuminance
- Flicker
- S/P Ratio
- HCL indexes (EML, mEDI, CS, CAF)
- Quality of Light (CRI, Ra,TM-30 Rf & Rg & vector,
- SDCM, DUV,CQS)
- Flicker Risk (frequency, percent, index, SVM)
- Blue light hazard

Those key modes contains 27 plus indexes with further upgrade services, and the product will certainly provides the best lighting inspection experiences for the expertise.

**In. Licht Ultra**- which is expected to be launched in Q3 2024.
The lighting industry will look forward to it. ■


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Good Light Group

The **Good Light Group** is a non-profit organisation. We are a group of scientists, lighting designers, sleep experts, and lighting companies focused on improving indoor lighting for health and well-being.

For more information: **info@goodlightgroup.org**

# Solid-State Lighting Market Report: ASIA

Dr. J. Norman BARDSELY, Chief Analyst at International Solid-State Lighting Alliance

**Dr. J. Norman BARDSLEY, Founder and SSL Analyst, Bardsley Consulting**
Dr. J. Norman Bardsley, a distinguished Professor of Physics, has earned international acclaim as an expert in solid-state lighting (SSL) through his advisory roles with the Department of Energy (DoE) and the International SSL Alliance (ISA). Renowned for his extensive and nuanced understanding of OLED technology, Dr. Bardsley possesses a comprehensive grasp of its manufacturing processes, cost structures, and ongoing research endeavors.

jnbard@pacbell.net

**This third article on the status of the global SSL industry discusses the role of China in market development and manufacturing and the opportunity for market growth in other developing countries in Asia.**

## Government Support in China

The establishment of the LED manufacturing base in China was driven by strong support from the national and local governments. Subsidies from Beijing enabled the strongest companies to build large factories, while regional and city governments helped to form the infrastructure necessary to turn the new technology into products. Demand was led by the need for slim backlights in flat panel displays (FPD). Transformation of the display industry was also aided by substantial government support, first in Korea and then in China.

In 2007, China's Ministry of Finance (MOF) cooperated with the National Development and Reform Commission (NDRC) to recommend "Interim Measures on Administration of Financial Subsidies for Promoting High-Efficiency Lighting Products". A large fraction of the subsidies of about 2.5B yuan (US$400M) from the central government in Beijing between 2008 and 2012 was focused on MOCVD facilities for LED chips. This funding had a global impact, for example in helping Aixtron and Veeco develop a new generation of equipment for epitaxy. The subsidies also helped Chinese companies to show profits even while making huge investments in the early stages of market growth. This made it possible for them to raise funds on the equity market. For example, the stock price of Sanan Optoelectronics rose from a value of 0.18 yuan in September 2006 to 43.56 yuan in July 2021. The stock price has dropped substantially since then, to 12.53 yuan at the end of April 2024, but the market capitalization of 62.5B yuan (US$8.6B) remains above that of Acuity Brands (US7.6B) and is more than double that of Signify (3.35B euros).


The stock price of Sanan Opto soared between 2008 and 2021.

The stock market impact has not been completely positive. Over-enthusiasm for capital investment led to fears of overcapacity and stock price declines, as seen in the chart for Sanan. Many small manufacturers did not survive through difficult periods and the total number of SSL suppliers has fallen from over 4000 to about 2500.

The majority of government funding for the lighting industry has come from local sources. Regional manufacturing hubs were created in several provinces, such as Guangdong, Fujian and Zhejiang. In 2012 Guangdong province issued an "LED Lighting Product Implementation Plan". Through a combination of subsidies, purchasing commitments by public authorities, technological innovation and standards development, the goals were to

- Popularize LED lighting in the whole society.
- Achieve energy savings of more than 50
- Drive the LED industry to annual sales of over 500B yuan.

This initiative enabled Guangdong to cap-

ture almost half of the industry's revenues in China and perhaps 25% of global revenues.

These local subsidies still persist. Digitimes Research reported that grants in the first half of 2020 amounted to 1.05B yuan. Other areas in China still strive to capture a share of the market. In February 2024, Changzhi City in Shanxi Province announced a 5-year plan entitled "Implementation Measures of Changzhi City to Encourage the High-Quality Development of the LED Industry".

Their plan includes:

- Factory construction subsidies of up to 35%
- Equipment purchasing subsidies of 15-50%
- Promotion and application of high value-added products
- Intelligent transformation of the industrial chain with grants up to 3M yuan
- Support for talent development with salary grants of up to 300,000 yuan per person.

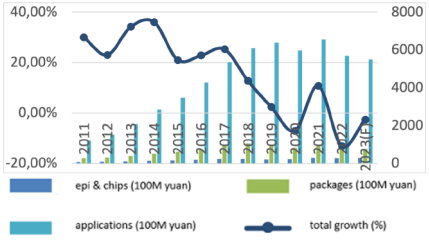
Encouraged by success in the penetration of the global SSL market, the attention of the central government has turned to other applications of wide-bandgap semiconductors (WBS), for example in power electronics for mobile devices. Industry and academia have responded, in R&D as well as in manufacturing. Since 2016, the China International Forum on SSL has been held jointly with the International Forum on WBS.

Most of this activity has involved GaN devices. Only five China-based companies boast SiC crystal growth expertise. However, in 2022 Sanan Opto received subsidies of 1.03B yuan from Beijing, including 700M yuan for a joint venture with ST Microelectronics to manufacture SiC chips on 200mm wafers which may come into production before the end of 2025. This will complement the existing SiC 'megafab' in Changsha based on 150mm wafers.

## SSL China in 2023

Each year the China Solid State Lighting Alliance (CSA) prepares an annual report on the status of the LED lighting market. This document, which is often referred to as the "Blue Book", is published right at the beginning of the year and so gives only preliminary data for the preceding year. This summary is based on the 2023 Blue Book, with some data updated from company reports.

The overall demand in 2023 was weak, with high inventory and insufficient capacity utilization. The total output value in 2023 was approximately 658B yuan, down 2.6% from 2022, of which the upstream epitaxial chip scale was 29.5 billion yuan, the midstream packaging scale was 78.2 billion yuan, and the downstream application scale was 550B yuan. The following chart shows that sales have fallen below the pre-pandemic levels of 2018 and 2019.




Revenues and growth rate of each link in the SSL industry in China 2011-2023.

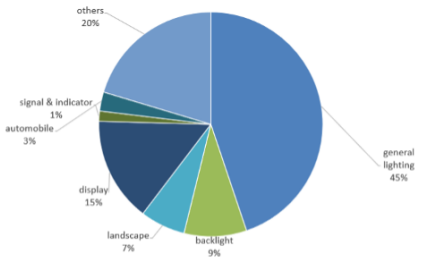
The total revenue of 658B yuan clearly includes some double or triple counting and exceeds most estimates of total global revenues for SSL.

Although the revenues of the leading chip makers have increased slightly, profitability declined substantially. Sanan Opto sustained an operational loss of 825M yuan, compared to profits of 125M yuan in 2022 and 1750M in 2021. Profitability was restored in 2024Q1, partly through a reduction in expenses, including in R&D. Faced with these challenges, the leading chip makers have formed partnerships with display panel manufacturers. Huacan Opto and Qianzhao Opto are now controlled by BOE and Hisense Video respectively, while Sanan has a joint venture with TCL. One exception to the general decline in profits was Jucan Opto, but the company attributes the improvement to its other business areas.

A similar situation was seen in the packaging sector, with increased sales but reduced profits. Jufei Opto was among the exceptions, with improved profits as well as sales. Consolidation continues. The number of companies engaged in LED packaging nationwide has fallen from more than 1,400 to just over 200.

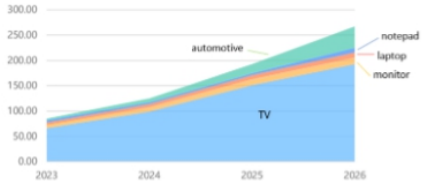
Among applications, the decline in the general lighting market is the most obvious. The operating income and profit of the sector fell by 6.1% and 14.4% year-on-year respectively. But, with 2023 sales of around 247B yuan, general lighting remains the dominant application.

One emerging sector that has shown rapid growth is mini-LEDs for display backlights.




General lighting is still the mainstay of SSL China.

The price of mini-LED chips dropped by more than 50% year-on-year, and the price of driver ICs fell significantly, due to the maturing of technology and improvement of yield rates. Domestic sales of TVs with mini-LED backlights in the first half of 2023 were 380,000 units, a year-on-year increase of 188%. The total mini-LED backlight module market is expected to grow from 8.5B yuan in 2023 to 26.8B yuan in 2026.




Mini-LED backlight module market size (100M yuan).

The packaging of mini-LEDs helped Mulinsen (MLS) to achieve higher sales and profits in 2023. Its overseas operations through LEDVANCE were stable and MLS may have joined the top 3 global lighting companies in revenue, along with Signify and Acuity Brands. Opple Lighting also reported gains in both respects and is expanding its presence in other Asian countries.

Outdoor lighting is also showing strong growth in China. According to Guanyan Tianxia, revenues rose from 98B yuan in 2018 to 164B yuan in 2022, driven mostly by public spending on roadway and landscape lighting. Night lighting has become an important part of "cultural tourism". The Guangzhou International Light Festival resumed in 2023 and attracted almost 100M visitors. In the 3rd quarter of 2023, over 1.5B yuan was invested in 25 regions to boost night lighting shows **[1]**.

Lakeside lighting shows in Xianyang and Jiujiang.

Overall, the lighting industry is regaining its optimism. At least 25 companies were involved in new construction projects in

2023, with a total investment of over 17.5B yuan. These include the world's largest lighting manufacturing base with 192 production lines built in Jiujiang by Signify at a cost of 2.8B yuan.

## SSL in Japan

Japan has traditionally been one of the major global bases for the lighting industry, particularly in Asia. It is difficult to assess its overall role in SSL production, since the major producers are either private or small units of large conglomerates. Some data is available through the Japan Lighting Manufacturers Association (JLMA).

In 2022 the value of imports of lighting products to Japan was 142B yen, far exceeding exports at 12.4B yen. JLMA estimates that 217M lighting fixtures were produced in Japan, with a value of 1030B yen, leading to total national sales of 224M fixtures with a value of 1260B yen (US$8.2B). Penetration of LEDs in these fixtures is extremely high, at close to 98%.

The situation regarding replacement bulbs seems to be very different. JLMA reports that 41M incandescent bulbs were sold in 2022 along with 59M fluorescent tubes and 18M other discharge lamps. Sales of LED bulbs and tubes were only 18M and 2.2M, respectively.

Looking at the performance of individual companies, LEDInside reports that global lighting revenues at Panasonic were US$935M in the 6 months ending September 30th, 2023, while those from Toshiba were US$408M. Both remain in the top ten global lighting companies. Koito Manufacturing and Stanley Electric consolidated their positions among the global leaders in automotive lighting. Koito's revenues in FY2024 rose by 10% to 950B yen and profits were up by 20% to 56B yen. Substantial sales gains were shown in every global region except for China. Stanley Electric's sales climbed by 8% to 472B yen, while profits rose by 3% to 36B yen.

Among the smaller companies with an overseas presence, Endo Lighting had an excellent year in general lighting and lighting controls, with sales of 52B yen for FY2024, up from 46B yen, and profits rising by 68% to 5.2B yen.

## SSL in Korea

Korea was the dominant supplier of flat panel displays for 17 years until 2021, using both inorganic and organic LEDs as light sources. However, its dominance of the OLED display market is being challenged by China. China accounted for 42.5% of the global display market in 2022, while Korea held a 36.9% share, according to the Korea Display Industry Association. In response, Korea's display industry has unveiled an ambitious plan to invest over 65 trillion won (US$49B) by 2027. The strategy, which was announced in May 2023 by the Korean Ministry of Trade, Industry and Energy (MOTIE), aims to increase Korea's global market share to 50% and widen the technology gap with competitors by more than five years.

The Korean government aims to facilitate these investments by providing support through tax incentives, public financing of up to 900B won, and infrastructure improvements. Strengthening the supply chain is another crucial aspect of the strategy. Korea aims to increase its self-sufficiency ratio in materials, parts, and equipment from the current 65 percent to 80 percent. The support will extend to small businesses operating in sectors such as fine metal masks, exposure machines, and packaging equipment. Recognizing the importance of skilled human resources, the public and private sectors will collaborate to train 9,000 talented engineers over the next decade. The government will establish specialized graduate schools and introduce new undergraduate majors to cultivate master's and doctoral level manpower.

Junghoon Lee, CEO of Seoul Semiconductor (SSC), has expressed concern that more than 99% of LEDs used at domestic light festivals and regional events are imported **[2]**. He specifically recommends public support for micro-LED display development. SSC's sales in 2023 were 1033B won, down from 1109B won in 2022 and 1301B won in 2021. Operating losses rose from 33B won in 2022 to 48B in 2023. To reduce costs, SSC has already moved most of its chip manufacturing to Vietnam and is transferring more of its development work to that country.

Among the smaller Korean companies, Seoul Viosys focuses on UV and micro-LEDs, along with IR/VCSELs and several LED product systems. Despite a 15% growth in sales in 2023 to 505B won, operating losses mounted to 73B won from 62B won in 2022. Lumens was able to report a small operating profit of 3.1B in 2023 with sales rising by 3% to 171B.

## SSL in India

India is the largest potential market for SSL in the next decade, with GDP growing approx. 8% per year and a population that now exceeds that of China. Its lighting industry has been reoriented to manufacture products based upon imported chips and packages.

In 2022 the Indian government launched a Production Linked Incentive (PLI) Scheme to incentivize local manufacturers by providing financial support and a friendly business environment, with a 7-year budget of Rs 62B rupees. One goal of the scheme is to fortify India's role in global supply chains and position Indian manufacturing industry as a core exporting nation. For lighting, the PLI initiative aims to boost local value addition from 25% to 85% by 2028, covering 87% of the LED sector's Bill of Material. Although the scope of the PLI includes LED chip making and packaging, the companies seem to agree that this is not viable at this time.

Further bolstering domestic electronics manufacturing of components is the upcoming scheme by the Ministry of Electronics and Industry, with an allocation of 200B rupees, along lines similar to the PLI.

Crompton Greaves estimates that current sales of lighting products are about 150B rupees. Philips Lighting India is still a dominant supplier, with one manufacturing plant and over 3200 employees. Statista estimates that the revenues of Philips India in 2021 were about 24B rupees. Panasonic Electric Works maintains a strong presence in India and is planning to increase exports of products there. AMS-Osram also still has some involvement.

Among domestic companies, Syska describes itself as one of the top 3 suppliers, with 15-20% of the market, but does not provide sales figures to confirm this. Dixon-India claims to be the 4th largest manufacturer of LED lamps in the world and to produce 50% of the LED lamps made in India, making 300M bulbs, 50M tubes and 18M downlights per year.

The fiscal year in India ends on March 31st. The revenues and operating profits of the lighting divisions of the major public companies are summarized in the **Table 1**.

| Company | Lighting Sales | | Profits | |
|---|---|---|---|---|
| | INR B | % Change | INR B | % Change |
| Bajaj Electric | 10.4 | -8% | 0.80 | -9% |
| Crompton Greaves | 10.0 | -6% | 1.00 | 5% |
| Dixon India | 7.9 | -25% | 0.59 | -35% |
| Havells | 16.3 | 2% | 2.47 | 1% |
| Surea Roshni | 15.7 | 2% | 1.21 | 28% |

Table 1: Lighting Sales and Profits for FY2024 (Billion Rupees).

## SSL in Indonesia

SSL has been a mixed blessing for the 280M people of Indonesia. The critical need to save energy and reduce the dependence on coal caused the government to promote the adoption of LEDs. By 2019, LEDs accounted for over half of the stock of 680M lamps and less than 10% were incandescent or halogen bulbs. This data comes from a comprehensive market study by CLASP and Price Waterhouse Cooper **[3]**.

Up until 2014, a substantial number of lamps were manufactured in Indonesia for domestic sales or exports. But local producers have been unable to match the low costs of LED lamps from China. So in 2018 less than 30% of the 160M lamp shipments were produced domestically. The proportion varied by technology, from 39% for incandescent, 27% for CFL, and 13% for LED. Total lighting exports from Indonesia fell dramatically from 56M units in 2014 to 2M in 2018. 96% of the imported lamps came from China.

Data from the Association of Indonesia Lighting Manufacturers (Gamatrindo) showed that they were trying to adapt to LED technology. Their members had a production capacity of 58M LED lamps but were able to sell only 6.3M units.

The Indonesian government is taking steps to rebuild its lighting manufacturing capabilities. Help was provided by the UN in 2020 through the 4-year project ADLIGHT **[4]**. This involves implementing regulations, procurement policies, new business models, and awareness campaigns to boost market penetration of energy-efficient LEDs. Eight local LED manufacturing companies received technical and financial assistance.

The creation of jobs based on new technologies is critical to the economic development of all countries in Asia. More recent data on the impact of these lighting initiatives in Indonesia and India will provide valuable guidance to other neighboring countries.

## Summary

This article provides a comprehensive overview of the solid-state lighting (SSL) industry in Asia, focusing on the transformative role of government interventions, particularly in China. Substantial financial subsidies from both local and national governments have been pivotal in establishing a robust SSL manufacturing base in China, driving significant growth and enabling Chinese companies to gain a competitive edge globally. Despite the benefits, the industry faces challenges like market saturation and the sustainability of smaller firms amidst aggressive expansion. Other regions in Asia are also leveraging similar strategies, aiming to harness SSL's potential for energy savings and economic growth. The SSL industry's future in Asia appears optimistic, with ongoing investments and innovations expected to drive further advancements. This regional focus on SSL not only underscores the critical role of governmental support in technological advancements but also highlights the dynamic nature of the global lighting industry. ■

## References

[1] https://www.alighting.cn/news/20231023/175294.htm
[2] https://www.mk.co.kr/en/society/11002197
[3] https://www.clasp.ngo/wp-content/uploads/2021/01/Indonesia-Lighting-Market-Study-and-Policy-Analysis.pdf
[4] https://indonesia.un.org/en/266443-advancing-indonesia%E2%80%99s-lighting-market-high-efficient-technologies-adlight-factsheet

## Additional SSL reports by Dr. Bardsley already published in this year's LED professional Review

LpR#102, Mar/Apr 2024, p44
**Solid-State Lighting Report – The Impact of LEDs on Electricity Consumption and Global Warming**

Through the adoption of LEDs, the lighting industry has made a substantial contribution to the mitigation of global warming. But stocktaking made in 2023 by the United Nations Environmental Program (UNEP) showed that the total global effort to reduce emissions of greenhouse gases (GHG) is falling far short of what is needed to achieve the targets set in the Paris Agreement of 2015. The World Meteorological Organization (WMO) has judged that 2023 was the hottest year on record and there seems to be no slowing in the rate of increase in the global mean temperature. The purpose of this report is to assess the contribution of lighting in reaching these goals and to urge the industry to maintain its concern about this important issue.

LpR#101, Jan/Feb 2024, p40
**Solid-State Lighting Report**

This summary of the latest ISA report on Solid-State Lighting (SSL) encompasses a comprehensive analysis of the SSL industry's progression, its impact on global energy use, and future outlooks. The report details the substantial strides made by SSL, emphasizing its potential in revolutionizing lighting while being energy-efficient. Initially, the report highlights the importance of SSL in the context of global warming and energy conservation. It underscores light as a crucial necessity and the role of SSL in providing high-quality, affordable artificial lighting worldwide, which has significant implications for global energy consumption and environmental sustainability. The report stresses the industry's technical advances and its leadership role in sustainable resource utilization. In summary, this SSL report offers a nuanced view of the SSL industry, celebrating its achievements while critically analyzing its challenges and future prospects. It serves as a call to action for continued innovation, collaboration, and commitment to making SSL a cornerstone of sustainable, equitable, and high-quality lighting worldwide.

This photo, as well as the cover of this issue feature Artemide's luminaire "Stellar Nebula". (c) Artemides.
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# Expert Talks on Light – Time Matters, Shining Light on Metabolic Health

Good Light Group, Society for Light Treatment and Biological Rhythms, the Daylight Academy, and Luger Research | 7th Edition

## Dr. Charna Dibner – Moderation

Charna Dibner completed her PhD in Medical Sciences under the supervision of Professor Dale Frank in the Department of Biochemistry at the Technion Israel Institute of Technology, headed by Nobel Laureate Professor Avram Hershko. She next moved to Geneva where she completed her postdoctoral training at the Faculty of Science, University of Geneva, with Professor Ueli Schibler, working on the mechanisms of transcriptional and temperature compensation of the mammalian circadian clocks. In 2009, she was appointed as a Group Leader of the Laboratory of Circadian Endocrinology at the Faculty of Medicine, acquired her Private Docent degree, and was nominated Associate Professor in 2021. Her work centers upon the implication of circadian oscillators in regulation of metabolic processes in mammals. In particular, she is interested in intricate interplay between the islet cellular clocks, and in the inter-organ desynchrony upon metabolic diseases, unraveling the roles of the circadian clocks in human metabolic diseases. Charna's work has been awarded with several prestigious Swiss prizes including Roche Research Foundation prize, Takeda prize for diabetes research, the awards by French Swiss Foundation of Diabetes Research, and Leenaards and ISREC Foundation awards for translational research.

## Dr. Kathryn Reid – From the Real World to the Lab: Why Light Matters for Metabolic Health

The impact of light is dependent on when it occurs relative to the internal biological clock, and as such the timing of when we get light or dark across 24-hours matters. Light exposure patterns are a modifiable factor that can have significant impact on health and wellbeing. Results from real world and laboratory-controlled studies that examine the impact of light exposure on health will be discussed. From pregnant women to older adults, data from real-world monitoring of light levels suggests that higher levels of light exposure in the few hours before and during sleep are associated with poor metabolic health. The mechanism underlying these findings are supported by controlled laboratory-based studies examining the impact of light on cardio-metabolic function. Together these studies suggest that interventions to optimize the pattern of light-dark exposure across the 24-hour day could be beneficial to health in vulnerable populations.

## Dr. Jan-Frieder Harmsen – Diabetes in the Daylight: Metabolic Benefits Through Natural Office Lighting?

He talks about a recently completed study, in which he tested if natural daylight during office hours is more beneficial for metabolic health outcomes of type 2 diabetes patients compared to constant artificial lighting.

## Recorded Talk

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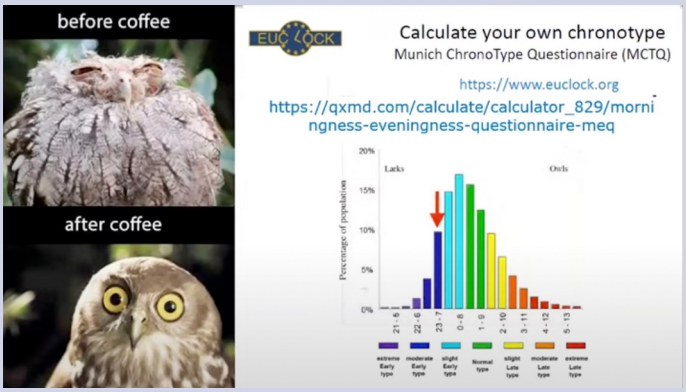


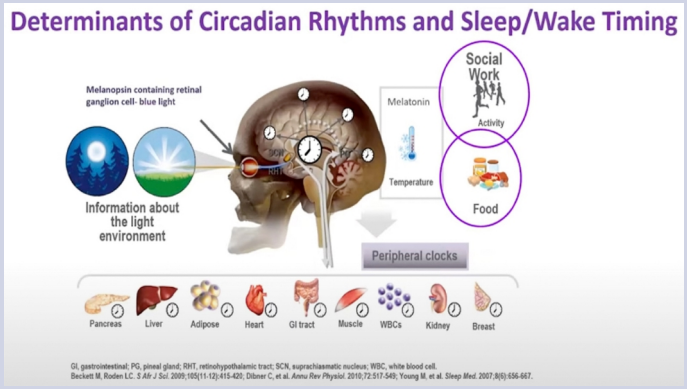


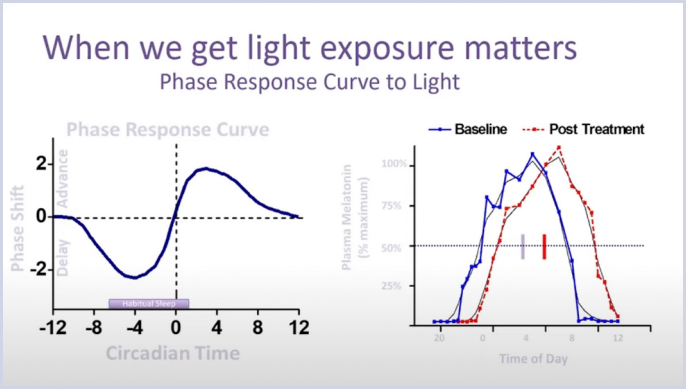


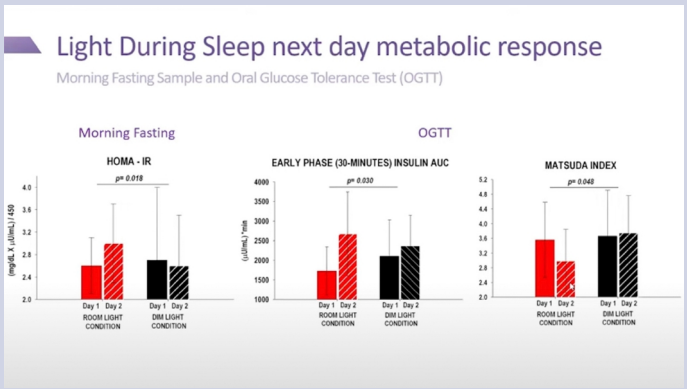


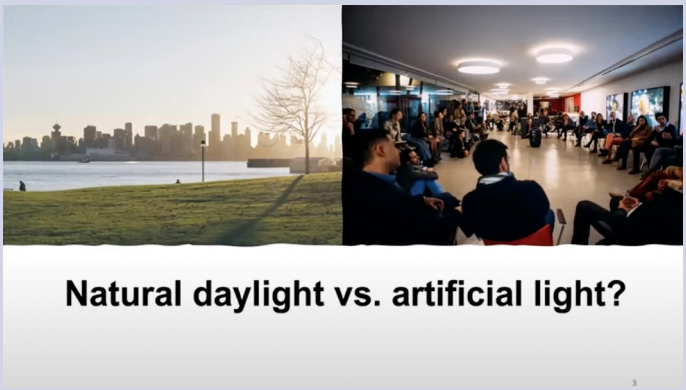


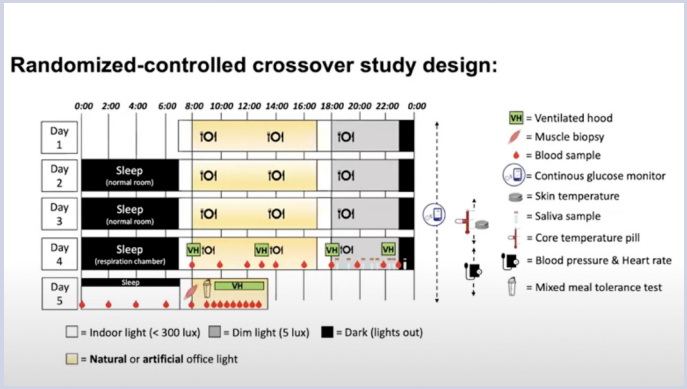


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## PREVIEW*
## July/Aug 2024 | LpR 104

### Good Light & Eco-Design

The July/August 2024 issue of LED professional Review will focus on the very latest topics in the world of lighting. We will be introducing a revolutionary phosphor technology that achieves high CRI values. A report from Signify will reveal the latest trends in 3D printed luminaires. This issue will also include the first publication of a new white paper from The Good Light Group. On top of all that, we will be introducing another expert to you in our continuing interview series with the CIE.
It goes without saying, that to round out this issue, there will be the latest international lighting news and a new LpS Digital Talks as well as a commentary from a leading lighting authority.

* *Subject to change without notice.*

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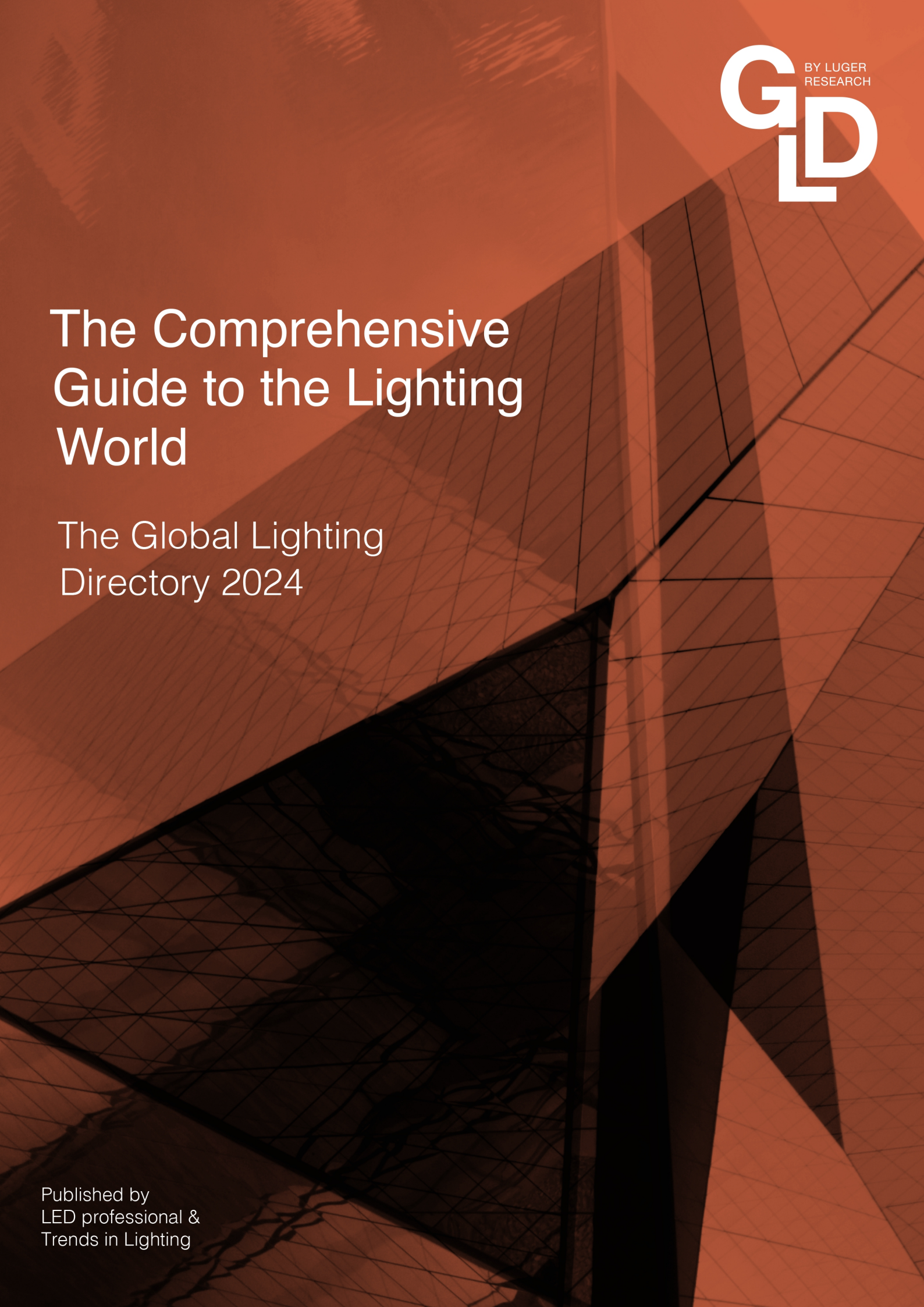

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