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Review

LpR 110

July/Aug 2025

LUMILEDS UNVEILS LED INNOVATIONS

DISINFECTION WITH AUTOMATED UV-C LED SYSTEMS

SUSTAINABLE PUBLIC LIGHTING PART I

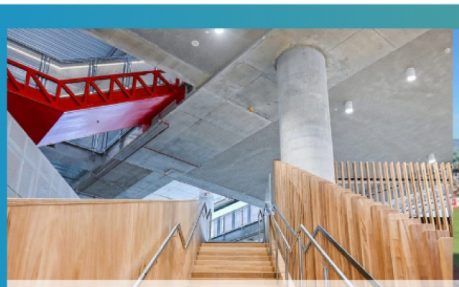
The Global Information Hub for Lighting Technologies and Design

Revolutionizing Light Measurement with Camera Technology

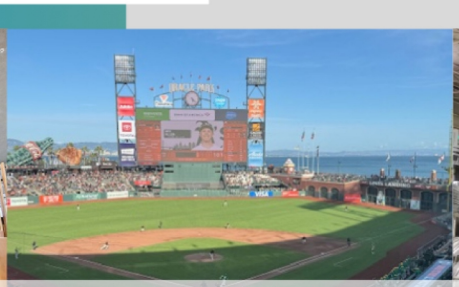
PAGE 32

Lighting Awards 2024 / 2025

WINNERS



Commercial Interior
bluebottle



Commercial Exterior
Best Use of D4i
Synapse Wireless

Industrial & Infrastructure
Smart & Connected Lighting
Beijing Hanmingde Technology Development Co., Ltd.

Residential
Philips Dynalite

Best Emergency Lighting Integration
Crown Electrical

Best Human Centric Design
KUMUX & Inventronics

Best Integration into Other Building Systems
Signify

Innovation in Lighting
Shenzhen Sunricher Technology Co.,Ltd.

Sustainability & Energy Efficiency
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LIGHT AGAINST GERMS AND FOOD WASTE

RESEARCH EXCELLENCE FROM AUSTRIA

LUMITECH
YOUR LIGHTING SOLUTION
INNOVATION WINNER 2025*
LIGHTING TECHNOLOGY | AUSTRIA
* Study by the IMWF Institute for Management & Economic Research / Kurier
AWARDED

LUMITECH: Shaping the Future with Advanced Lighting Technologies

Since its founding in 1997, LUMITECH, headquartered in Jennersdorf, Austria, has been a pioneer in the field of LED and UV-LED lighting technologies. Collaborating closely with research institutions and industry partners, the company continues to lead the way in developing forward-looking, energy-efficient lighting solutions that address real-world challenges.

Recognized Industry Leadership

A recent study by the IMWF Institute for Management and Economic Research analyzed 1,900 Austrian companies across various sectors. **LUMITECH Lighting Solution emerged as the top company in the lighting technology** category-highlighting its innovation capabilities, technical expertise, and significant market presence.

Innovation for Food Safety & Sustainability

LUMITECH's **NaturalMeat** lighting solution sets new standards in food illumination. By using a specially developed light spectrum, the technology slows the greying process of meat and sausage products, extends shelf life and helps reduce food waste. Independently evaluated by the Fraunhofer Institute, NaturalMeat also boosts energy efficiency and product safety, while supporting regional manufacturing.

In collaboration with Graz University of Technology and Joanneum Research, LUMITECH also advances the **LED4foods** project. The aim is to reduce spoilage of fresh foods like produce and meat in supermarkets by applying optimized lighting conditions. Initial findings confirm that specific light settings can significantly delay aging and improve product freshness on shelves.

UV-LED Technologies for Public Health

LUMITECH is also helping address global health concerns with its high-performance UV-C LED components. In a breakthrough initiative, the company contributed to the development of an autonomous **UV-LED disinfection robot** for hospital use. The robot navigates rooms independently and eliminates viruses, bacteria and multi-resistant pathogens from surfaces—without chemicals-using short-wave UV-C light.

In another project, a **field study in kindergarten environments** is evaluating a compact, ceiling-mounted UV-C LED disinfection unit. Designed to resemble a smoke detector, the device provides continuous, chemical-free surface disinfection in high-demand public spaces. The study demonstrates the technology's effectiveness, safety, and real-world applicability in childcare settings.

Dr. Stefan Tasch
CEO LUMITECH Lighting Solution GmbH

Whether in healthcare, food retail, or public safety, intelligent lighting holds remarkable potential. LUMITECH positions itself not only as a technology provider but as a true innovation driver from Burgenland. Through interdisciplinary research and a strong focus on sustainable impact, the company continues to deliver tangible solutions to today's pressing challenges.

LUMITECH
YOUR LIGHTING SOLUTION

Technologiepark 10 | 8380 Jennersdorf

www.lumitech.com

Human Health, Technology & Sustainability

We're excited to bring you another edition filled with thought-provoking content and cutting-edge innovation.

Dr. Wunsch opens this issue with a commentary urging us to rethink how we perceive light and light sources — proposing a new path toward human wellbeing through lighting. We're also pleased to feature an exclusive interview with two leading LED experts from Lumileds, Dr. Oleg Shchekin and Dr. Toni López, who offer insights into the latest breakthroughs in solid-state lighting.

A compelling field study from Lumitech demonstrates how UV-C LED lighting can significantly reduce microbial load under real-world conditions — presenting a highly effective, automated lighting solution for disinfection.

The team at [o3u] introduces a groundbreaking camera-based system that enables real-time photometry, setting a new benchmark in lighting measurement and development workflows.

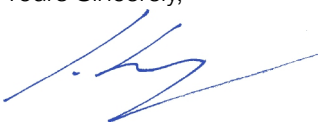
We were also honored to attend Zumtobel's 75th anniversary celebration — a fantastic event featuring expert talks, panel discussions, and an inspiring gala evening. In this issue, we highlight key takeaways from this milestone event, reflecting on the multifaceted perspectives of light that were shared.

In the first part of a two-part article series, Bartenbach presents an in-depth study on sustainability in public lighting, focusing on responsibilities and thematic challenges. Tapio Rosenius dives into the technological dimension under the title "From Calm Technology to Ambient Communication". Tapio introduces a real-time system for visual environments — a powerful new approach for lighting design.

We hope you enjoy reading this issue and find inspiration in its pages.

Warm regards,

Yours Sincerely,



Siegfried Luger

Founder & CEO of Luger Research e.U.
Publisher of LED professional, Trends in Lighting, LpS Digital, and the Global Lighting Directory

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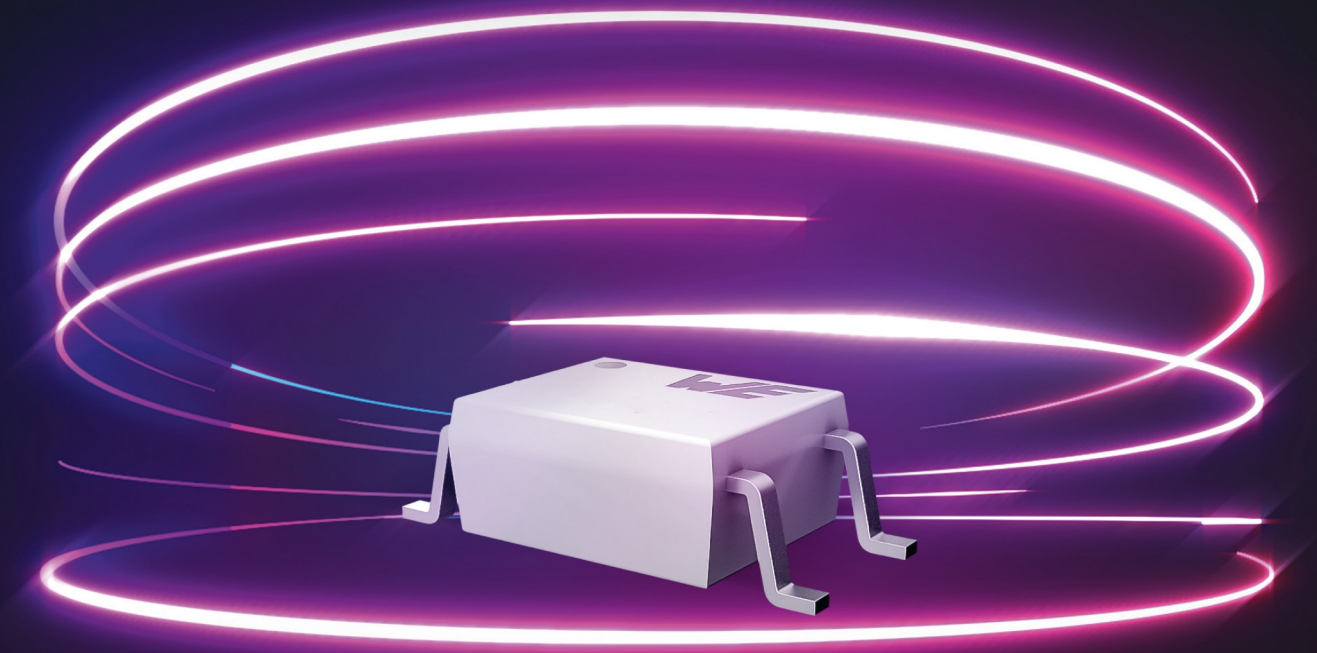

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- Copper leadframe for high reliability
- Stable CTR over whole temperature range
- High CTR in low current operation

DIP-4 SOP-4 LSOP-4

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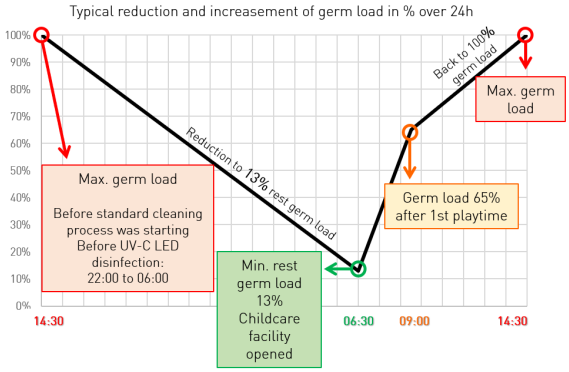
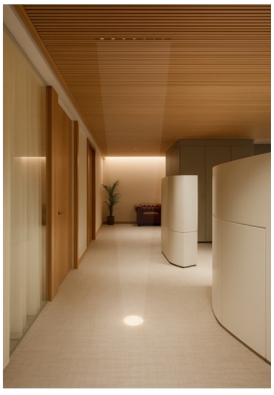
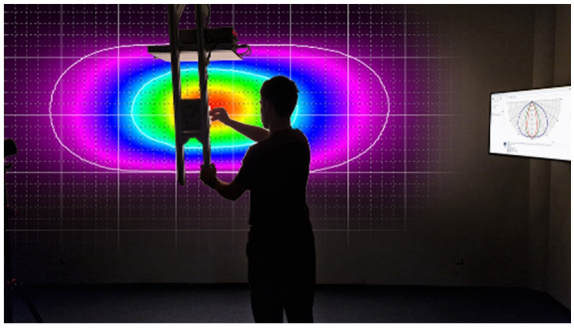
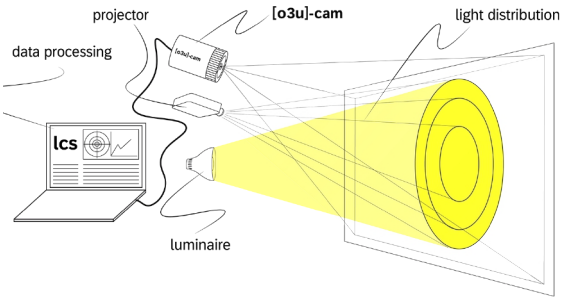


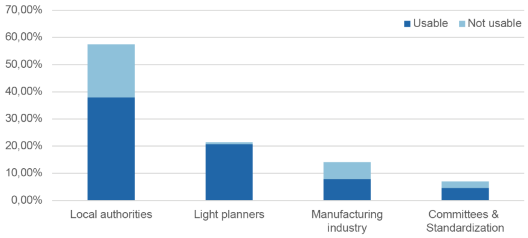






ANNIVERSARY

SUSTAINABILITY



LIGHTING DESIGN

LPS DIGITAL TALKS

ADVERTISING INDEX

Healthy Lighting Beyond Dogma: Redesigning Light for Human Wellbeing

Dr. Alexander Wunsch

Dr. Alexander Wunsch, MD, PhD, is a physician, light therapist, independent researcher, and scientific consultant. From 2008 to 2019, he served as a lecturer in the Master of Arts program in Architectural Lighting Design at Wismar University of Applied Sciences. His research is focused on the physiological and pathological effects of light on humans, and he has been a vocal critic of the ban on incandescent lamps. His work advocates for a paradigm shift in the field of photobiology and calls for a health-centered redefinition of lighting standards.

Dr. Wunsch emphasizes the necessity of shifting from the utilization of energy efficiency as the predominant criterion for indoor lighting, promoting instead the adoption of salutogenic lighting concepts grounded in human biology. This approach prioritizes the beneficial impact on health over considerations of technical or economic feasibility.

wunschart@gmail.com

For over a century, the development of artificial lighting has been driven by technical feasibility and economic efficiency. From thermal light sources like incandescent bulbs to "cold" technologies such as fluorescents and LEDs, the industry has prioritized engineering goals over physiological needs—often at the expense of human health.

Contemporary light sources focus on reducing heat loss and increasing luminous efficacy. But this shift led to a spectral imbalance: the transition from thermal to cold light removed essential components of the spectrum, such as near-infrared (NIR), and introduced flicker and poor color rendering. While sunlight, fire, and incandescent lamps provide a biologically rich and visually comforting experience, many modern sources fall short - despite being promoted as "daylight-like."

This marketing sleight of hand relied heavily on the concept of correlated color temperature (CCT), which mimics the look of natural light but not its spectral substance. CCT ignores critical biological effects, creating the illusion that artificial light can replace sunlight simply by matching its visual appearance.

In reality, the pursuit of maximum energy efficiency leads to biologically impoverished light: the best energy efficiency class yields the worst spectral composition. High energy efficiency means low infrared (NIR) output and exaggerated short-wave components. This spectral imbalance can cause retinal damage, increase visual stress and induce hormonal maladaptation. At the same time, the reduction of NIR deprives the retina and other tissues of wavelengths essential for photobiomodulation (PBM) - light-mediated cellular support and regeneration.

Contrary to popular belief, "biologically effective" does not mean "biologically beneficial". Light rich in short wavelengths can increase alertness during the day - but the suppression of melatonin is only a proxy for an avalanche of potentially harmful reactions. If light sources promote alertness during the day, this effect is not mainly due to melatonin suppression - since melatonin levels are already low - but rather to increased secretion of stress hormones like catecholamines and cortisol, which can induce systemic stress. For a population that exceeds 30% of the general public - namely, individuals who require medication for hypertension - the objective is not to stimulate their physiology through light, but rather to implement a lighting scheme that is hormonally neutral and does not induce chronic stress. Light can be pathogenic!

Modern dynamic lighting systems can adjust spectrum and intensity throughout the day, but unless designed with biological goals in mind, they risk doing more harm than good. Supporting circadian health and visual comfort requires a shift from narrow performance metrics to human-oriented (not to be confused with human-centric!) criteria.

Unfortunately, today's regulations hinder rather than help. Thresholds and standards for lighting products often ignore recent scientific evidence. Health-supportive solutions - such as full-spectrum, flicker-free, NIR-enriched lighting - are sidelined by energy efficiency rules that fail to account for long-term physiological outcomes.

What's needed is a paradigm shift: away from a technocratic focus on what is efficient, and toward a salutogenic lighting philosophy - one that promotes health by physiological compatibility. This means embracing lighting designs that support circadian alignment, visual clarity, cellular regeneration, and psychological wellbeing. We now have the LED technology to deliver truly healthful light. What's missing is a regulatory framework that allows its implementation. Lighting success should not be measured in lumens per watt alone but in its capacity to sustain human physiology over time.

Conclusion

Healthy lighting is not a luxury - it is a necessity in our increasingly indoor lives. As professionals, researchers, and standard setters, we must take responsibility for creating light that respects the complexity of human physiology. That means being honest about trade-offs, acknowledging the limits of current standards, and designing lighting that aligns with our biological blueprint - not just our energy budgets. ■

Good light
for a healthier and happier life

Discover how good light indoors can improve sleep, energy and physical and mental well-being.

www.goodlightgroup.org

Photo by Copernico P on Unsplash

Good Light Group

The Good Light Group is an international non-profit organisation promoting the use of biologically effective light, indoors and outdoors, for better sleep, mood and overall health. We collaborate with leading researchers, architects, lighting designers, engineers and lighting companies to bring evidence-based daylight solutions into everyday environments.

Learn more or become a participant: **info@GoodLightGroup.org**

LightingEurope Drives Harmonization of Environmental Declarations with Open Technical Memorandum for Control Gears

www.lightingeurope.org

LightingEurope publishes open technical memorandum to support reliable and harmonized EPDs for control gears for light sources.

LightingEurope and its members have recognized the increasing demand from the market and the importance of delivering reliable sustainability information for lighting products, empowering customers to make informed purchasing decisions and supporting the reduction of the environmental footprint for municipalities, businesses, and individuals.

LightingEurope previously identified the complexities and lack of harmonization in LCA rules for luminaires and contributed actively to the revision of a dedicated set of Product Specific Rules (PSRs) (PEP Ecopassport PSR0014). This effort brought valuable lighting industry knowledge to the Programme Operator and resulted in the successful publication of revised rules. These rules are now being promoted for standardization through Global Lighting Alliance, IEC standardization initiatives, and Programme Operator mutual recognition agreements.

Building on this experience LightingEurope identified the further need to develop clear rules, requirements, and guidelines to conduct LCAs for key luminaire components, namely the light source and the control gear for the light source.

To meet this need and to support the market's growing demand, LightingEurope has published a neutral Technical Memorandum that defines Functional and Declared Units, Reference Service Life, Reference Flow Elements and default scenarios for control gears for light sources.

Elena Scaroni, LightingEurope Secretary General emphasised: "We have published these rules to support the increasing need for reliable sustainability information and to continue driving the highest possible level of harmonization of LCA rules. Only through accuracy and harmonization can EPDs become a reliable and effective tool for our industry and for the wider market. Therefore, this document is freely available to all interested LCA Programme Operators and Standardisation Organizations via the LightingEurope website."

Teresa Selvaggio, Director of Public Affairs remarked:" This publication complements the previous work completed by LightingEurope and is intended to interact with existing core Product Category Rules published by different Programme Operators and Standardization Organizations. In addition to this document on control gears, our experts are currently also working on developing specific rules for LCA of light sources."

LightingEurope invites feedback and questions from all interested organizations and remains open for future exchanges. The Technical Memorandum on Control Gears for light sources is available here (lightingeurope.org). ■

Lighting: A Critical, Yet Overlooked, Technology in the EU Green Transition

www.lightingeurope.org

As Europe strides towards more sustainability, the energy efficiency industrial ecosystem is pivotal, with lighting playing a crucial, yet often underappreciated role. Beyond mere utility, lighting enhances life quality, is a cornerstone of energy efficiency and should be better recognized as such in EU legislation. Supported by 17 of our national association members, we publish a statement highlighting the vital role of lighting in Europe's green and competitive future.

The impact of lighting technologies
In Europe, lighting represents about 12% of the electricity consumption. Transitioning to energy-efficient lighting offers an immediate opportunity to reduce both energy demand and CO_2 emissions. Europe is only halfway through the shift to LED technology, and combining LEDs with sensors and controls can unlock energy savings of up to 80%.

Europe's lighting industry: A hub of innovation.
The European lighting market, valued at over €20 billion, is a hotbed of innovation, sustaining around 120,000 jobs, with over 600 patents filed between 2021 and 2022. The sector has a strong European footprint, with most R&D conducted on the continent.

A Call for Recognition and Action

To fully leverage the benefits of lighting, we urge policymakers to:

- Recognize lighting as an essential technology for the green transition, including through incentives and financing support via EU budget instruments.
- Implement ambitious energy efficiency measures and renovation policies at the national level.
- Prioritize quality and sustainability in public procurement.
- Simplify and clarify lighting product rules, without overhauling existing requirements.
- Strengthen the enforcement of existing EU rules, especially in online markets.

How to Access the LightingEurope Statement.
Read the statement and the full list of recommendations here (lightingeurope.org). ■

European Parliament IMCO Report Falls Short on Product Compliance Online

www.lightingeurope.org

The European Parliament's Committee on the Internal Market and Consumer Protection (IMCO) adopted its draft own-initiative report entitled "Product Safety and Regulatory Compliance in E-commerce and Non-EU Imports."

"While the recognition of widespread non-compliance in online sales and the acknowledgment that the current system fails to adequately address these issues are welcome, it is disappointing that the report stops short of proposing a meaningful solution to a problem that undermines the integrity of the Internal Market and erodes the competitiveness of European companies", stressed Elena Scaroni, Secretary General of LightingEurope.

"EU legislation should ensure that there is always an economic operator established in the EU for the products sold on the EU market, whether offline or online. Neither the Digital Services Act, nor the General Product Safety Regulation are setting requirements that are ambitious enough to close the existing legal loophole", added Marion Ebel, Director of Corporate Affairs.

The 2024 results of our mystery shopping

exercise reveal alarmingly high rates of non-compliance among lighting products sold on online marketplaces in the EU. Of the 275 products surveyed (G4 lamps on mains, LED strips and Children's Night lamps), 100% of those inspected online were found to be non-compliant. In addition, 20 products, including children's night lights and LED strips, were selected and tested against the relevant safety standards in an accredited laboratory, and all were found to be non-compliant.

"By failing to assign liability to online marketplaces in cases where products are sold by non-EU sellers with no identifiable importer, authorized representative, or fulfilment service provider, the EU effectively enables a system that facilitates the entry of non-compliant products into the Union. This not only overburdens already stretched Market Surveillance Authorities but also places compliant European businesses at a competitive disadvantage", concluded Marion Ebel.

For more information, please contact Elena Scaroni, Secretary General of LightingEurope, though elena.scaroni@lightingeurope.org.

About LightingEurope
LightingEurope is the voice of the lighting industry, based in Brussels and representing 32 companies and national associations. Together these members account for over 1,000 European companies, a majority of which are small or medium-sized. They represent a total European workforce of over 80,000 people and an annual turnover exceeding 15 billion euro. LightingEurope is committed to promoting efficient lighting that benefits human comfort, safety and well-being, and the environment. LightingEurope advocates a positive business and regulatory environment to foster fair competition and growth for the European lighting industry. More information is available at www.lightingeurope.org. ■

Signify Names As Tempelman as Chief Executive Officer

www.signify.com

Signify (Euronext: LIGHT), the world leader in lighting, announced that As Tempelman will become the new Chief Executive Officer (CEO) of Signify from September 1, subject to his appointment to the Board of Management, with Željko Kosanović continuing as interim CEO until then.

"We are thrilled to appoint As Tempelman as CEO of Signify," said Gerard van de Aast, Chair of the Supervisory Board of Signify. "His strategic vision, energy and proven track record in driving sustainable growth, while building an inclusive high-performance culture, made him the clear choice to lead the company forward."

"With more than 130 years of history, Signify has always been a pioneer. The innovation, passion, and purpose that define this company are incredible, and that's what drew me here. I am very excited to be joining the team," said As Tempelman. "Looking to the future, I believe there is a real opportunity to grow. To build on existing strengths, unlock new possibilities, and continue to lead the way in lighting and beyond, improving lives for people and communities around the world."

As Tempelman currently serves as CEO of Eneco, an integrated sustainable energy company operating throughout the Netherlands, Belgium, Germany and the United Kingdom. Under his leadership, Eneco has delivered against ambitious business and climate initiatives, tripling company profitability since 2020, while reducing GHG emissions by 40% per annum. Prior to Eneco, As held senior leadership positions at Shell in Asia, Europe, the Middle East and Africa.

An Extraordinary General Meeting (EGM) will be held in July, at which shareholders can vote on As' appointment to the Board of Management. ■

Signify Innovation to Take Center Stage at Light + Building 2026

www.signify.com

Signify (Euronext: LIGHT), the world leader in lighting, announced that it will join Light + Building 2026, the world's leading trade fair for lighting taking place from March 8 to 13, 2026 at Messe Frankfurt. The company's expansive exhibition booth will feature the latest products, connected systems and service innovations from Signify and its global portfolio of leading lighting brands.

"As Signify, we're proud to be driving meaningful progress—and as we look ahead, we are more committed than ever to lead from the front, with our ecosystem of smart, connected and sustainable lighting solutions

that can elevate entertainment, enhance well-being and productivity for our customers and users."

Building on the company's strong heritage, Signify will present an elevated brand presence at Light + Building 2026—with a focus on its professional and OEM offerings. From Signify innovations such as myCreation, NatureConnect and BrightSites, Interact IoT software, Philips LED luminaires and Dynalite lighting controls, as well as smart home brands Philips Hue and WiZ, Signify continues to lead the way across the full spectrum of lighting.

"We're excited to showcase the latest innovations from our portfolio of leading brands to customers from across Europe and beyond." – Željko Kosanović, CEO ad interim at Signify

Customers visiting the Signify booth can interact with Signify's ecosystem of leading brands across applications including intelligent buildings, connected public and outdoor lighting and entertainment.

About Light + Building
Light + Building is the world's leading trade fair for lighting and building services technology. The Light + Building event will take place from 8 to 13 March 2026.
www.light-building.com ■

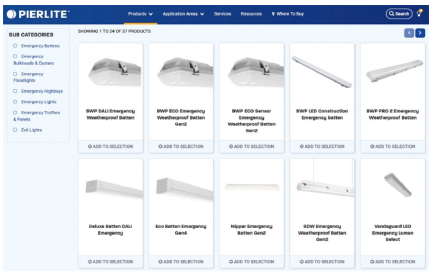
Signify Launches Interact Emergency Lighting System for Seamless Cloud-based Control, Monitoring and Testing of Emergency Lighting

www.signify.com

Signify (Euronext: LIGHT), the world leader in lighting has launched a new wireless emergency lighting portfolio and monitoring system, enabling building managers to control, monitor and test emergency lighting and produce compliance reports, through a secure cloud-based dashboard.

Powered by Signify's Interact connected lighting system developed for intelligent buildings, the new system enhances the testing process by automating function and duration tests, while delivering data insights and health status alerts. Interact Building Manager enables building operators to monitor and manage both general and emergency lighting through a cloud-based dashboard. This supports multiple testing schedules and delivers detailed reports for regulatory documentation and reporting. The system also simplifies maintenance and supports compliance with emergency lighting standards as per local regulations.

Greg Nelson, Executive Vice President - Systems & Services at Signify said: "For building managers and maintenance teams alike, regular testing and maintenance of emergency lighting is crucial, but can be time-consuming and prone to human error. Signify's new wireless emergency lighting portfolio and Interact Building Manager provides visibility and control over your emergency lighting with regular proof of performance to ensure compliance with relevant standards while reducing operational complexity and cost."



There are four key configurations to meet the varying needs of buildings: general lighting fixtures with built-in emergency capabilities; wireless DALI (Digital Addressable Lighting Interface) extenders and sensors; wireless exit signs and emergency lights. Everything from general lighting to emergency lighting can be commissioned and deployed under one contract and one dashboard, enabling cost savings and efficient maintenance and monitoring of an entire lighting system. Alternatively, emergency lighting can be installed and commissioned on its own to achieve mandatory building compliance.

Greg Nelson, Executive Vice President - Systems & Services at Signify said: "With our connected wireless emergency lighting portfolio, building operators can find tailor-made solutions while also reducing cost, streamlining operations and meeting essential compliance standards. Signify's expertise in both general and emergency lighting means we can act as a single trusted partner for a wide range of customer needs."

Interact already supports millions of connected light points in large-scale installations worldwide and is built on robust cybersecurity principles to ensure that the confidentiality, integrity, and availability of users' data is protected and maintained. For more details, click here.

The new wireless emergency lighting solution is being first made available in Australia and New Zealand through the Pierlite portfolio; it will be made available in Europe in early September. Here is a list of Pierlite portfolio products for emergency lighting: Emergency - Pierlite. ■

Emergency Lighting: A Key Priority Amid Building Remediation

www.mackwell.com

Recent developments to the Building Safety Act 2022, alongside the introduction of the Leasehold and Freehold Reform Act 2024, have outlined significant changes to the UK's approach to building safety and accountability. These changes have introduced a more stringent framework for ensuring that buildings, particularly those deemed high-risk, undergo appropriate and often overlooked due to funding, remediation. The introduction of remediation orders and a sharper focus on interim fire safety measures ensures that residents are protected while longer-term works are undertaken.

This renewed scrutiny is driving a wave of remediation activity across the country, particularly in residential blocks with already identified safety deficiencies. Since terrible tragedies such as the Grenfell Tower fire, attention has been placed on cladding and structural issues, alongside fire safety measures, such as emergency lighting. In the event of a fire or power outage, emergency lighting plays a primary role in supporting both evacuation and emergency response.

The updated legislation makes it clear that building owners and accountable persons must take full responsibility for the safety systems in place. For contractors, consultants and facilities managers, this presents a growing opportunity to bring existing systems up to standard and deliver new solutions that align with the legal and safety requirements.

The changes in legislation now place clear legal duties on the 'responsible person'(often building owners or managing agents) to identify, fund, and carry out necessary

remedial work to address risks to life in buildings. Specifically, the Building Safety Act introduced Remediation Orders and Remediation Contribution Orders, giving the Building Safety Regulator and the First-tier Tribunal (FTT) the power to enforce remediation of fire safety defects, including inadequate emergency lighting, faulty alarm systems, and other critical safety failings.

The Leasehold and Freehold Reform Act 2024 further supports leaseholders by limiting the financial burden on residents, placing the onus directly on the responsible persons. Failure to follow these legislations can now result in legal penalties, and in extreme cases, criminal liability.

For buildings relying on interim measures such as waking watches, responsible persons can no longer delay action. Waking watches were introduced as a temporary fire safety measure in high-risk buildings, particularly those identified with cladding or fire compartmentation issues. Their incredibly costly but essential role provides on-site fire wardens who monitor the building around the clock and raise the alarm in the event of a fire. While intended as an interim solution, waking watches have faced significant scrutiny due to their astronomical ongoing costs and the inconsistency in effectiveness. As a result, regulatory focus has shifted toward replacing waking watches with more reliable, long-term safety solutions, such as the installation of compliant fire detection and emergency lighting systems.

Regulators are increasingly insisting that interim solutions be replaced with permanent, compliant safety systems. This shift shows that inactivity is no longer tolerated, and proactive, accountable remediation is now legally imperative.

At Mackwell, we know that emergency lighting is the foundation of an effective fire safety strategy. Our systems are designed to perform when it matters most, and with increasing focus on digital monitoring and data-led maintenance, we're helping clients stay ahead of compliance. Our Automatic Test System (ATS), N-Light, helps clients stay ahead of compliance requirements. It can be easily integrated into existing buildings using our wireless technology, and with our cloud-based platform, users can remotely monitor one or multiple buildings. At Mackwell, we remain committed to delivering the technical support, guidance and high-performance solutions that building safety demands.

Emergency lighting is not a background detail - it's a life-saving measure. As more buildings come under remediation scrutiny, now is the time to reassess, upgrade and invest in emergency systems that meet today's expectations and tomorrow's standards.

Article by David Lang-Smith, Sales & Marketing Director UK & Europe | Emergency Lighting Experts.

About Mackwell
Mackwell is one of the leading providers of technology solutions for the global lighting industry, with ties to many major international companies in over 40 markets and export businesses. With a background firmly grounded in electronics, Mackwell has developed a wealth of experience in lighting throughout the World and an enviable reputation for the design and manufacture of reliable, innovative electronic components. This enables the company to provide customers with innovative solutions that give them a competitive edge in their target markets. ■

CUBESIGN II – The Maintenance-free LED Safety Luminaire by Zumtobel

https://z.lighting

CUBESIGN II by Zumtobel, the rectangular successor of the classic CUBESIGN escape route marking cube, is now even more versatile thanks to a protection class of IP54, recognition distances of up to 60 meters and multiple installation options, from the retail sector to airports and industrial manufacturing. The durable, maintenance-free LED safety luminaires in the CUBESIGN II range allow emergency exits in rooms of different sizes to be clearly marked.

Safety has never looked so good: the new CUBESIGN II LED safety luminaire by Zumtobel for marking escape routes combines maximum visibility, reliable operation and flexible use in a range of different surroundings. Thanks to its optimised form factor, the rectangular luminaire with an aspect ratio of 1:2 blends into any room design and can display a wide range of pictograms.

Whether in supermarkets, large DIY retailers, production halls or airports, CUBESIGN II ensures emergency exits are extremely easy to find – for increased safety in public spaces. It is available in two sizes with different recognition distances: 30 meters for medium-sized rooms and 60 meters for larger halls. Protection class IP54 ensures CUBESIGN II is protected against the ingress of dust and splashes of water – meaning it is also suitable for use in harsh industrial environments. Thanks to the extended temperature range of up to 55°C, the LED safety luminaire can withstand even higher ambient temperatures, such as those found in large data centres, for example.

The Swiss army knife of safety lighting

The wide range of CUBESIGN II's mounting accessories creates a variety of installation options. Depending on individual room requirements, users can choose between installation directly in the ceiling, a chain attachment with four eyelets, a wall bracket in white sheet steel, and three different pre-wired pendant variants in lengths of 30, 50 or 100 cm. The LED safety luminaires can also be easily integrated into existing TECTON and TECTON II track systems. This flexibility significantly reduces installation costs and also enables the resource-saving utilization of existing infrastructures, for improved sustainability.

Maintenance-free and durable thanks to modern power supply

In terms of power supply, CUBESIGN II users can choose between connection-free variants with an integrated battery (E1D, E3D, E1BC, E3BC) and variants for connection to an external power source (ECD, ECP, ECC or

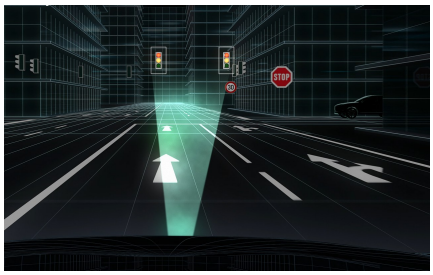
ELP). The connection-free versions of the safety luminaires have a long service life thanks to innovative lithium iron phosphate batteries. The higher energy density of this battery type means the battery packs themselves are more compact, which in turn reduces power consumption and weight and extends the permissible temperature range. It also extends the luminaire's service life and minimizes the amount of maintenance required.

The self-contained versions can be connected to the Bluetooth Casambi wireless lighting control system, while the ELP version with a central battery can be connected to Zumtobel's nBox group battery system. ■

FORVIA HELLA Advances the Development of Software-only Products with Newly Established Entity "Ignite by FORVIA HELLA"

www.hella.com

The international automotive supplier FORVIA HELLA is intensifying its activities in the area of software-based business models and is advancing the development with a new company founded at the beginning of the year. HELLA Ignite GmbH ("Ignite by FORVIA HELLA") aims to accelerate the development of software-only products in a rapid and agile manner. In parallel with product development, Ignite by FORVIA HELLA is currently being gradually expanded; by the end of the year, the company is expected to consist of an internationally diverse team of around 40 software development experts.



"As it stands today, software has become indispensable for everyday mobility. It plays an essential role in driver assistance systems, comfort and safety features, in-vehicle entertainment, and vehicle connectivity. However, software will be even more vital for the mobility of the future, with the market expected to double over the next five years according to current estimates," says Kay Talmi, Managing Director of Ignite by FORVIA HELLA. "We are among the most renowned electronics suppliers worldwide and already integrate software functionalities into many products in which we are market leaders.

Against this backdrop, it is logical and promising to strategically address the software market from this robust foundation, supported by a dedicated unit established for this purpose."

The main focus of development lies in software products that are closely linked to the core businesses of FORVIA HELLA's three Business Groups — Lighting, Electronics, and Lifecycle Solutions. These include, on the one hand, business models in the field of lighting electronics or the processing and monetization of sensor data. On the other hand, Ignite by FORVIA HELLA is also working on entirely new software-only business models, such as the "Traffic Rules Engine" (TRE), which was introduced as a conceptual innovation at the Consumer Electronics Show (CES) 2024 in Las Vegas and has since undergone significant further development.

This software module, developed in close cooperation with TÜV Rheinland, monitors the compliance of automated vehicles (SAE Level 3 and higher) with applicable regulations, traffic laws, and case law based on sensor and map data. The solution is tailored to the specific country in which the automated vehicle will be deployed. Planned maneuvers are assessed for legal admissibility on the same basis. Should a deviation be detected, real-time feedback is provided to the vehicle control system. To ensure that the latest regulations of each country are always applied, the TRE can be continuously updated over-the-air.

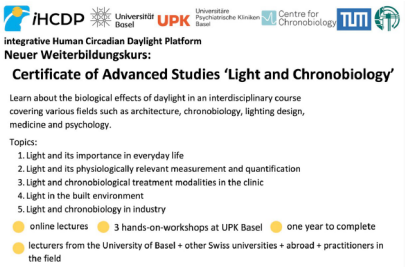
The target is to integrate the TRE into a vehicle for the first time by year-end and to have TÜV Rheinland validate the software on a test track, using real-world traffic scenarios. The initial focus will be on highway driving, with vehicles classified under SAE Level 3 ("highly automated driving"), wherein certain tasks can be executed independently and without human intervention. ■

Certificate of Advanced Studies (CAS) in Light and Chronobiology

https://ihcdp.org

The CAS Light and Chronobiology integrates topics covering the biological effects of daylight from various fields such as architecture, chronobiology, lighting design, medicine and psychology. This opens up theoretical and, above all, practical applications for improving public health.

The Integrative Human Circadian Daylight Platform (iHCDP) is a project led by four researchers at the Centre for Chronobiology at University of Basel/University Psychiatric Clinics Basel, Max Planck Institute Tübingen



and Technical University Munich. The platform aims to catalyze any means necessary for the use of (day-)light to improve general health, quality of life and living conditions across the life span, based on biological, psychological and societal needs.

To bring together researchers, clinicians, light designers, architects, and educators in the fields of daylight research, ophthalmology and vision science, and sleep- and circadian medicine the team established a Certificate of Advanced Studies (CAS) in Light and Chronobiology associated with University of Basel.

The CAS Light and Chronobiology integrates topics covering the biological effects of daylight from various fields such as architecture, chronobiology, lighting design, medicine and psychology. This opens up theoretical and, above all, practical applications for improving public health. Attached you find a flyer. We'd be glad if you could share it with everyone who might be interested in this course. Registration is open until 31 July. ■

GOPRO XINYOU Cosmetic Lamp – Harnessing Light Science to Revolutionize Skincare, Ushering in a New Era of Home Phototherapy

www.goproled.com

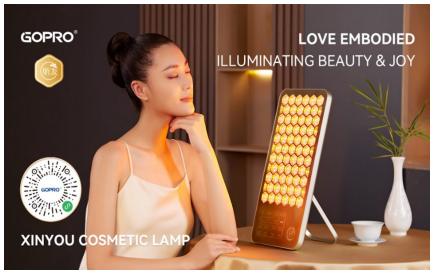
As semiconductor light technology advances, the demand for safe, effective skincare solutions has surged. LED phototherapy, once confined to medical settings, now breaks into home care, offering a breakthrough approach to common skin concerns. However, the market is flooded with inconsistent and potentially unsafe devices, leaving consumers searching for professional-grade, reliable alternatives.

Backed by GOPRO's 2019 National Award for Scientific Advancement, the XINYOU Cosmetic Lamp merges clinical-grade phototherapy with home usability, delivering medical efficacy in a user-friendly design.

Precision Light Therapy: 5 Wavelengths, 10

Skincare Modes The XINYOU Cosmetic Lamp combines five targeted wavelengths for comprehensive skin rejuvenation:

- 423nm Blue-Violet Light: Combats acne by targeting P. acnes bacteria.
- 465nm Blue Light: Balances sebum production and soothes inflammation.
- 595nm Yellow Light: Reduces redness and strengthens skin barriers.
- 635nm Red Light: Boosts collagen for firmer, youthful skin.
- 940nm Near-Infrared: Penetrates deep to brighten and tighten.



Innovative Engineering for Maximum Efficacy:

- 396 High-Power LED Chips: Arranged in a honeycomb matrix for 51400cm² of even, full-face coverage.
- Optimized Beam Angle & Grid Design: Eliminates patchy energy distribution—a common flaw in cheaper devices.

Clinically Proven Safety, Globally Certified Reliability

Developed with cutting-edge research, rigorously tested by Chongqing Junmei Hospital through extensive clinical trials across diverse skin types, the XINYOU Cosmetic Lamp delivers proven efficacy without side effects. Its proprietary "Optical Energy Code" technology ensures precise wavelength accuracy, even energy distribution, and stable light output—backed by big data validation.

Safety assured through 39 stringent quality checks, including spectral analysis, energy consistency, and pulse stability testing. Unlike generic alternatives, it's SRRC & SGS certified with flicker-free RG0 blue light (retina-safe), offering complete phototherapy security.

Technology with Care: XINYOU Cosmetic Lamp Illuminates Healthy Beauty

Move beyond traditional skincare routines with limited results. XINYOU Cosmetic Lamp utilizes advanced phototherapy technology to activate cellular renewal from within, delivering long-lasting, visible improvements. A cost-effective alternative to expensive clinical treatments and endless skincare products, it's designed for lasting value.

Now, everyone can experience scientifically-proven beauty care at home. XINYOU Cosmetic Lamp harnesses the power of light to reveal healthier, more radiant skin—where cutting-edge technology meets everyday beauty needs, making professional-grade rejuvenation accessible to all. ■

Alfalite Launches SKYPIX, a New Ceiling-mounted LED Panel for Virtual Production Environments

https://alfalite.com

Alfalite, the only European manufacturer of LED displays, announces the launch of SKYPIX® RGBW & IM, a new series of ceiling-mounted LED panels designed specifically for virtual production (VP XR) environments. This new solution introduces a capability previously unseen in the industry: combining RGB video playback with an integrated white lighting channel to deliver more natural, coherent, and adaptable scenes from above.

With a 3.9 mm pixel pitch, up to 9,000 nits of RGB brightness, and a 7,680 Hz refresh rate, SKIPIX offers precise light control, a color temperature range between 3,200–6,504ºK, and a TM-30 color rendering index (Ra) of 90. Its average power consumption of just 35W (90W max) makes it an energy-efficient option for long studio sessions.

A standout feature of SKYPIX is its Invisible Marker (IM) system, which replaces traditional physical tracking markers with a virtual, invisible sticker compatible with existing tracking technologies. This system ensures accurate, real-time synchronization and allows for the configuration of customizable IM constellations that embed metadata directly into the shoot.

Lighting control is managed through a dedicated application that enables real-time adjustment of both color and intensity—by zone or by pixel—with user-defined presets tailored to production needs.

"With SKYPIX, we're taking the integration of image and light within virtual production volumes one step further," says Luis Garrido, Executive Director of Alfalite. "We listened to studios and lighting technicians to create a panel that not only displays content, but also lights the scene with unprecedented realism and communicates with the broader production system. It eliminates the maintenance and synchronization issues associated with traditional tracking markers. Once again, we're surprising the market with a cutting-edge solution unlike anything previously available for film, television, advertising, and broadcast. It's a tool designed to let creators focus on storytelling without compromising technical precision."

The SKYPIX series is aimed at film, TV, advertising, live event, and broadcast productions working within VP XR environments, reinforcing Alfalite's commitment to developing purpose-built solutions for this rapidly evolving sector.

About Alfalite
Alfalite is a leading European LED screen manufacturer based in Spain, with different facilities that carry out LED screen design, manufacturing, and certification. Alfalite manufactures screens using the best materials and components on the market, which allows them to meet the highest standards and the most demanding customer specifications in critical environments. Visit https://alfalite.com ■

pureLiFi Unveils Kitefin XE the Next Generation LiFi System

www.purelifi.com

pureLiFi has announced the release of its latest LiFi system, Kitefin XE, designed to protect networks in an era marked by growing security threats. This cutting-edge wireless technology, first released exclusively within the National Security community, is now available to a wider spectrum of sectors, from government and defence to enterprise customers and beyond.

Guaranteeing data security has become an increasingly complex task for both governmental bodies and private businesses. The Kitefin XE system is founded on technology crafted for the National Security community and has demonstrated its reliability in the most secure settings where communication safety is paramount. Customers have reported that Kitefin XE allows them to introduce wireless capabilities where previously not possible, improving mission viability and success.

This revolutionary system allows for high-speed wireless internet connectivity through Invisible Light rather than Radio Frequencies (RF) used in traditional wireless technologies such as WiFi and Cellular. LiFi provides a revolutionary level of security unmatched by RF technologies as it is not susceptible to detection, interception and jamming. LiFi also offers massive capacity that outperforms WiFi in real-world environments, and its low latency capabilities offer a better user experience.

Alistair Banham, CEO of pureLiFi, stated, “Securing sensitive data, whether it’s critical to national security, protecting intellectual property, and company data, is becoming increasingly challenging for both governments and enterprises. Kitefin XE will enable wireless communication in previously impossible scenarios and revolutionise the way companies deploy connectivity, providing confidence and protection in this evolving security landscape.”

pureLiFi is part of In-Q-Tel’s (IQT) portfolio, the not-for-profit strategic investor for the U.S. national security community and its allies.

Clayton Williams, Managing Director of IQT, remarked, “IQT is excited to support the broader launch of Kitefin XE. This innovation has the potential to transform how our partners approach wireless connectivity—and help enterprises stay secure in today’s complex cybersecurity landscape.”

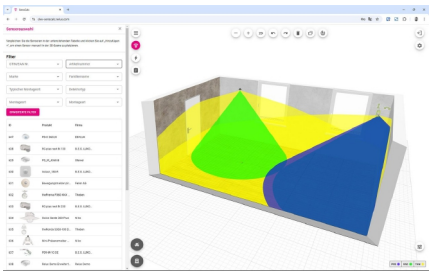
Kitefin XE is the latest in a series of Kitefin systems developed for government and defence that save missions and lives. Kitefin Tactical and Kitefin Office were deployed with the US Army in the first-ever large-scale deployment of LiFi. Building on their predecessors’ success, Kitefin XE offers room-filling LiFi coverage of over 80 Sq. Meters and provides Gbps capacity, making it the highest-performing LiFi system available on the market for government and defence, which complies with IEEE 802.11bb standard. All pureLiFi systems are based on IEEE 802.11 protocols, making them the simplest LiFi systems to integrate into existing networks. Kitefin XE is also available for both Ethernet and fibre deployments.

With Kitefin XE, pureLiFi sets a new standard in secure, high-capacity wireless communication technology, paving the way for a future where data security is uncompromised. ■

New Unique Online Tool for Planning PIR Sensors with Energy and Amortization Calculation

https://relux.com

SensCalc is the free online planning tool for PIR sensors. The only online tool in the world. Calculate the energy efficiency and amortization of your sensor installation with certified data in accordance with IEC 63180 and sensNORM 2022.



A RELUX planning tool developed in co-operation with Energie Schweiz, BFE, METAS, sensNORM and Schweizer Licht Gesellschaft SLG.

SensCalc provides electricians, planners and private individuals with a free online tool for planning PIR sensors. The platform enables energy and amortization analyses directly on the website - innovative, practical and user-friendly.

Requirements for the planning of PIR sensors

Planning PIR sensors requires a large amount of data and calculations. In addition to the spatial conditions, such as room size and utilization, parameters such as light intensity, sensor range and potential energy savings must also be taken into account. Planning errors can lead to inefficient systems that either do not provide the desired level of comfort or fail to achieve the desired energy savings.

Functionality and advantages

The online tool is accessible via the homepage www.senscalc.ch. After logging in (as a guest or with their own account), users can plan PIR sensors directly in the browser. The tool offers a wide range of functions:

- Energy saving calculation: SensCalc calculates the potential energy saving according to SIA 387/4 based on the parameters entered.
- Amortizationanalysis: The tool calculates the amortization period of the planned installation and provides important economic key figures to help you make a decision.
- Visualization of sensor efficiency: The tool displays the sensor coverage graphically, making the optimum placement visually visible.
- User friendliness: Thanks to the intuitive user interface, even complex projects are easy to carry out. The tool is suitable for both experienced professionals and beginners.

Relevance for the industry

The importance of PIR sensors in the context of energy efficiency should not be underestimated. According to the guidelines of the Swiss Lighting Society (SLG), the targeted use of PIR sensors can save up to 60% of energy in the lighting sector. These savings not only result in a reduction in operating costs, but also make a significant contribution to sustainability and the fulfilment of legal requirements.

By simplifying complex planning and clearly visualizing the results, the tool reduces errors and saves time. Planners and electricians are given a solid basis for making decisions and optimising the installation of energy-efficient systems.

Practical application

It is very easy to use: after entering the basic data - such as room size, type of use and installed light output - the tool automatically calculates the optimum number and positioning of the PIR sensors. In addition, energy savings and amortization time are displayed based on current energy prices.

The GTIN/EAN numbers of the products not only make it easier to plan and present arguments to building owners and decision-makers, but also show where these products can be purchased.

Manufacturers of PIR sensors can make their products available on SensCalc.

With an entry in SensCalc, you can make your sensor products available to a broad community. The data should be supplied in GLDF format. Alternatively, the data can also be supplied in the form of an Excel file. This also includes L3D models, product data sheets, installation instructions and marketing documents. A corresponding template can be found on the landing page. The sensors must be measured on a measuring system in accordance with SensNORM or IEC63180 so that the products can be presented in the best possible way.

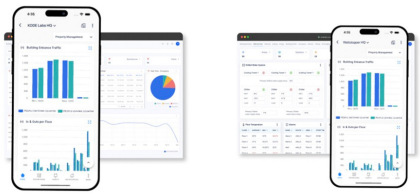
Voices from manufacturers and users

SensCalc is the result of a powerful initiative for usage-dependent efficiency in lighting. This has been our central concern as Steinel for many years. SensCalc removes further hurdles for all market participants and thus represents an important step towards sustainability and resource efficiency as part of the national targets. ■

Legrand Unveils Wattstopper i3 Platform

www.legrand.us

Legrand®, a global leader in electrical and digital building infrastructures, announced the launch of the Wattstopper i3 Platform, a next-generation lighting and building intelligence solution powered by KODE Labs, a global leader of advanced smart building technology.



The partnership positions Legrand to lead the lighting controls industry into a new era of unified experiences, seamless integrations, and data-driven control, making it easier to transform buildings into intelligent, responsive environments.

Wattstopper i3 unites Legrand's established Wattstopper DLM and Wattstopper PLUS systems under a cohesive interface. With KODE's award-winning OS at its core, the platform consolidates data from lighting, HVAC, occupancy sensors, and third-party building systems into actionable insights. Wattstopper i3 allows operating teams to plug into new and existing systems to control and optimize building systems in a single, intuitive dashboard – whether for a single property or entire portfolio. "The Wattstopper i3 Platform represents the future of smarter building management," said Tom Lowery, President of Lighting and Building Control Systems at Legrand. "By consolidating critical building systems into a single interface, we're enabling building managers to make data-driven decisions that improve performance and reduce operational costs. This partnership allows us to optimize a building's value – today and in the future."

With the launch of Wattstopper i3, Legrand is delivering more than an operating system, the company is delivering a strategy for the future of smart buildings. The platform features:

Seamless plug-and-play integrations across existing and legacy lighting control ecosystems Occupancy-based automation, dynamic scheduling, and real-time zoning Energy optimization and predictive insights for faster, smarter decisions A unified look and feel across Legrand's networked lighting control interfaces for a premium, consistent experience This combination enables integrators to deliver more with less effort, allowing Legrand's partners to offer lighting solutions that are easier to implement and more competitive than ever before.

Disrupting a Fragmented Market In a market dominated by proprietary systems and siloed platforms, Wattstopper i3 delivers a compelling alternative: an open, agile platform designed for rapid deployment and future scalability.

"Being chosen to power Wattstopper i3 is a proud moment for us," said Etrit Demaj, co-founder of KODE Labs. "Together with Legrand, we're making it possible to deploy smarter lighting systems with ease, integrate with almost anything, and give customers the open, data-rich environments they've been waiting for"

Empowering a Smarter Ecosystem
This launch marks an important step forward in how OEMs and software platforms can work together to meet the evolving needs of the industry. As interoperability, speed, and intelligence become more critical, the Wattstopper i3 Platform helps position Legrand to better support clients looking for smarter, more connected building solutions.

By partnering with KODE Labs, Legrand is not just enhancing its technology stack, it's changing the way lighting controls are specified across the market. From streamlining integrations with leading ecosystems, to enabling digital services, AI-powered operations, and real-time data analytics, Legrand is arming its partners and customers with tools that redefine lighting control as a service. With Legrand's global scale and KODE's disruptive platform, Wattstopper i3 is redefining what's possible in lighting control and smart building management. This launch marks a major step forward for the industry – and a clear signal that the future belongs to intelligent and connected solutions.

About Legrand and Legrand, North and Central America Legrand is the global specialist in electrical and digital building infrastructures. Its comprehensive offering of solutions for residential, commercial, and data center markets makes it a benchmark for customers worldwide. The Group harnesses technological and societal trends with lasting impacts on buildings with the purpose of improving life by transforming the spaces where people live, work and meet with electrical, digital infrastructures and connected solutions that are simple, innovative and sustainable. Drawing on an approach that involves all teams and stakeholders, Legrand is pursuing a strategy of profitable and responsible growth driven by acquisitions and innovation, with a steady flow of new offerings that include products with enhanced value in use (energy and digital transition solutions: datacenters, digital lifestyles and energy transition offerings). Legrand reported sales of €8.6 billion in 2024. The company is listed on Euronext Paris and is a component stock of the CAC 40, CAC 40 ESG and CAC SBT 1.5 indexes. (code ISIN FR0010307819). https://www.legrand.us/

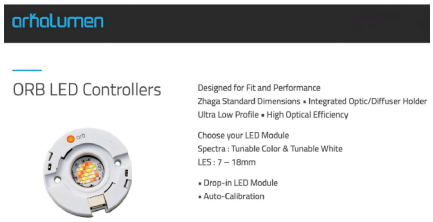
About KODE Labs Detroit-based KODE Labs is a smart building software company transforming real estate management and tenant experience through its innovative, data-centric operating system, KODE OS. The open enterprise platform leverages a software-as-a-service (SaaS) model to optimize building performance, integrating data from building management systems, IoT, and operational systems into a unified, cloud-based solution. KODE Labs enables thousands of real estate portfolios globally to operate their buildings seamlessly, economically, and sustainably. For more information, visit kodelabs.com. ■

Arkalumen's ORB Wins "Best in Category – Drivers" at the 2025 LightFair Innovation Awards

www.arkalumen.com

Arkalumen is proud to announce that its groundbreaking ORB product has won Best in Category – Drivers at the 2025 LightFair

Innovation Awards, recognizing it as the top innovation in driver technology and a leading advancement in tunable color lighting solutions.



Presented at LightFair, the Innovation Awards celebrate products that set new standards for performance, creativity, and impact. The ORB stood out for its unique combination of high-precision tunable spectral control, modular flexibility, and compact, high-performance design. The ORB is the first product of its kind to integrate multi-channel tunable color capabilities into a fully modular, Zhaga-based form factor. It supports up to five independently controlled output channels, enabling precise spectral tuning for white or full-color lighting. The ORB introduces a transformative approach to round (50mm diameter) tunable spectral light sources by combining advanced thermal performance with unmatched modularity. Its design allows for direct thermal contact between the LED module and the heat sink, enabling cooler, more efficient operation and higher lumen output per LES area. At the heart of the ORB's innovation is its modular architecture—delivering fully integrated systems tailored to specific performance requirements, including a wide range of LED module options with different LES sizes, lumen outputs, and custom spectral mixes.

The ORB's optical efficiency is driven by its compact 8mm height and an exceptionally short light path to the optic—as little as 4.5mm—resulting in significant performance advantages over traditional integrated solutions. These design efficiencies contribute to a 20–30% increase in overall system efficacy. Additionally, the ORB is compatible with optional attachable light guides, which further improve optical control by guiding light directly to the base of the optic. This enables tighter beam angles and a reduced effective LES size, giving designers greater flexibility in achieving precise light distribution.

"We are honored to receive this prestigious recognition from LightFair," said Sean Murray, President at Arkalumen. "The ORB reflects our team's deep commitment to advancing lighting technology and providing our partners with flexible, high-performance solutions that enable greater creativity and precision. This award affirms our vision to lead the way in next-generation illumination."

The ORB is redefining what's possible for fixture design, offering an unparalleled balance of color quality, system efficiency, and design versatility. For more information about the ORB product family, visit www.arkalumen.com ■

Redefining Horticulture with Light, Intelligence, and Innovation

https://ams-osram.com

What does the future of horticulture look like? For ams OSRAM, it centers on customized light, intelligent technology, and sustainable systems. At GreenTech 2025, the company will showcase its role as a global innovation leader in professional horticulture lighting, sensing and plant treatment—presenting a portfolio that sets new benchmarks for efficiency, sustainability, and crop optimization.

From June 10 to 12 in Amsterdam, GreenTech visitors can explore how the latest-generation LED and sensor solutions from ams OSRAM enhance plant growth, save energy, and promote sustainable farming. At Hall 05, Booth 05.357, attendees will experience hands-on demonstrations of UV-C disinfection systems, chemical-free weed control, and high-performance greenhouse LEDs, including a UV-C robotic arm, a drone, and an algae reactor—all bringing sustainability to life.

Spark curiosity. Fuel growth. Shape the future. The major highlight of ams OSRAM's trade fair presentation will be the new high-power LED OSCONIQ® P 3737 GEN 2 - with the highest efficiency in its class and a strong focus on sustainability. It is the perfect choice as a toplight mounted on greenhouse ceilings, for interlighting between rows of plants and flowers, and as a standalone light source for vertical farming. Thanks to its 82.4% total efficiency in Hyper Red and a photon flux of 6.09 µmol/s with minimal energy consumption, it significantly boosts photosynthetic performance and noticeably shortens crop cycles. Compared to its predecessor, the GEN 2 version provides 3.2 % more performance, 2.2% higher efficiency, and supports a maximum drive current of 2,800 mA in both Hyper Red and Far Red. This reduces the number of LEDs required, lowers energy consumption, and enables compact, multi-channel luminaire designs. The OSCONIQ® P 3737 GEN 2 is part of a comprehensive horticulture portfolio covering all key wavelengths—from Hyper Red and Far Red to Deep Blue. Another version of the high-power LED, the OSCONIQ® P 3737 Batwing, will be launched later this year.

Sustainable, innovative solutions: disinfection at the flick of a switch
Sustainable horticulture approaches that ams OSRAM is pushing forward also include cutting-edge UV-C LEDs and spectral sensors. UV-C LED technology offers numerous advantages to farmers and agricultural holdings. UV-C light positively influences a variety of key parameters: it facilitates pest and disease control, accelerates growth rates, boosts crop yields, and improves both nutrient uptake and plant resistance to pathogens. UV-C LEDs from ams OSRAM are tailored to match the unique demands of each application, striking the perfect balance between germicidal performance, top-level quality, efficiency, and cost-effectiveness. The company also offers innovative solutions for sustainable weed control: camera-based systems combined with 455 nm laser diodes from ams OSRAM enable farmers to boost their productivity through efficient and reliable weed detection and eradication. Chemical-free and with high precision.

A new key innovation for intelligent lighting systems
State-of-the-art drones and agricultural robots can be equipped with a versatile range of spectral sensors and cameras designed to collect valuable data on plant health, phenotyping, and water stress. With the addition of the new TCS3448, a 14-channel multi-spectral sensor, the company has further strengthened its sensor portfolio. Compact, efficient, and software-compatible with existing solutions such as the AS7343, the TCS3448 simplifies the development of next-generation miniaturized spectral systems—perfect for urban farming, medical technology, industrial lighting control, and much more. With a spectral range of 350 to 900 nm, integrated flicker detection up to 1 kHz, and an ultra-compact footprint of just 3.1 × 2.0 × 1.0 mm, the TCS3448 delivers precise light and color data for a wide range of applications. ■

You may send your international lighting news to editors@led-professional.com

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From Nightscapes to Metasurfaces: Lumileds Unveils the Next Generation of LED Innovation – Oleg Shchekin & Toni Lopez, Lumileds

In this exclusive interview, Lumileds experts Dr. Oleg Shchekin (CTO) and Dr. Toni López (Scientist) reveal how cutting-edge LED innovations—from low-blue outdoor lighting to metasurface-enhanced microLEDs—are shaping the future of energy efficiency, visual comfort, and sustainable design. They share insights on technical breakthroughs, real-world applications, and what's next for the industry.

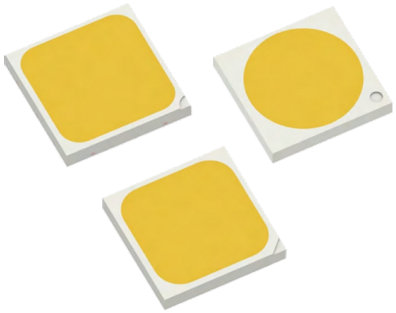
lumileds.com

LED professional: Lumileds is advancing outdoor lighting solutions with reduced blue content. What are the primary goals behind this initiative, and how do they align with public health and environmental concerns?

Oleg Shchekin & Toni Lopez: We observed a growing public concern with the blue content in outdoor lighting. Further, we are seeing municipalities acting on this concern by addressing both CCT and blue content in outdoor lighting ordinances. While it is possible for amber or phosphor converted amber (pc amber) LEDs to meet colorimetric or photometric low blue requirements, we created a better solution in terms of efficacy (lm/W). It is also important to understand that the blue content varies substantially between pc amber LEDs. Our products that use NightScape Technology™[1] have the blue content clearly specified, for example, at less than 2%, and each LED is tested to meet those specifications. This creates certainty and confidence for our customers, who make light fixtures, and engineers and designers who specify these fixtures.

LED professional: From a technology standpoint, how did you achieve a low-blue spectrum while maintaining color quality and efficiency?

Oleg Shchekin & Toni Lopez: It is somewhat surprising that Incandescent lamps or High-Pressure Sodium lamps are referred to as having low blue content, while they still produce 6.5–7.0 % of their light visible between 400 nm and 500 nm. For reference, a 2,700 K LED produces about 12% in that range, and it is still about 2.9% for 1,800 K LEDs.



Lumileds LUXEON NightScape Technology LEDs significantly reduce the percent of blue content between 400nm and 500nm to less than 2%.

Our goal was to optimize efficiency while meeting a blue % threshold of less than 2%, while keeping color rendering and overall visual appearance functional and pleasing. Lumileds' R&D drew on its extensive phosphor library and employed high phosphor loading techniques—to preserve reliability—and identified an optimal solution at 1,900 K, achieving less than 2% of visible light emission between 400 nm and 500 nm.

LED professional: How do these solutions compare to traditional outdoor lighting in terms of energy efficiency, longevity, and visual comfort?

Oleg Shchekin & Toni Lopez: Because we use well-established building blocks for our low blue content LEDs, they achieve the same longevity and robustness as their 3,000 K or 4,000 K siblings. Color rendering is comparable to a pc amber LED source and is good for distinguishing colors because the spectral distribution is broad. In that sense, it is very different from low-pressure sodium lamps, which are nearly monochromatic, and only render shades of orange. Another important element for visual comfort is chromaticity (or color point). The source that we created closely mimics the chromaticity of a candle flame, which is pleasing to many people. Finally, we were able to achieve a 13% improvement in efficiency vs. 1,800 K (which has more blue) and PC Amber.

LED professional: You recently announced a breakthrough in microLED technology in collaboration with Eindhoven University of Technology[2]. Can you explain the core of this innovation?

Oleg Shchekin & Toni Lopez: The team was able to integrate structures of a few tens of nanometers inside the microLED chip. This resulted in increased light extraction from the chip and a narrower forward beam.

LED professional: What are the key performance advantages of your microLEDs compared to conventional LEDs or OLEDs?

Oleg Shchekin & Toni Lopez: Our aim is to create microLEDs with the same efficiency as regular LEDs. While we are not there yet, they can already beat OLEDs, and as we continue to develop them, extend their efficiency advantage. MicroLEDs also have better output stability than OLEDs and can be multiple orders of magnitude brighter.

[1] https://lumileds.com/technology/led-technology/nightscape/

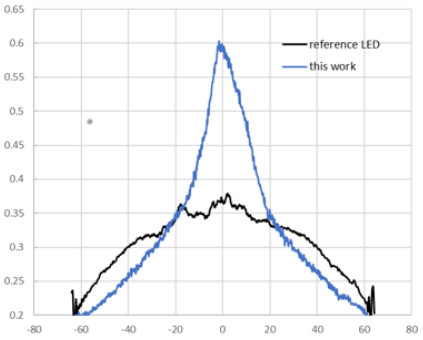
[2] https://lumileds.com/breakthrough-microled-development-delivers-improved-emission-directionality-and-efficiency/

LED professional: What are the main hurdles in bringing this microLED technology to mass production, and how is Lumileds overcoming them?

Oleg Shchekin & Toni Lopez: Fortunately, Lumileds can produce high-grade microLEDs with its current epi reactors and wafer processing tools. The main challenges for mass production seem to be more downstream, including the areas of high-yield display assembly and making sure that various parts of the value chain are well connected.

LED professional: What makes metasurfaces a superior approach for controlling light directionality compared to traditional optics?

Oleg Shchekin & Toni Lopez: The advantage of metasurfaces is that they sit inside the chip and can be compactly integrated near the active region at sub-wavelength distances. The electromagnetic field can thus tightly couple right from the emitter source to the metasurface, which effectively acts as a nanoscale antenna array to collectively radiate the field with a high steering degree. The geometrical features and optical characteristics of the metasurface combined with its close proximity to the source enables the manipulation of light properties such as amplitude, phase and polarization in ways that are simply not possible with traditional optics.



A comparison of angular intensity distribution highlights that double on-axis intensity was achieved with microLEDs containing embedded metasurfaces. X-Axis: Incidence Angle (degrees), Y-Axis: Far-field Intensity (output normalized, arbitrary units).

LED professional: How do you ensure these advanced structures are compatible with current LED fabrication and packaging processes?

Oleg Shchekin & Toni Lopez: Photonic metasurfaces can be engineered and designed in compact form factors with structure sizes featuring low aspect ratios and industry standard materials. The research team searched for compatible methods that fall within the capabilities of advanced semiconductor fabrication wafer processing tools and processes as we use them today. The LED packaging processes are essentially not impacted.

LED professional: Which material science advancements have enabled you to effectively manipulate the Local Density of Optical States (LDOS) in your devices?

Oleg Shchekin & Toni Lopez: This innovation is the result of a decades-long advances in several key areas: epitaxy structure, refining nanoscale fabrication methods, and improving device design. A major focus has been engineering how light and electrons interact. This ensures better efficiency and performance in our devices. These achievements come from years of research combining material science, photonics, and LED fabrication, with an important collaboration from Eindhoven Technical University that helped speed up our progress.

LED professional: Embedding metasurfaces can raise thermal and reliability challenges. How is Lumileds addressing these issues in product development?

Oleg Shchekin & Toni Lopez: When we move from research to product development, we address overall product performance, including thermals. We foresee that metasurfaces can be implemented without thermal drawbacks at high current densities. For microLEDs in display applications, which operate at relatively low current density, there should not be issues.

LED professional: How close are you to real-world integration of metasurface-enhanced LEDs in areas such as AR glasses, wearables, or automotive HUDs?

Oleg Shchekin & Toni Lopez: It will be a few years before metasurface-enhanced microLEDs end up in commercially available products. We are working closely with system integrators to bring the technology to consumers. We have done this before, when we brought camera flash to mobile phones, LED backlights to large displays, and helped introduce the first cars with LED taillights and headlights.

LED professional: Do you see metasurface-enabled LEDs as market disruptors or more as performance boosters for existing applications?

Oleg Shchekin & Toni Lopez: We would consider them as a vital booster of the disrupting product category of microLEDs.

LED professional: Which industry sectors do you believe are best positioned to adopt microLED and metasurface technologies in the next 2–3 years?

Oleg Shchekin & Toni Lopez: Metasurface technology has benefits for direct-view displays because it helps deliver higher intensity and brightness from an even smaller chip, which helps reduce the overall system cost. The increased directionality also benefits Augmented Reality applications.

LED professional: Could you share an example of a real-world customer application that demonstrates the potential of your current research?

Oleg Shchekin & Toni Lopez: You can think of applications that use a secondary optic to narrow or direct the light distribution, such as architectural wall grazers or entertainment lighting.

LED professional: How does your roadmap support industry trends like miniaturization, integration, and multifunctionality (e.g., combining sensing and lighting)?

Oleg Shchekin & Toni Lopez: Lumileds supports its customers in the Automotive, General Illumination, and Consumer Electronics with modules that integrate several system components. Customers appreciate our contribution in the product definition and development phase when they don't have the bandwidth or capability to do these integrations. We have multiple decades of experience with these "L2" products, and we are also a valuable partner in the production of these integrated LED products, because we apply the same quality procedures and mindset as we do in our front-end and LED production.

LED professional: With growing pressure around energy use and carbon footprint, how do your latest developments support global sustainability goals?

Oleg Shchekin & Toni Lopez: With our low blue content LEDs, we hope to contribute to reducing light pollution through a better spectral solution and by creating awareness of the issue. Proper shielding and aiming to avoid light going up or sideways also support reduced skyglow and less ecological disruption resulting from light at night.

Meta-surface optimized microLEDs reduce display power consumption, especially for a near-eye display that is part of Augmented Reality glasses. At a fraction of the size of a large TV, but still appearing like one through your glasses, it also consumes a fraction of the power.

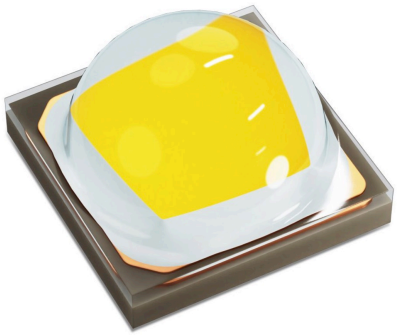
We support customers with integrated modules containing a heatsink and sometimes drive circuitry, especially in the automotive market. These improve the repairability of, for example, a car headlamp because the LED module can be reused if the headlamp requires replacement.

LED professional: Lumileds recently improved lumen-per-dollar performance in high-power LEDs. What specific innovations enabled this leap in system efficiency?

Oleg Shchekin & Toni Lopez: We recently announced upgrades to LUXEON HL2X, which came from improved efficiency and output, but also from continued improvements to the production process. The efficiency improvements of these 700 mA 2.7 V parts have been relentless, and we now have an output of 370 lm with an efficacy of over 190 lm/W at 85 °C junction temperature (for 70CRI parts).

LED professional: Multi-color arrays are another of your recent innovations. Can you explain the technological background and the market demand they address?

Oleg Shchekin & Toni Lopez: To be accurate, the Lumileds R&D team has achieved multiple colors within individual microLEDs by creating a stack of multiple colors separated by only a few microns, realized in a single epitaxial growth. The advantage for display applications is that you reduce the microLED count from 3 to 1 per pixel. For Augmented Reality Displays or Head Up Displays, there is no longer a need to bring the light from three separate panels together, as all three colors sit within the same panel.



LUXEON HL2X-V is the latest addition to the HL2X family. It offers a new, high-power value option of the already powerful and robust LUXEON HL2X. LUXEON HL2X-V parts offer an even higher lm/$ value proposition that enables existing solutions using a high-power 3535 LED to improve their position in the market and for new lighting solutions to offer never-before-possible performance.

This approach also has advantages for other multi-color systems (for example, Red, Green, Blue) because one LED can deliver multiple colors from the exact same source, which results in perfect color mixing because the colors sit right on top of each other.

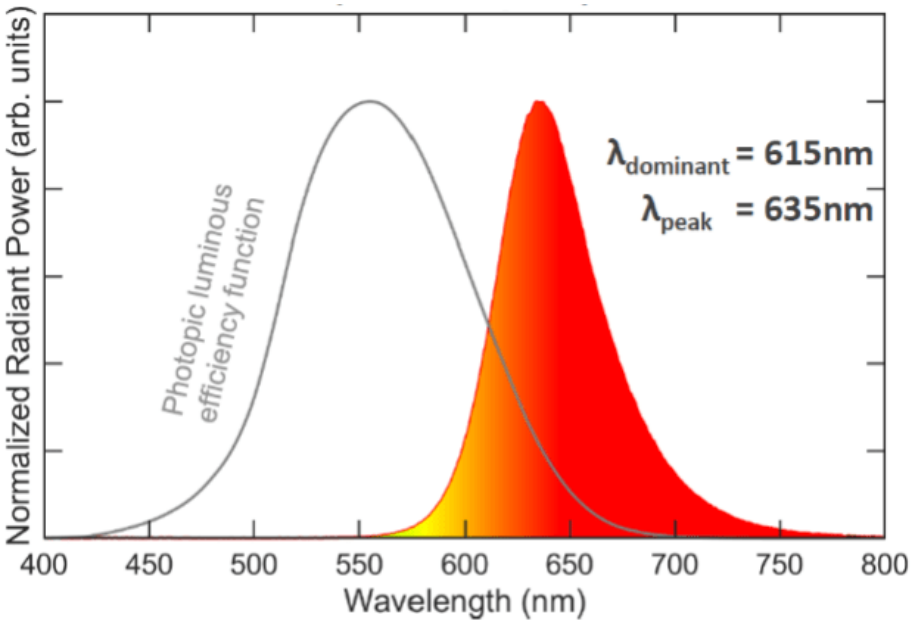
LED professional: Deep dimming is essential in high-quality lighting systems. What approach does Lumileds use to enable precise dimming while preserving color stability?

Oleg Shchekin & Toni Lopez: As an LED manufacturer, we have long recommended that our customers use pulse width modulation (PWM) for very low output levels to ensure consistent output and color between individual LEDs. The challenge with that approach is that if the driver modulation frequency is insufficient, it can result in flicker or ghosting. By improving the LED chip material consistency, we can now achieve good consistency at very low current levels in our deep dimming LEDs. Customers can now achieve deep dimming with current amplitude modulation, without the need for high-frequency PWM drivers.

We first introduced this approach for Automotive Rear Signaling LEDs that combine brake and taillight functions.

LED professional: Red InGaN LEDs have long been a challenge in the industry. Where do we stand today in terms of performance and scalability?

Oleg Shchekin & Toni Lopez: For very small microLED size (<5 µm), InGaN Red is already more efficient than the alternatives of Red based on AlInGaP or blue converted with quantum dots. Lumileds has demonstrated InGaN Red at a long



Lumileds has extended its record-setting advances in its InGaN Red LED development. The InGaN material system is an attractive alternative to AlInGaP for creating red light sources because it harmonizes manufacturing with Green and Blue LEDs, which are also based on InGaN.

dominant wavelength of 620 nm of 14% wall plug efficiency for high power devices and is now working to port those results to microLEDs. Our team achieves these Red InGaN results using our high-volume production equipment, which makes us confident that it can scale to high volume.

LED professional: Where do you see the most significant untapped potential for microLEDs over the next 5 to 10 years?

Oleg Shchekin & Toni Lopez: MicroLEDs have the potential to change displays that we know today, like OLED or LCD, or help create new categories like Augmented Reality Displays or displays in glass. All are exciting. The technology continues to hold promise and opportunities to stick to our mantra to make the never-before-possible, possible.

LED professional: Do you anticipate metasurface-enhanced LEDs could one day replace legacy display or lighting technologies at scale?

Oleg Shchekin & Toni Lopez: Narrowing the beam and improving the source efficiency have inherent advantages. We expect that this technology will find its way into many applications. The achievement of enhanced light extraction and radiative rate is a prelude to future LED products with higher efficiency than what is possible with the current state-of-the-art technologies.

LED professional: Thank you so much for this exclusive and extensive interview. It was a pleasure talking with you.

Oleg Shchekin & Toni Lopez: Thank you very much. ■

Dr. Oleg Shchekin is the Chief Technology Officer of Lumileds and is responsible for technology roadmap and incubating new technologies and product concepts that enable Lumileds to lead the industry. Oleg brings over 20 years of innovation, technical development and organizational leadership in semiconductors and LEDs to his role. Dr. Shchekin joined Lumileds in 2005 and has held a number of technical and leadership roles. He has guided LED product efficiency roadmaps, phosphor materials development, incubated and transferred new technologies and products to development, and established and developed a number of technical competencies in R&D. Dr. Shchekin's previous professional experience includes epitaxial semiconductor crystal growth, semiconductor lasers, and flexible organic semiconductor integrated circuits. His work has been recognized by various awards as well as industry review journals. Dr. Shchekin holds Ph.D. and M.S. degrees in Electrical Engineering and a B.S. degree in Physics from the University of Texas at Austin.
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Dr. Toni López is a Distinguished Scientist and member of the R&D group at Lumileds, where he plays a key role in advancing LED and MicroLED technologies. His work focuses on enhancing light emission efficiency and directionality through nanophotonics engineering. Prior to joining Lumileds, Toni worked at Philips Research Laboratories, where he focused on enhancing power semiconductor devices in switched-mode power supplies for automotive and computer applications. Toni holds over 100 granted patents worldwide and over 30 conference papers, journal publications and invited talks. He received his B.Sc. in electrical engineering with honors, his M.Sc. in electronics and communication engineering, and his Ph.D. with the highest honors at the Polytechnic University of Catalunya, Barcelona, Spain.
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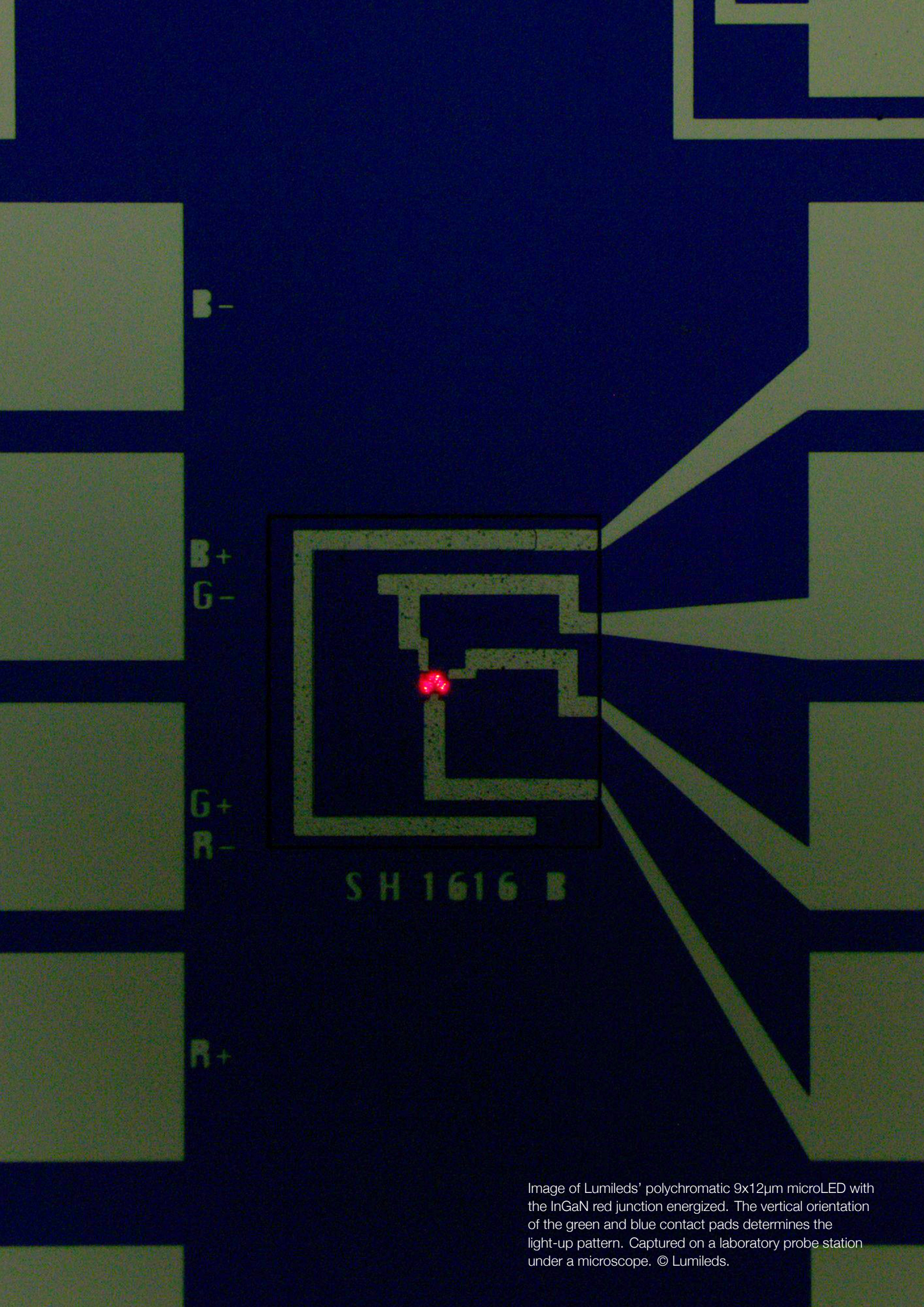

Image of Lumileds' polychromatic 9x12µm microLED with the InGaN red junction energized. The vertical orientation of the green and blue contact pads determines the light-up pattern. Captured on a laboratory probe station under a microscope. © Lumileds.

How Automated, Chemical-free UV-C LED Systems Significantly Reduce Microbial Load in Real-world Conditions

DI Stefanie Kern[1], Teamleader R&D at Lumitech

The topic of necessary disinfection has been omnipresent not only being underscored since the COVID-19 pandemic. When someone coughs or sneezes, countless tiny virus microdroplets are released into the air, which can cause infection by inhalation directly or settle on surfaces and then cause smear infection by touch. It has been known for some time that UV light can kill up to 99.9% of viruses and bacteria. The light destroys (by cracking) the molecular components, because subsequently UV-C successfully disables the DNA & RNA of the microorganism rendering it unable to replicate (schematic representation in Figure 1). Stopping their reproduction consequently prevents them from infecting anyone else. Therefore, ultraviolet light (which is also part of sunlight) is a longstanding tool in the battle against microbial pathogens.

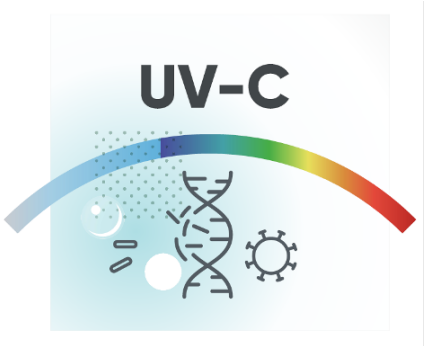

Figure 1: UV-C light: mode of action.

In a nutshell: with a proper dose (time and emitting power) UV-C light can kill all sorts of bacteria, fungi, and virus particles without (toxic) chemicals, such as chlorines, or other resilience causing materials.

From Mercury Tubes to LED Innovation

The UV light is currently mainly produced by mercury tubes, which have the following disadvantages: the dangerous mercury content per se and the limited tube lifespan, especially for high switching frequencies. However, thanks to the LED technology there is a disruptive innovation just starting (similar to the general lighting) in order to replace the tube technology with environmentally friendly LEDs. Moreover, LEDs make a free choice of form-factor possible, which means design is no longer restricted to previously mandatory tube-design.

Product Overview: The UV-C LED Disinfector

The following detailed field-study illuminates the results of disinfection with UV-C light powered / generated by LEDs for disinfection in the particularly demanding environment of a childcare facility. This is done by the so-called UV-C LED disinfector (**Figure 2**), developed by the Austrian company Lumitech. It is a small, ceiling-mounted device similar to a smoke detector (regarding its design), with an integrated UV-C LED module for surface disinfection.

Product Features

- Fully automated surface disinfection by UV-C LED irradiation

Figure 2: UV-C LED disinfector (Lumitech).

- Integrated sensor intelligence for highest safety in automatic mode: rooms/surfaces are irradiated by UV-C light only if no persons are present
- Visual indication for displaying the operating mode
- Timing control
- Possibility for integration into DALI networks
- Simple mounting and installation: standalone device on the surface, only to be connected to mains supply voltage
- UV-C LED disinfection of a 50 m^2 room in 8 hours
- General proof of concept available from OFI (Austrian research and testing institute), tested on bacteriophages (viruses that infect and replicate within bacteria) of the type Pseudomonas phage phi6.

Pilot Study Setup and Methodology

It is commonly known that institutions such as schools or especially childcare facilities tend to be affected by a higher germ load than other places, since infections can spread more easily among (little) children. Therefore, applying UV-C LED disinfection

[1] stefanie.kern@lumitech.com

in childcare facilities seems to be a very sensible approach, which is e.g. already described in [1]. In childcare facilities, it is not uncommon for toddlers to put a lot of things in their mouths. For investigating the effectiveness of the UV-C LED disinfector in a real environment, 3 group rooms of a childcare facility in the village Sankt Martin an der Raab (located in the South-East of Austria) were made available as a testing field: 1 nursery room with children between the ages of 1 and 3 (denoted as GR1 in the following) and 2 childcare facility rooms with children between the ages of 3 and 6 (denoted as GR2 and GR3 in the following).

Each group room was equipped with 2 UV-C LED disinfectors in a simplified operation mode as requested by the childcare facility staff: the sensor-controlled automatic mode was deactivated, and the timing function was set to a fixed UV-C LED radiation between 22:00 and 06:00. The number of installed UV-C LED disinfectors was based on a simplified calculation of the provided UV-C LED radiation dose: Starting from a radiating power of ~276 mW (transmission of the used quartz glass cover included) and the radiation distribution of the disinfectors with peak wavelength of 275 nm, the number of UV-C LED disinfectors for each room as well as the test positions (distance between disinfector and test position 2m-2.2m on average) was chosen. That way, and setting a radiation durance of 8 hours, an average dose value of 30 mJ/cm^2 was calculated, which approximately covers the known dose values needed for eliminating SARS-CoV-2 and influenza viruses and E.coli bacteria up to 99.99% (log4), described e.g. in [2] for a typical UV-C wavelength of 254 nm (based on standard mercury low pressure lamps), but also in [3] for higher UV-C LED wavelengths.

The childcare facility pilot study was carried out over an overall period of three weeks, split into two weeks in September/October 2024 and one week in November of the same year to include weather-related influences (occupancies indoor/outdoor).

There were four fixed test dates defined for each test day:

- 06:30: opening time, before first contamination after UV-C LED disinfection over night
- 09:00: directly after first playtime in the childcare facility (children are indoors)
- 11:30: directly after second playtime in the childcare facility, before lunch
- 14:30: after last contamination caused by children's attendance and before standard manual cleaning process.

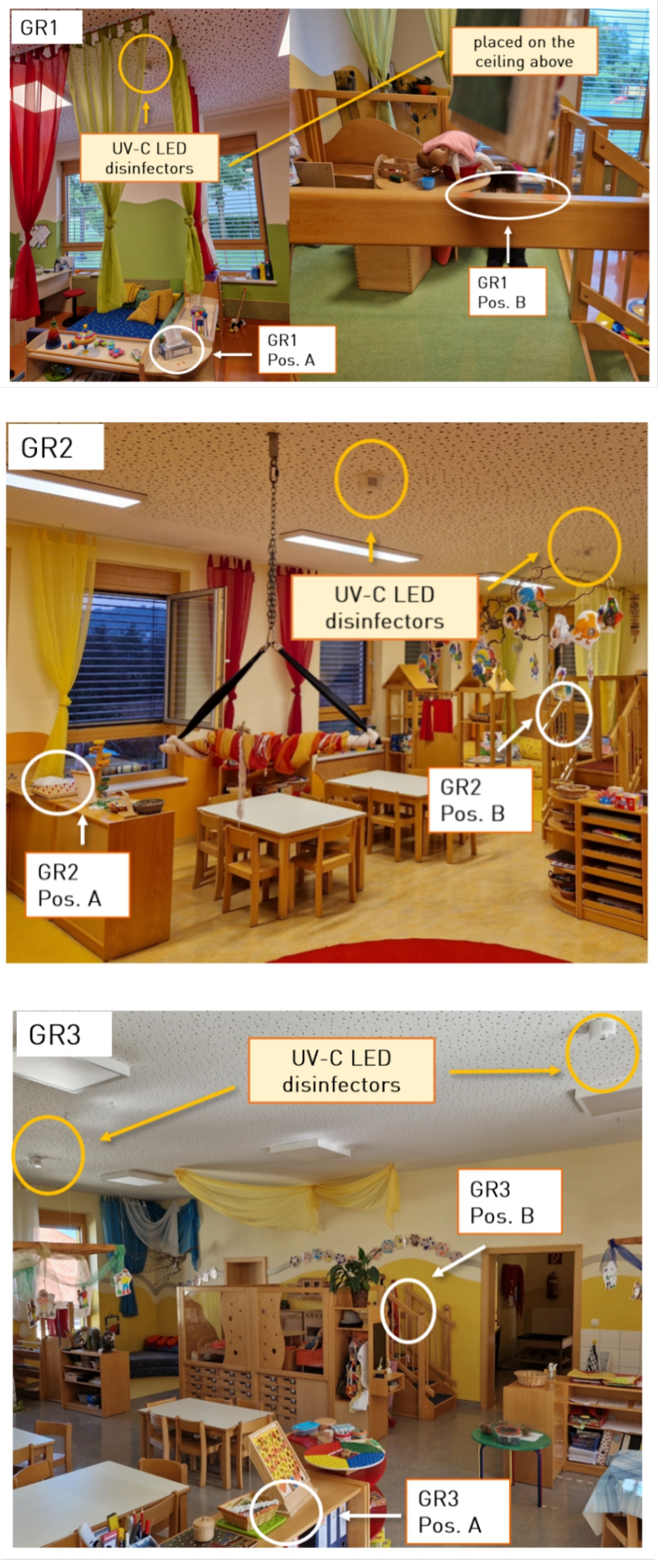

Figure 3: Group rooms, positions of UV-C LED disinfectors and sample points.

For all test runs, the germ contamination of the specified surfaces in the group rooms was determined by using dip slides of type Hygicult TPC [4] for the most common bacteria and fungi. After sampling, these dip slides were incubated and then evaluated, partially by an external lab (W.H.U. GmbH Bischofshofen - Labor, Prüf- und Inspektionsstelle). Analysis data were expressed in so-called CFU per cm^2, where CFU means colony forming unit (standard unit for microbiological investigations). It should be noted that there are no concrete regulatory CFU/cm^2 limit values for surfaces in e.g. childcare facilities, but only general hygienic recommendations [5]. **Figure 3** shows GR1, GR2, GR3 with the positions of the installed UV-C LED disinfectors and the positions of the sample points. These points were chosen after consultation with the childcare facility staff primarily as points with high "touching frequency" and less considering their optimum UV-C radiation position. **Table 1** summarizes the attendances and room occupancies of the whole test period as well as the chosen test setup:

- No UV-C LED disinfection carried out, standard cleaning process performed
- UV-C LED disinfection carried out between 22:00 and 06:00 (every night, also during the weekend), no standard cleaning at the sample points
- UV-C LED disinfection between 22:00 and 06:00 (every night, also during the weekend) and standard cleaning at the sample points performed.

Results: Germ Load Reduction in Practice

For the results, presented in the following, all obtained data underwent a validity check[3]. Valid data were averaged to generate curves for the germ load, depending on the chosen test setup, that are as generic as possible in the context of this concrete pilot study. It is noted that germ load data belonging to test time 11:30 have been excluded in the final evaluation of the results because there was no significant change to the germ load data belonging to test time 09:00 (changes only

[3] Clearly, the pilot study is subject to some slight uncertainties (100% reproduceable results are not possible e.g. due to daily routines, children's behavior etc. are not completely comparable from day to day).

Date DD.MM.YYYY	GR1	GR2	GR3
23.09.2024	9 children Occupancy until ~10:45 (afterwards outdoors) **Setup: UV-C LED + cleaning**	14 children Occupancy until ~10:15 (afterwards outdoors) **Setup: UV-C LED + cleaning**	18 children Occupancy until ~10:15 (afterwards outdoors) **Setup: UV-C LED + cleaning**
24.09.2024	9 children Occupancy until ~10:45 (afterwards outdoors) **Setup: UV-C LED + cleaning**	13 children Occupancy until ~10:15 (afterwards outdoors) **Setup: UV-C LED + cleaning**	19 children Occupancy until ~10:15 (afterwards outdoors) **Setup: UV-C LED + cleaning**
25.09.2024	9 children Occupancy until ~10:45 (afterwards outdoors) **Setup: UV-C LED + cleaning**	15 children Occupancy until ~10:15 (afterwards outdoors) **Setup: UV-C LED + cleaning**	19 children Occupancy until ~10:15 (afterwards outdoors) **Setup: UV-C LED + cleaning**
30.09.2024	8 children Occupancy until ~10:45 (afterwards outdoors) **Setup: cleaning only**	13 children Occupancy until ~10:15 (afterwards outdoors) **Setup: cleaning only**	18 children Occupancy until ~10:15 (afterwards outdoors) **Setup: cleaning only**
01.10.2024	10 children Occupancy until ~10:45 (afterwards outdoors) **Setup: cleaning only**	14 children Occupancy until ~10:15 (afterwards outdoors) **Setup: cleaning only**	17 children Occupancy until ~10:15 (afterwards outdoors) **Setup: cleaning only**
02.10.2024	10 children Residence only indoor **Setup: cleaning only**	16 children Residence only indoor **Setup: cleaning only**	16 children Residence only indoor **Setup: cleaning only**
25.11.2024	10 children Occupancy until ~12:30 **Setup: cleaning only**	14 children Occupancy until ~11:00 (afterwards outdoors) **Setup: UV-C LED, no cleaning**	15 children Occupancy until ~11:00 (afterwards outdoors) Between 12:30 and ~15:00 2 children present (afternoon care) **Setup: UV-C LED, no cleaning**
27.11.2024	10 children Occupancy until ~12:30 **Setup: cleaning only**	16 children Occupancy until ~11:00 (afterwards outdoors) **Setup: UV-C LED, no cleaning**	14 children Occupancy until ~11:00 (afterwards outdoors) Between 12:30 and ~15:00 4 children present (afternoon care) **Setup: UV-C LED, no cleaning**
28.11.2024	11 children Occupancy until ~12:30 **Setup: cleaning only**	16 children Occupancy until ~11:00 (afterwards outdoors) **Setup: UV-C LED, no cleaning**	15 children Occupancy until ~11:00 (afterwards outdoors) Between 12:30 and ~15:00 5 children present (afternoon care) **Setup: UV-C LED, no cleaning**

Table 1: Attendances, room occupancies and test setups of the pilot study.

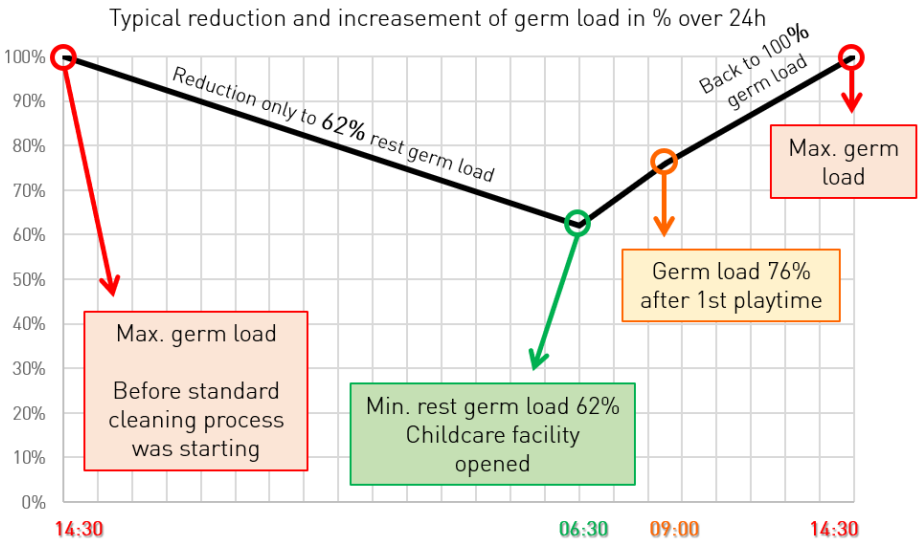

Figure 4: Resulting germ load curve for standard cleaning process only.

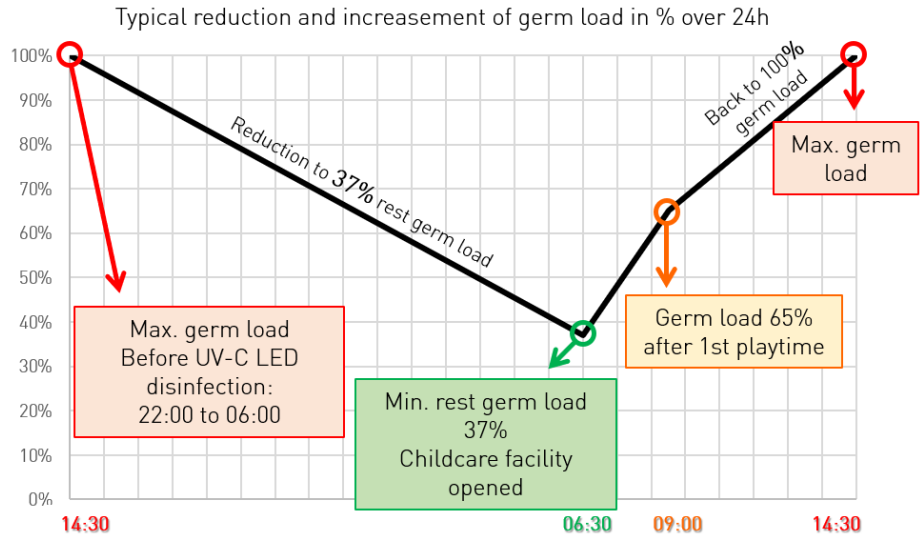

Figure 5: Resulting germ load curve for UV-C LED disinfection only.

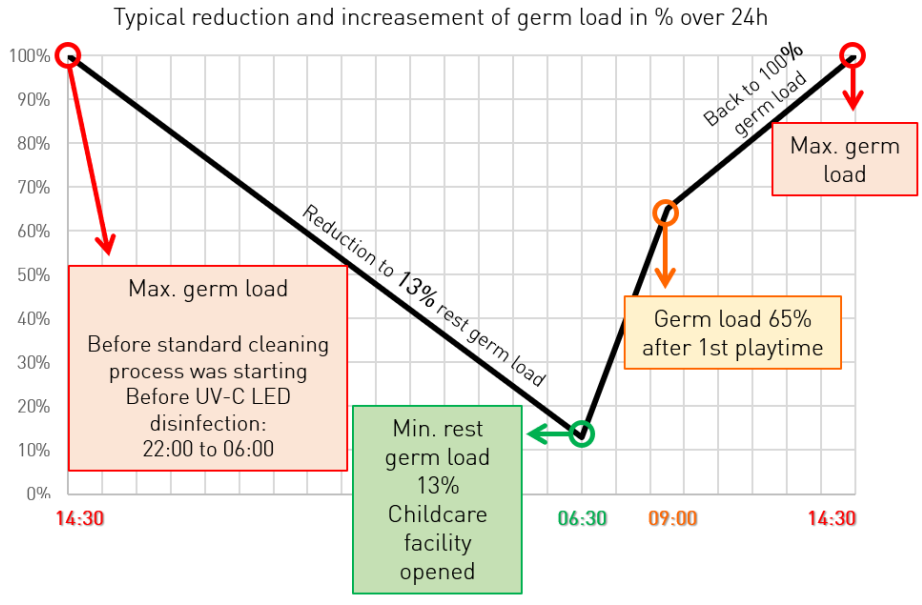

Figure 6: Resulting germ load curve for UV-C LED disinfection in combination with standard cleaning process.

within the calculated variation). Explanation: typically, not continuous occupancy of the rooms between 9:00 and 11:30 due to several activities. Furthermore, it is noted that transitions between different germ load values are illustrated as linear approximations in **Figure 4**, **Figure 5**, **Figure 6** and **Figure 8** for a clearer demonstration of the results.

In addition to **Figure 4**, **Figure 5**, **Figure 6** and **Figure 8**, it can be summarized that:

- **Figure 4**: Without UV-C LED disinfection, but carrying out the standard manual cleaning process, the maximum germ load of 100% detected at 14:30 on a test day was reduced to a minimum germ load of 62% detected at 06:30 in the morning on the following test day, where between these dates no children were present. **Obviously, 62% is quite a high rest germ load level and shows that standard cleaning might not be sufficient, especially for high absolute maximum values as e.g. 1,500 CFU/cm^2**, which was detected a few times during the pilot study for setups without UV-C LED disinfection and for which **the consulted external lab made the urgent recommendation for additional disinfecting measures**.
- **Figure 5**: With active UV-C LED disinfection between 22:00 and 06:00, but without the standard cleaning process performed for the selected sample points, the maximum germ load of 100% detected at 14:30 on a test day was reduced to a minimum rest germ load of 37% detected at 06:30 in the morning on the following test day, where between these times no children were present. **This shows that UV-C LED disinfection (in the setting chosen for this pilot study) has a clearly higher impact on germ load reduction than standard cleaning only**.
- **Figure 6**: With active UV-C LED disinfection between 22:00 and 06:00, and carrying out the standard cleaning process, the maximum germ load of 100% detected at 14:30 on a test day could be reduced to a minimum rest germ load of 13% detected at 06:30 in the morning on the following test day, where between these times no children were present.
- The smallest measured value for rest germ contamination in the morning was 5 CFU/cm^2 for the setup “UV-C LED disinfection in combination with standard cleaning process”, **which can be interpreted as no existing germ load**.

- **Figure 7** shows a comparison of dip slides with bacterial growth after three days of incubation. The **top slides** refer to samples taken at a test position in the afternoon at 14:30, while the **bottom slides** show the samples taken at the same position the following morning, after cleaning and overnight UV-C LED disinfection.

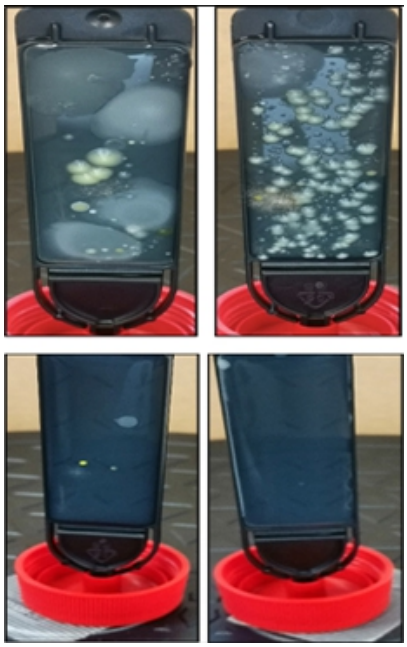

Figure 7: Dip slides after incubation, before and after cleaning and UV-C LED disinfection.

These impressive results show that applying UV-C LED disinfection with the chosen product, even if used in a simplified operation mode for the 8 hour period during the night, leads to a considerably higher reduction of microorganisms on the surfaces than applying only the standard cleaning process. An already higher reduction of the germ contamination as a starting point in the morning futhermore leads to a flattened increase of the germ contamination in the course of the day (**Figure 8**) and therefore to a general reduced risk for infections. In addition, it could be seen that UV-C LED disinfection only (without cleaning) might not be sufficient regarding germ load because there is of course also dust, dirt, etc. Therefore, the need for standard cleaning processes still remains.

It can be clearly stated that UV-C LED disinfection, based on the given radiance parameters, can make an important contribution to the reduction of bacterial load in institutions with a possible high presence of infectious germs, even if only used during the closing hours.

As an upside potential, the germ load curves for active UV-C LED disinfection (**Figure 8**) could be flattened from morning to afternoon by switching to the automatic mode of the UV-C LED disinfector (as stated earlier). Outdoor time slots would be recognized by the disinfector as no presence so that the device would activate itself for UV-C LED disinfection during the day as well.

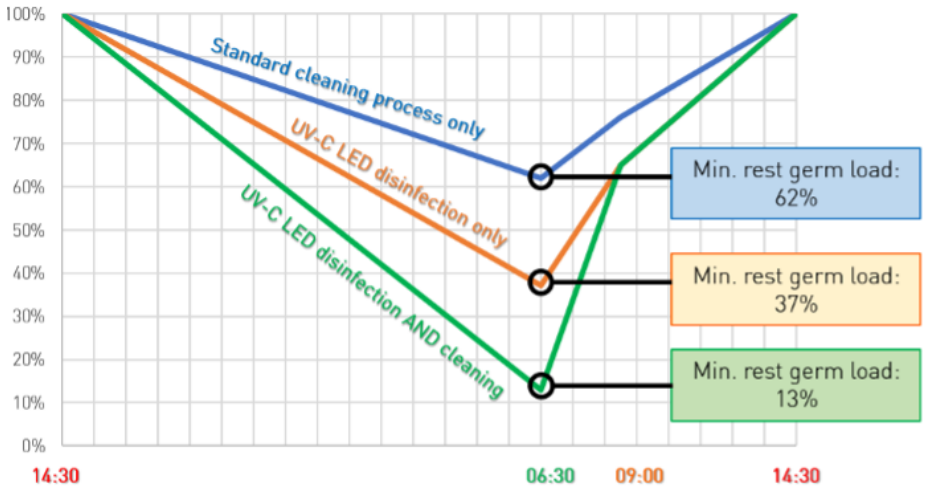

Figure 8: Comparison of resulting germ load curves for the different test setups.

Regarding concerns about potential material damage, tests have been conducted on various materials (especially plastics). They have shown that no yellowing, brittleness, etc., occurred. Based on the average solar irradiance (2.24 mW/cm^2 at 270–380 nm), the following comparison can be made: One year of continuous (24/7) irradiation by the UV-C room disinfector (mounted on the ceiling at a height of 3 m) corresponds to only one hour of direct sunlight exposure. A negative impact on the condition of irradiated materials and surfaces can therefore be ruled out.

Conclusion and Outlook

The field study impressively demonstrates the proven effectiveness of germicidal ultraviolet technology based on UV-C light generated by LEDs for disinfection in standalone safe operating mode.

LUMITECH as LED innovation-leader develops and manufactures state of the art UV-C LED-technology (COB as well as SMT) in Austria, with best in class UV-C efficiency combined with specific optics, well considered thermal management, and optimized layout- and connection-technology especially for UV like the UV-C room-disinfector, that was used in the field study described above and which can be used autonomously while guaranteeing intrinsically safe operation. All this as an upper-room germicidal system in a well-known design for surface mounting on the ceiling similar to commonly used smoke detectors. ■

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Real-Time Photometry with [o3u]-cam

Mag. Wilfried Pohl and Mag. Christian Anselm, MSc., [o3u]

The Lighting Market

The European lighting industry faces major challenges.

LED manufacturers offer a wide range of high-quality LEDs with various power ratings, efficiencies, color temperatures and CRIs. Optical components (lenses and reflectors) and light engines are available at low cost and in high quality for almost every application. Various wired and wireless control systems enable project-specific and user-centerd control of lighting systems for almost every application.

This means that the barrier to implementing attractive, highly functional lighting is becoming smaller and smaller, and competitive pressure is increasing massively. New companies are entering the market without previous experience in the lighting industry, but with cost-optimized supply chains (e.g. from the Far East) and scaled networks in manufacturing (containers/mass-produced goods).

Cost-down-approach > Me-too
Many European lighting manufacturers are therefore focusing on ever shorter product development cycles with reduced development budgets. Minimizing their costs increasingly limits differentiation to the external design of the housing. One credo is platform thinking, with the aim of creating as extensive a catalogue of luminaires as possible for every application. The lighting technology is often interchangeable, the products comparable, and the low price promises capacity utilization and market share (downward orientation).

Level-up in niche markets > Differentiation
A few smaller lighting manufacturers are bucking the mainstream trend, reducing their portfolios and focusing on niche products of the highest quality to meet individual customer needs. The projects require intensive consultation, the volumes implemented are smaller, and the margins are higher (upward orientation). In addition to high-quality product design and complex implementation, the quality of the light plays a central role.

Focus on light quality
Successful service to the upmarket segment requires more than just the traditional supply of (standardized) luminaires. Luminaire manufacturers are usually partners to architects in the implementation of individual project requirements. The design of the luminaire itself, a customized (miniaturized) size for integration into the architectural environment, and the positioning of the luminaire are all important factors. High quality in terms of function and materials, a well-thought-out installation, ease of maintenance and flexible control are essential. Minor compromises in system efficiency are accepted in order to achieve the highest possible light quality. The product is defined by the feasibility of individual lighting design ideas.

Future: Individual (personalized) lighting production
Automation in industry is increasingly being replaced by ‘intelligent’ robots, which will enable cost-effective individual mass production of products in the future. Various manufacturers already offer customers the option of using a ‘configurator’ to select individual combinations of accessories and lighting components (e.g. optics with different light packages, light distributions, etc.).

In the future, customers could create their own individual designs for decorative parts using special design modelling (e.g. using a computer-assisted morphing algorithm) and have them manufactured using additive manufacturing methods.

The combination of digital configurators and additive manufacturing can open up entirely new dimensions in terms of flexibility and efficiency. Customers will benefit from an unprecedented variety of design options and can tailor products precisely to their requirements. The direct transfer of configuration data into the production processes would significantly reduce the time from idea to finished product.

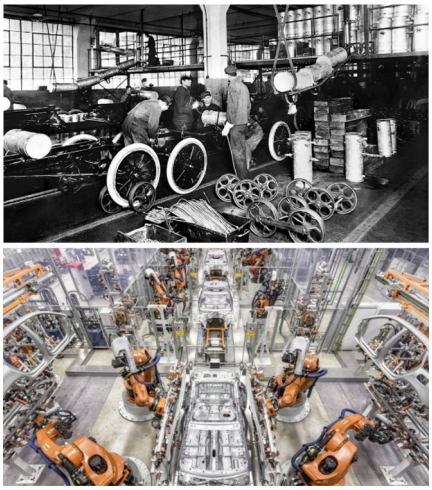

Figure 1: Manual line production (top), individual mass production using robotics (bottom) [1].

In principle, these design options are not limited to aesthetic features but should also include optical properties in the future. This requires a rapid optical design process that enables project-specific optical development in the shortest possible time and includes the manufacture of optics using 3D printing.

Rapid Optical Design

The implementation of innovative products in the lighting industry generally follows the classic development steps [2]. In the development process, once the requirements have been clarified, a system concept is developed and the optical system is worked out in detail. Simulation programs are used to simulate the lighting performance data to then produce a functional model or prototype.

Optical simulation programs work with mathematical models that cannot accurately represent various effects (e.g. scattering on surfaces and transmitting materials, manufacturing tolerances, etc.). In addition, the relevant optical material parameters are often not available in practice, leading to sometimes significant deviations in the simulations results. Real functional models and prototypes are therefore nec-

essary to verify the results of theoretical calculations and to carry out the final optimizations and adjustments.

Time-consuming testing cycle
These functional models and prototypes are measured using goniophotometer systems, and the corresponding planning data is provided (e.g. Eulumdat files). The system analysis is computer-assisted, while visualization takes place separately by standard lighting design programs (e.g. Dialux, Relux). Conclusions about the functionality of the luminaire samples require the entire process chain of measurement, analysis, evaluation and separate visualization. This takes time and ties up (specialist) human resources and equipment (infrastructure).

Rapid Optical Design
In many cases, the desired development goal can be achieved much more quickly if the development process and final fine adjustments are carried out experimentally on real samples (experimental circle). Until now, this approach has required cumbersome measurements with a goniophotometer to evaluate the results photometrically. This cycle can be significantly shortened with the [o3u]-cam, and the result of an experiment is immediately visible photometrically, enabling a continuous optimization process (**Figure 2**). Another major advantage of this approach is that the effect of various improvement measures can be experienced in real time.

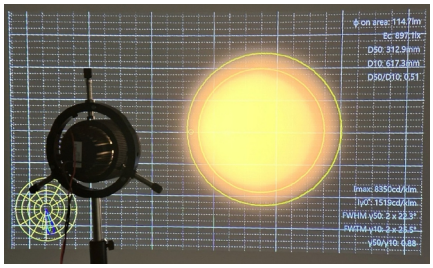

Figure 3: Light distribution superimposed with the photometric measurement data.

The [o3u]-cam

Goniophotometers are used to measure the angle-dependent luminous intensity distribution (LID) of a light source. There are a variety of different design principles for goniophotometers, but such measuring systems generally require special environments, and the measurement cycles (including mounting of the test object) range from a few minutes to hours, depending on the resolution and integration time required, with the measurement duration increasing significantly with the selected angular resolution (e.g. for narrow-beam systems and detection of cut-off edges).

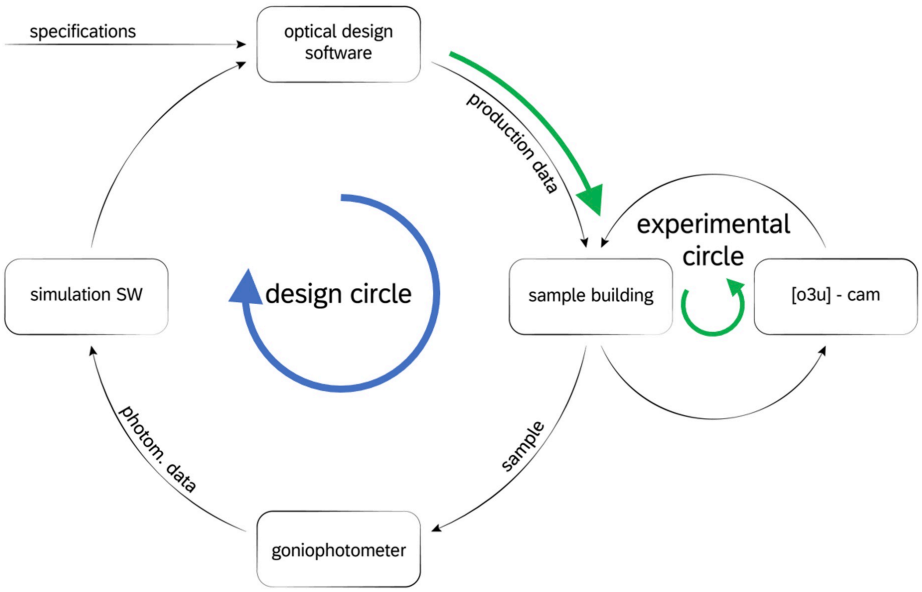

Figure 2: Reduction in development times (design circle) through [o3u]-cam (experimental circle).

The goniophotometer thus characterizes the light source itself more or less precisely and describes its lighting distribution behavior. However, in order to evaluate the effect of light sources and luminaires in a lighting application, simulation programs such as Dialux or Relux are required, which map the light from the light source onto reflective surfaces (illuminance) and generate perceptible effects (luminance) from this.

The patent-pending [o3u]-cam **[3]** (**Figure 4**) evaluates the reflected light from a measurement surface and provides absolute measurement values in real time. The software offers all common analysis methods as well as special features and visualizations for evaluating industry-specific parameters, e.g. for medical standards in the case of analyzing surgical lights. This allows to immediately measure and visualize the effects of modifications to the optics, changes to the housing, etc. on the distribution itself and key observables.

This allows the lighting effect to be directly related to the metrological characteristics of the underlying optical system. Changes to the optics and modifications to luminaires can thus be experienced both in terms of their lighting effect in the room or on the reflective surface and in terms of their photometric characteristics.

The measurement method is based on capturing the reflected light from a diffuse measurement surface with a camera and, together with geometric parameters, calculating photometric values such as the luminous intensity distribution (LID). Calibration with a calibrated Luxmeter or spectrometer converts the initial relative values into absolute measurement values.

The data is processed in proprietary 'light characteristic software' (LCS) and evaluated and visualized in terms of both the reflective surface and the source. Comprehensive access to raw data, typical exports of measurement data in lighting design formats and customer-specific reports enable easy further processing of the measurement data.

Figure 4: The [o3u]-cam.

One of the main advantages is that the entire LID is captured in a single image in fractions of a second with high resolution (typically 1-5 pixels/mm).

In luminaire or optics development environments, changes such as different accessories, the influence of materials/surface

properties or zoom concepts can be measured very quickly. The [o3u]-cam and LCS analysis software provide direct support for the development process of lighting components and luminaires and give direct numerical feedback, e.g. for modifications:

- to the light engine (different LED packages),
- to the optics (e.g. reflectors/lenses with different beam angles, zoom positions)
- the lighting components (attachment of diffusion foils, honeycomb structures)
- the mechanical design (apertures, diaphragms)
- the surfaces (glossy/matt or colored/white/black housing)
- etc.

Figure 6 shows an example of the change in LID when a cut-off device (honeycomb attachment) is added: the full width at half maximum (FWHM) decreases from 28.2° to 15.4°, and the efficiency from 76.8% to 52.6%.

Mobile, flexible applications, e.g. for checking or comparing luminaires in a planning project on site, are also possible thanks to the compact design and simple setup with a mobile or existing measuring surface.

The [o3u]-cam with feedback via the projector links the appearance (perception) with the photometric key figures. In this way, the user gets a feel for the photometric data, the metrics become tangible for them, and the data is linked to sensory perception.

This approach creates a continuous workflow that provides a sound basis for lighting decisions right from the design and development phase. The direct feedback between visual impression and precise measurement not only allows for faster evaluation, but also for targeted optimization of the optical design – without having to go through multiple software or device levels. The [o3u]-cam thus creates a new quality of collaboration between design, technology and application, particularly in the development of architecturally integrated functional luminaires. The early integration of objective data supports creative processes, minimizes unnecessary iteration loops and significantly accelerates the implementation of sophisticated lighting concepts.

The high measurement speed also enables use in quality control in manual or automated production lines for luminaires or optical components.

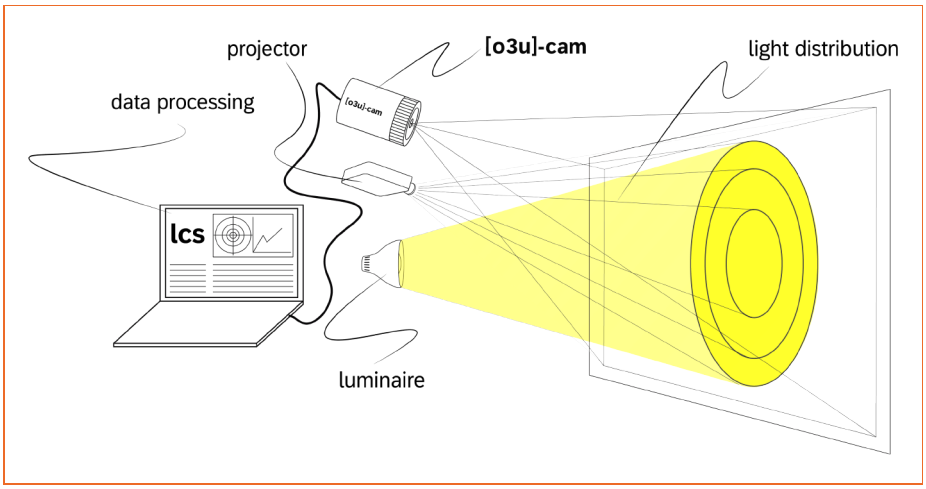

Figure 5: Functional principle of the [o3u]-cam.

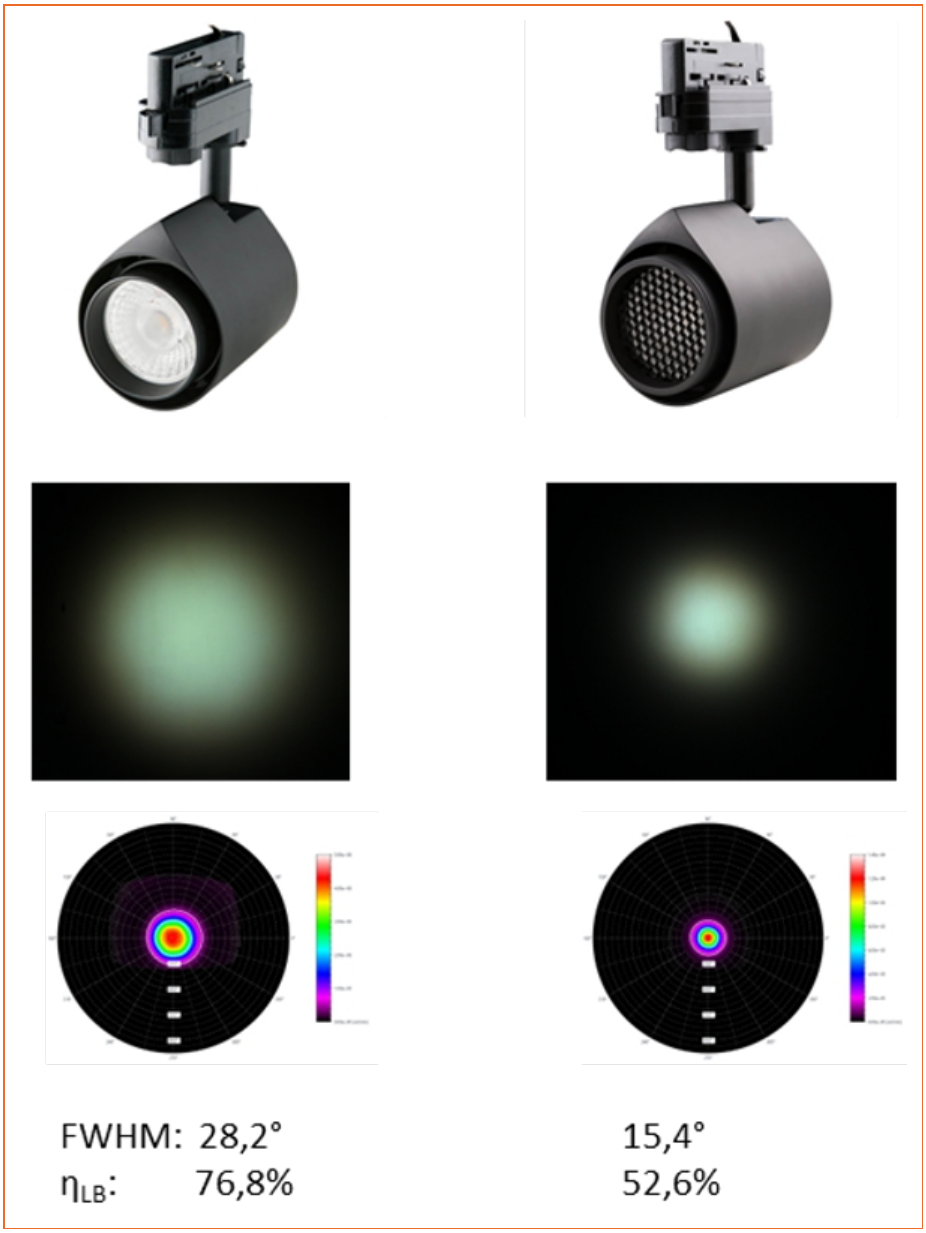

Figure 6: LID modification with a honeycomb accessory.

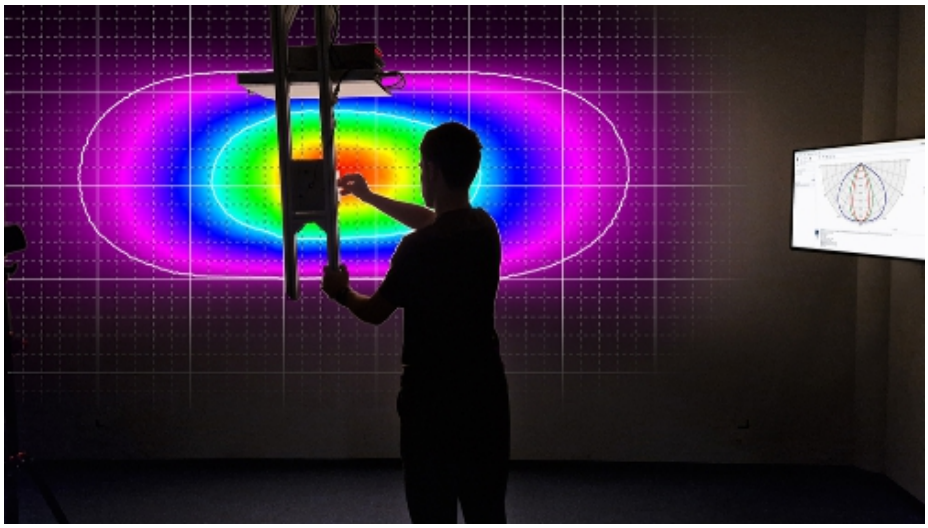

Figure 7: [o3u]-cam with superimposed photometric parameters (here half-value and tenth angle).

The [o3u]-cam for Quality Control in Development and Production

The [o3u]-cam as a compact and fast measurement system is also suitable for seamless inline quality control of optical components, light engines, and luminaires during production. Unlike singlepoint measurements, the entire light distribution can be analyzed for quality control. Whether test specimens are inserted manually or automatically by robotic handling systems, [o3u]-cam integrates effortlessly into manufacturing lines or laboratory environments. In fractions of a second the system captures reflected light and delivers a comprehensive set of photometric performance parameters. These include luminous flux, illuminance, and uniformity, as well as detailed metrics such as luminous intensity distribution curves, beam angles, and optical efficiency. This depth of analysis allows for a complete characterization and documentation of the optical behavior of each component or product.

By comparing the measured data with predefined simulation targets or previously approved reference samples, customized quality criteria and rejection thresholds can be defined for virtually any lighting performance metric. This enables a precise pass/fail evaluation for each unit under test. Defective or subpar optical components are immediately identified and sorted out before they enter the next production step. This not only reduces waste and rework costs but also ensures a consistently high-quality assembly process. Additionally, all measurement results can be archived, enabling full traceability and the ability to retrospectively analyze the optical performance of every individual component or luminaire produced.

The [o3u]-cam thus provides a powerful tool for manufacturers who demand reliability, precision, and traceability in optical quality assurance—whether in small-batch production or fully automated, high-volume environments.

In Automated Mass Production

Figure 8 shows an example of position control: on the left, the light intensity distribution when the LED is correctly positioned; on the right, when the LED is slightly misaligned. This incorrect positioning is immediately detected by [o3u]-cam and rejected from the production line.

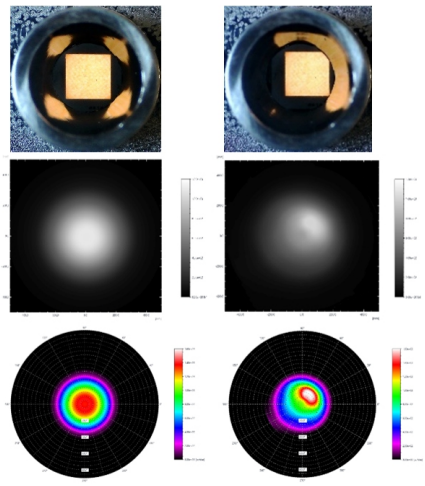

Figure 8: Effects of incorrect positioning of an LED in the optics.

The [o3u]-cam is successfully used in the production control of optical components. The measurement of photometric performance data is integrated into the manufacturing process of the light engine/optics/luminaire in such a way that defective photometric components can be detected and rejected before they are installed in the luminaire housing. Expensive post-process steps are avoided, and the production of defective assemblies is eliminated.

The Test Box for Manual Component Testing

A standardized test box has been developed for individual quality checks on optical components. It works in much the same way as the test in automated production, with the only difference being that the components to be tested can be inserted into the tube manually. The target values for the optics to be tested are entered via an easy-to-use interface, and the LCS program then determines whether this target value is achieved (good test item) or whether the test item must be rejected.

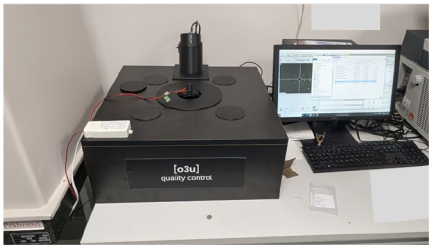

Figure 9: Manual quality control with the test box.

The Medical Test Stand

The [o3u]-cam system can also be used to perform high-precision quality control of surgical luminaires in accordance with EN 60601-2-41 (3rd edition). This standard defines stringent requirements for surgical lighting. The defined parameters have so far been determined using time consuming, selective individual measurements. The [o3u]-cam supports manufacturers and laboratories in meeting and documenting compliance reliably by automatically measuring the full photometrical behavior in seconds, and completely new performance indicators can also be derived from this.

Among other things, this test bench has the following unique features:

- **Comprehensive Light Field Analysis**
  [o3u]-cam performs an in-depth evaluation of the illuminance (Ec) and light distribution, including the measurement of D50 and D10 diameters, which are critical for characterizing the usable light field and homogeneity. This ensures that the surgical light provides consistent illumination at the required intensity and with minimal falloff across the working area.
- **Realistic Shadow Simulation**
  Another feature of [o3u]-cam is its ability to measure the reduction in light intensity caused by realistic shadowing.

By simulating the presence of surgical staff—such as a surgeon's hands or assistant's head—the system quantifies how shadows affect the illumination field, offering insights into the shadow dilution performance of the luminaire. This is especially important in surgical environments where uninterrupted visibility is critical.

- **Spectral and Colorimetric Measurements**
  In addition to spatial light distribution, [o3u]-cam can integrate measurement devices with spectral measurement capabilities such as.
  • Color Rendering Index (CRI) and detailed Ri values
  • Correlated Color Temperature (CCT)
  • Color consistency and chromaticity analysis
  This enables users to assess whether the light source meets the visual requirements for accurate tissue differentiation and low visual fatigue during procedures.

- **Visualization and Client Communication**
  [o3u]-cam includes the option for integrated or external display systems, allowing real-time visualization of measurement results. These displays can show:
  • Light field overlays
  • Distribution curves
  • Shadow simulation outcomes
  • Spectral graphs and CRI charts

This makes the system ideal not only for internal quality control and product development, but also for demonstrating optical performance at trade fairs, showrooms, or during client presentations.

From Lighting Design to the Luminaire

The integration of the [o3u]-cam into lighting design marks a decisive step forward: architects and lighting designers can immediately experience and optimize the effect of the luminaires they have planned. The [o3u]-cam thus closes the gap between theoretical planning and the actual lighting effect.

This approach can be extended to entire lighting scenarios: if you set up a lighting scenario in a real room that is designed experimentally (e.g. with a 'lighting synthesizer') according to aesthetic and emotional requirements (perception), you can use the [o3u]-cam to capture the image, determine the photometric data of the scene, and then blend it into the scene with the projector so that it overlaps with the appearance when viewing the scene.

Once the desired appearance for the scene has been defined, the photometric requirements (e.g. LID) for various luminaire arrangements can be determined at the touch of a button using the [o3u]-cam and the associated LCS software.

This means that different lighting solutions can be studied and compared in a very short time: you can see the appearance and photometric data at a glance, i.e. you can immediately read the photometric target values for a desired appearance, or vice versa, you can immediately see how the specifications (requirements) need to be changed for a particular solution with certain photometric key data in order to achieve the desired appearance. Photometric target values are, for example, visual indicators such as illuminance, uniformity, shadows, light colors, but also 'health' (non-visual) indicators such as melanopic equivalent daylight illuminance (mEDI). All this can be done in a matter of minutes; it is just a question of computing power.

Innovation Example: Linear Sun

The "Linear Sun" is an example of the experimental development of functionally integrated lighting. The basis for a balanced spatial effect in architecture-integrated solutions is the complete concealment of the luminaires themselves and the retention of the architectural elements. This requires, on the one hand, precise light control with accurate optics and, on the other hand, passive apertures whose (surface) design can be freely adapted to the ceiling environment. The idea behind the artificial sun was to combine several narrow-beam individual optics along a line in such a way that they overlap at a defined distance to form a strong sunspot. With the help of the [o3u]-cam, the individual optics are adjusted for the respective application so that they precisely achieve the photometric target values. Special cut-off tubes conceal the luminaire, which is mounted behind a slot, invisibly in the ceiling.

Such project-specific solutions not only open up new creative freedom for architects and lighting designers but also require precise and flexible implementation in the product development process. From the initial sketch to final production, a systematic approach is essential to ensure the desired light quality, energy efficiency and suitability for everyday use. The interaction of state-of-the-art simulation and mea-

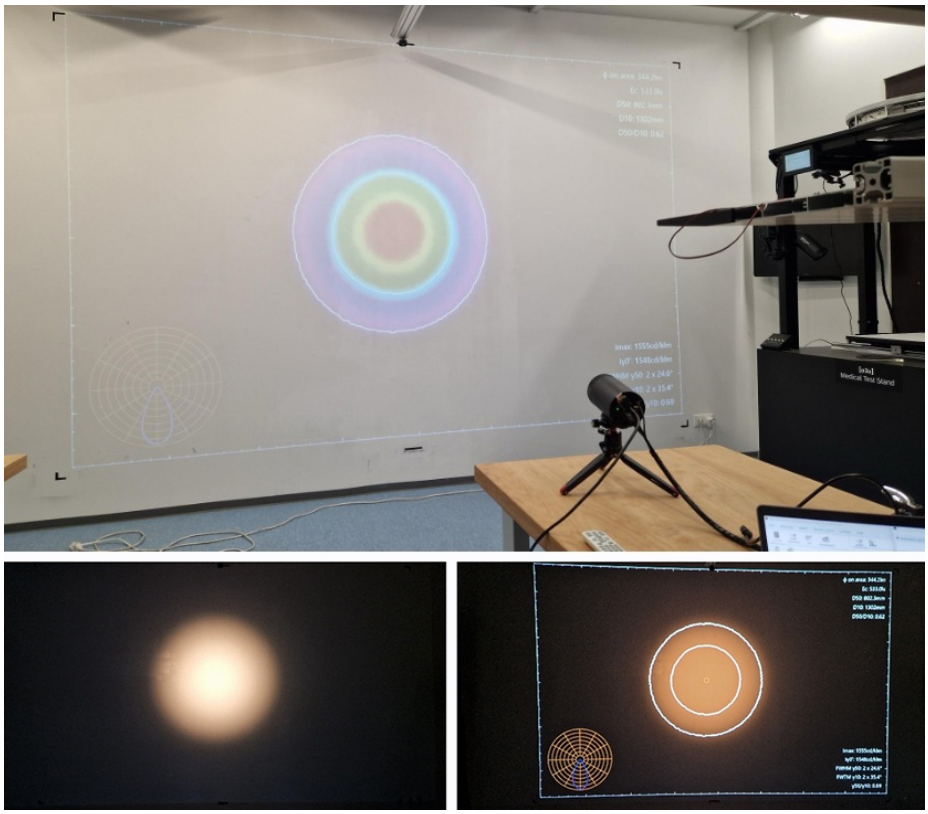

Figure 10: Overlaying photometric data with appearance. Top: Exemplary measurement setup (light image) with superimposed measurement information (projector). Bottom left: Image of the light distribution. Bottom right: Light image superimposed with half-value and tenth value of maximum/central illuminance.

surement technologies is essential here, as it allows conclusions to be drawn at an early stage about the subsequent lighting appearance and performance in a real environment. In this way, every new product idea is accompanied by a sophisticated process that ideally combines creative vision and technical feasibility.

Summary

The [o3u]-cam closes a gap in the development process by creating a direct link between visual perception and the objective photometric evaluation of the luminaire. It captures the complete appearance of a luminaire and immediately converts these visual impressions into precise photometric data. This makes it possible to quickly and easily evaluate the relationships between design, light distribution and functional requirements at an early stage. Sources of error that previously arose from separate measurement and visualization steps are minimized and the development time is significantly reduced. This increase in efficiency opens up new scope for creative lighting design and enables targeted fine-tuning of lighting parameters right from the functional prototype stage. ■

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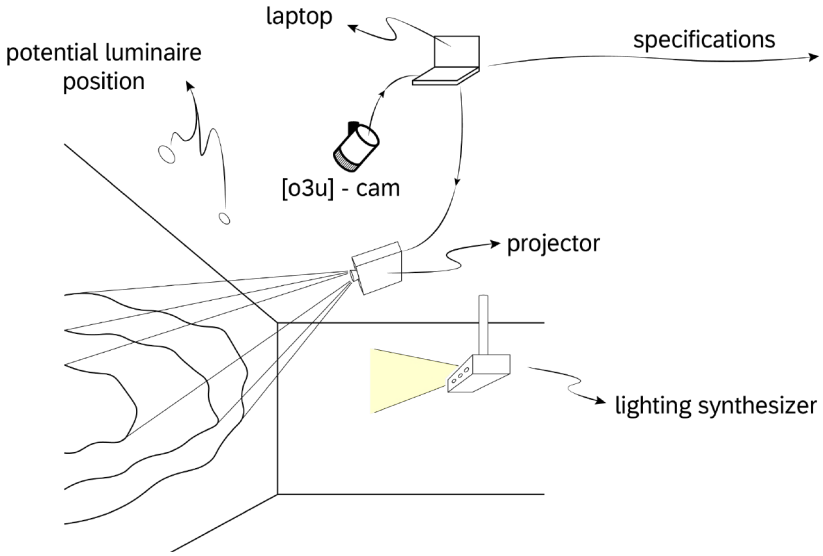

Figure 11: From lighting design to the luminaire.

Figure 12: Linear Sun, Photo of a Mock-up (left), Visualisation of an application.

Mag. Wilfried Pohl (left) and Mag. Christian Anselm, MSc. (right).

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75 Years of Zumtobel – Anniversary Year with Multifaceted Light Perspectives

75 years of Zumtobel – 75 years of passion for light, technology and design. On the occasion of Zumtobel's 75th anniversary, it gives space to a wide range of light perspectives at a temporary exhibition at the Dornbirn Light Forum. Since mid-May, fascinating light art installations from artists like Brigitte Kowanz, François Morellet, Miriam Prantl and Sofia Hagen have been on display, as well as expressive photo portraits of employees and a Future Lab installation from a collaboration with three international universities. In parallel with the opening of the exhibition, Zumtobel launched TECTON II, the second generation of its successful continuous-row luminaire system.

"What we all share within the Zumtobel Group is a passion for light. There is hardly a more beautiful product than light: highly emotional and sophisticated", says **Alfred Felder, CEO of the Zumtobel Group**, and adds, *"The mix of different talents and also the interaction between different cultures is what we stand for and what keeps us flexible. Our innovative culture reflects curiosity and open-mindedness."*

Karin Zumtobel, Chairwoman of the Supervisory Board of the Zumtobel Group, says: *"We pass on the essence of what Zumtobel is about. With our profound knowledge, committed employees and partners and the high demands we place on ourselves. We want people to get together at our company in order to create new things and contribute our share to a positive future."*

Dornbirn Light Forum – expertise and meeting point at the original site

Zumtobel is celebrating at the place where the success story of today's lighting group began in 1950. 15 years later, another production facility with 4,000 square meters of space was commissioned at the original site in Dornbirn's Höchsterstrasse. Today, this former factory hall is home to the Zumtobel Group's Light Forum: a light space, where the strong brands – Zumtobel, Thorn and Tridonic – showcase their expertise in lighting as well as the latest technologies. A space to experience light, designed in cooperation with the Innsbruck studio of the Norwegian architectural firm Snøhetta.

Patrick Lüth, Snøhetta partner and Managing Director of the Innsbruck studio, extends congratulations on the anniversary: *"I am pleased that the Zumtobel Group's Light Forum plays a special role in the celebrations of the company's anniversary. At the very place where Dr. Walter Zumtobel founded his company in Dornbirn, Snøhetta worked with Zumtobel to design a space for co-creation, presentations and an exchange around the topic of light, which is also open to the public. Now, as then, the building represents the company's identity and innovative strength and optimally embodies the corporate culture."*

Inspiring Personalities

The opening of the exhibition was accompanied by a round table talk with very personal insights from Jürg and Fritz Zumtobel – both of whom stepped down in 2020 after decades at the helm of the company – and Karin Zumtobel, Chairwoman of the Supervisory Board. Renato Turri, CEO World-Architects, hosted this talk as well as the two days and the round table on the launch of TECTON II with Zumtobel and the guests of partner Pininfarina, the Italian design studio and engineering group.

The audience was inspired by the keynotes of London artist Dominic Harris on "Color, Light and Technology: A Holy Trinity", of Vitra Design Museum Director Mateo Kries, who talked about "Out of the Box – Shaping Futures with a Museum", and the representatives of the Future Lab contributions from different universities: Anett-Maud Joppien, TU Darmstadt, Adrian Allen, Central Saint Martins, University of the Arts London, and Cherine Saroufim, Académie Libanaise des Beaux Arts (Alba), Lebanon. Contributions by Vorarlberg artist Miriam Prantl on "Light – the Essence of Perception" and London-based Vorarlberg designer and architect Sofia Hagen on "Robotic Reincarnation: Crystalline" were equally inspiring. Both artists are currently showing their light art installations at the Zumtobel Group Light Forum in Dornbirn.

Light Art – Pacemaker for Technological Development

For more than seven decades, Zumtobel has helped shape the lighting industry: through state-of-the-art technology, its own design aspirations and light solutions which have always aligned with the needs of people and the environment. Time and again, the collaboration with artists and architects was a pacemaker for technological development. The "Light Art Path" on the occasion of the 75-year anniversary at the Light Forum in Dornbirn symbolically shows a cross-section of light art object-s/installations and Zumtobel Masterpieces, including works by Sam Durant, Ólafur

ZUMTOBEL Group

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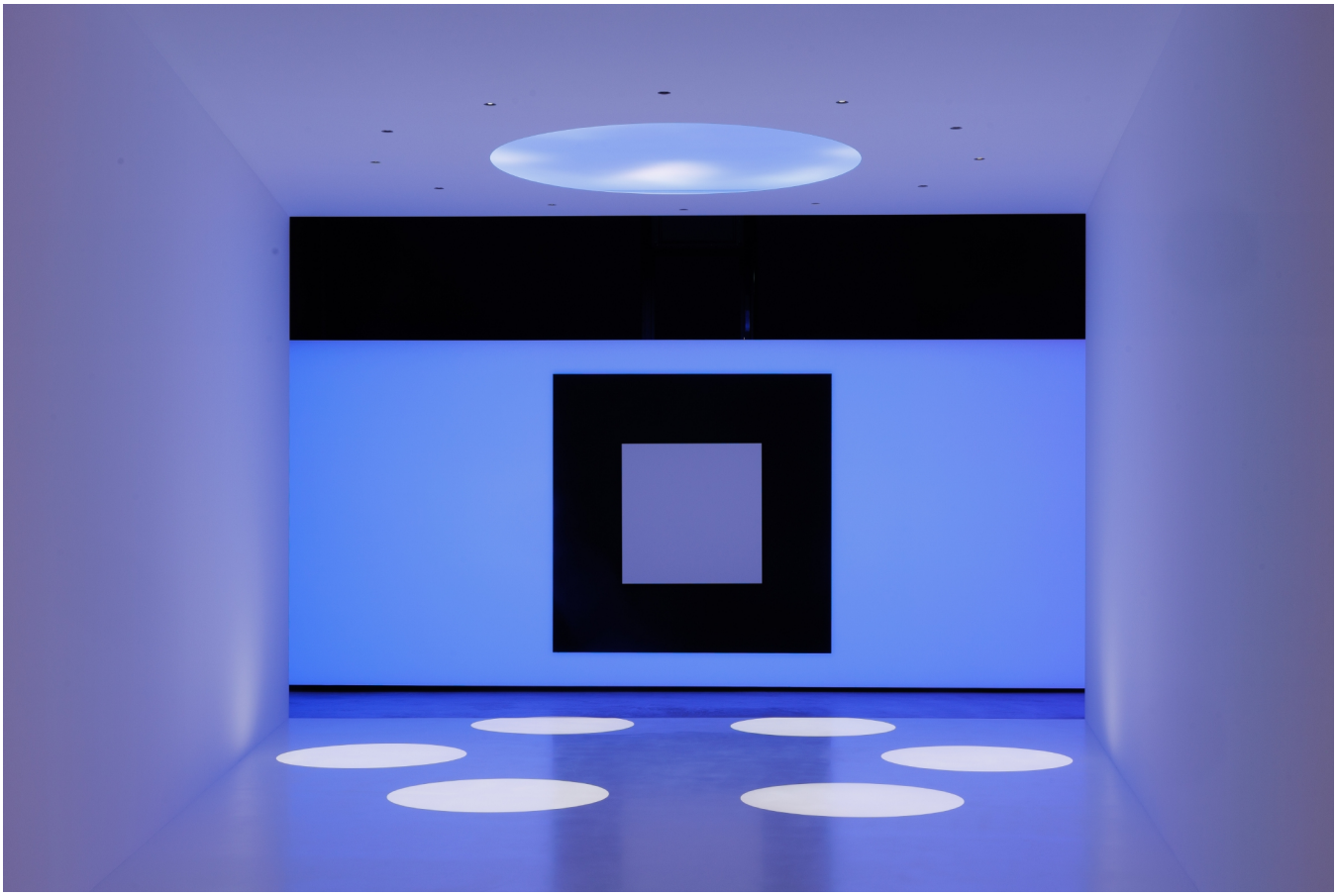
A conversation with Jürg Zumtobel (right), Supervisory Board Chairwoman Karin Zumtobel, Fritz Zumtobel and host Renato Turri (left) offered personal insights into the family company history. Photo: © Nina Bröll.

For the development of TECTON II, the next generation of its successful continuous-row luminaire, Zumtobel partnered with the Italian design studio and Engineering company Pininfarina. At a round table talk at the Light Forum on the occasion of the product launch, Pininfarina CEO Silvio Angori (left), Fabio Calorio, SVP Brand & Collaboration Pininfarina (second from right), as well as Andreas Fussenegger, Senior Director Product & Application Management at Zumtobel (right), reported on the successful collaboration. The conversation was hosted by Renato Turri, CEO World-Architects. Photo: © Nina Bröll.

London digital artist Dominic Harris, known for his immersive combinations of art, technology and nature, titled his keynote speech "Colour, Light and Technology: A Holy Trinity" Photo: © Nina Bröll.

Mateo Kries, Director Vitra Design Museum, inspired with his keynote speech at the Light Forum on "Out of the Box – Shaping Futures with a Museum". Photo: © Nina Bröll.



Light experience space Light Forum Dornbirn. Photo: © Nina Bröll.

Elíasson, Zaha Hadid, Brigitte Kowanz, Daniel Libeskind, François Morellet, Miriam Prantl, James Turrell and Ben Vautier.

Karin Zumtobel: "Light artists and architects challenge us extremely: They seek perfection. They want to create an impact. This is how unique pieces or special products made in small numbers are created." **Alfred Felder** adds: *"We often have to balance architectural desires and technical feasibility. But it is exactly these challenges that motivate us again and again to make the seemingly impossible possible."*

New Light Installation from the Artistic Cooperation with Miriam Prantl

A new light sculpture has been created during the anniversary year in a long-standing cooperation between Zumtobel and Vorarlberg painter and light, video and sound artist Miriam Prantl: the SPHERES. Currently on display in front of the Light Forum, it embodies the interaction of shape, light, color and movement. Four intertwined steel rings – like large, interwoven wheels of light – form a single sphere. Changing light sequences and shimmering colors flow in pulsating kinetics through and along the light sculpture. To create an impression of floating, which is important to Miriam Prantl, the points of light from the LED lines move along the ring structures in opposite directions. Collisions and harmonies of light alternate within the programming.

"[…] At night, the surface shimmering by day recedes into the background, and the play of light in Spheres comes to life. The sculpture pulses, creating circuits and networks of light, color and motion. Its sphere expands into the surrounding space, enveloping the environment. An immersive and spatial field of influence emerges," **Miriam Prantl describes the installation.** ■

For further insights, listen to the Zumtobel Group podcast **"Making Light an Experience in Art"** featuring Miriam Prantl and Sofia Hagen. Listen the podcast...

Zumtobel Group AG

The Zumtobel Group aims to create well-being and improve people's quality of life through light – as a group, and through all its individual brands, Thorn, Tridonic and Zumtobel. As a leading supplier of innovative lighting solutions, the Group offers its customers around the world a comprehensive portfolio, where the focus is invariably on people and their needs. The company's know-how about the effects of light on people, acquired over decades, forms the basis for sustainable and future-oriented lighting solutions that are increasingly energy- and resource-efficient while providing the best possible quality of light. The Group is listed on the Vienna Stock Exchange (ATX Prime) and currently holds a workforce of around 5,300 employees. In the 2023/24 financial year, the company posted revenues of EUR 1,127.0 million. The Zumtobel Group is based in Dornbirn in the Vorarlberg region of Austria. For further information, please visit z.lighting

Zumtobel. The light.

Our passion is to create quality lighting solutions that deliver total perfection. We are driven by a conviction that the right kind of light can create the right atmosphere in a building at any time of day or night. When tailored to people's individual needs, light becomes something of an experience. We are always exploring new ways to come up with inimitable and timeless designs and are inspired by a unique creative ambition. When working on the lighting of tomorrow, we are driven by our innovative corporate philosophy of continuously improving the aesthetics of light. With passion, a sense of beauty and a forward-looking approach, we are constantly seeking to use light to help improve people's quality of life.

Sustainable Public Lighting, Part I: Responsibilities and Thematic Challenges

Dipl.-Ing. Johannes Weninger[1,2], MMag. Martina Ascher[1], MSc. Maximilian Dick[1]; Bartenbach

Lighting in public spaces is increasingly subject to complex requirements. In addition to general sustainability goals such as improved energy efficiency and reduced resource consumption, future systems are also expected to significantly promote the recyclability of individual components. Moreover, they should contribute to an overall enhancement of the quality of public spaces and generate fewer negative environmental impacts, such as light pollution and effects on urban biodiversity.

On behalf of the Austrian Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology (BMK), Bartenbach developed comprehensive recommendations for action based on a stakeholder survey, with the aim of supporting the long-term achievement of national and international sustainability goals. This first part of a two-part article series focuses on the findings related to responsibilities, environmental awareness, and thematic challenges in the context of public lighting.

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Introduction

Global electricity consumption for public lighting is roughly equivalent to Germany's annual electricity usage [1]. The majority of this demand comes from cities, where lighting can account for up to 65% of municipal electricity budgets. With continued urbanization and an estimated 60% of the world's population expected to live in cities by 2050 [2], both the demand for public lighting and the associated financial and environmental burdens are increasing.

Although the adoption of LED technology has led to a general decline in energy consumption for artificial lighting [3], further improvements in energy efficiency remain essential to reduce global electricity use. However, achieving current climate and environmental policy goals requires a more comprehensive approach that considers the entire lifecycle of lighting systems from resource use and energy consumption to planning strategies that minimize negative environmental impacts. This, in turn, demands the involvement of all stakeholders across the entire value chain [4,5].

The broader availability of advanced technologies is helping to address many of today's challenges, but it also introduces new demands. For instance, the control components in lighting systems often have shorter lifespans than the LED modules themselves. To ensure long-term resource efficiency, standardized interfaces and modular, manufacturer-independent components are becoming increasingly important to maintain system functionality and technological sovereignty. In addition to technical considerations, public lighting must meet a range of application-specific needs, including visual performance, psychological comfort, and long-term health. These requirements also include attention to gender-specific perceptions of safety [6] as well as physiological effects, such as the disruption of circadian rhythms by nighttime lighting [7].

Balancing these diverse and sometimes conflicting demands makes designing public lighting systems particularly challenging. For example, light levels needed to ensure a general feeling of nighttime safety can negatively impact health, reduce visual comfort, and increase energy consumption. On the other hand, low-energy lighting scenarios may not provide sufficient visibility or meet user expectations. Thus, sustainability targets must be assessed contextually and approached from a broader, system-level perspective.

On behalf of the Austrian Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology (BMK), Bartenbach conducted a comprehensive evaluation of current and emerging lighting technologies, assessing their ecological, economic, and social potential. This included mapping technological capabilities against a complex set of requirements and identifying implementation barriers through a stakeholder survey. The result is a dedicated action guide for Austrian authorities, designed to ensure that technological advancements in public lighting can contribute as effectively as possible to reducing environmental impacts by 2035. The findings of the stakeholder survey are presented in a two-part article series. While the second part will focus on technological solutions and strategic recommendations, the following sections will explore responsibilities, environmental awareness, and the thematic challenges surrounding public lighting.

Stakeholder Survey

To achieve a comprehensible picture of all existing requirements and limitations across the entire value chain, the target groups of the survey ranged from local authorities

and lighting designers to manufacturers and regulatory institutions. Depending on the group, participants were addressed at both national and international levels. For the target group of public authorities, participation was limited to countries with regulatory frameworks comparable to Austria.

The overarching aim of the survey was to quantify the current status of how key issues in outdoor lighting are being addressed, assess the potential of emerging key technologies, and identify perceived barriers between the individual stakeholders. While the overall objectives were consistent across all target groups, the survey was specifically tailored to reflect the responsibilities and areas of expertise of each group.

In total, approximately 70 individual questions were developed per group. Completing the entire questionnaire took an average of about 25 minutes.

Stakeholder Survey

A total of 1,264 individuals were reached through the online survey. Following a qualitative review of the responses, 239 datasets were considered usable, representing 18.9% of the individuals reached (**Figure 1**). Among the groups surveyed, the highest number of responses came from public authorities (126 datasets, 52.7%), followed by lighting designers (70 datasets, 29.3%), the manufacturing industry (27 datasets, 11.3%), and regulatory institutions (16 datasets, 6.7%). In total, 70.7% of responses came from male participants with a high educational attainment.

The surveyed municipalities showed wide structural and lighting-related diversity and expressed a clear shift toward environmentally conscious practices, such as dimming or replacing upward-facing systems. However, public involvement in lighting decisions was rated low (12%), with most choices guided by regulations and politics rather than citizen input or tourism marketing potential.

Most of the lighting planners surveyed operated in small enterprises (77%) with a strong self-reported innovation focus. Nearly half had developed lighting master plans and frequently design public lighting installations, favoring low color temperatures and dimming strategies while largely avoiding upward-facing systems.

The lighting industry surveyed showed considerable diversity in enterprise size and a clear focus on high-quality, innovative products. Innovations are mainly driven by current standards, with a strong emphasis on functional and creative solutions, while cutting-edge technologies such as machine learning are rarely implemented.

Regulatory institutions showed a stronger focus on sustainability topics, while urban design and technologies were less prioritized. Current lighting norms are considered sufficient for traffic safety and urban attractiveness but fall short in addressing environmental and health impacts, prompting calls for greater inclusion of expert recommendations in regulations.

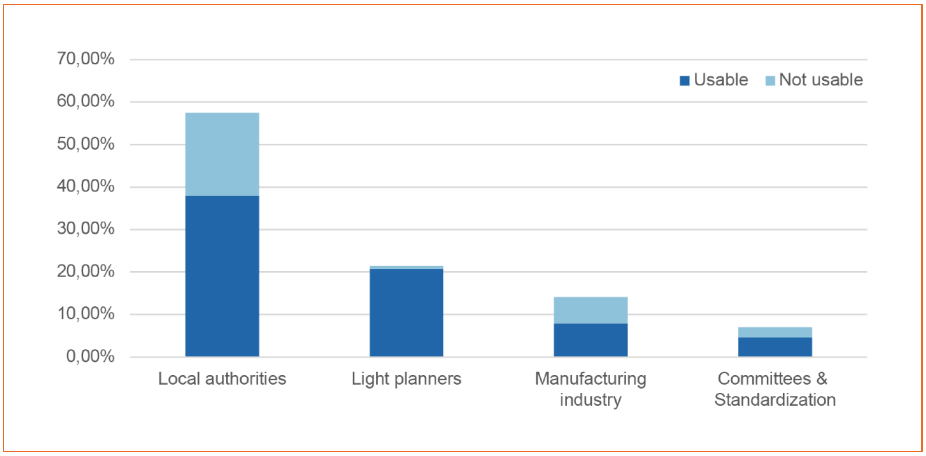

Figure 1: Usable and non-usable survey responses by stakeholder group normalized by total survey responses.

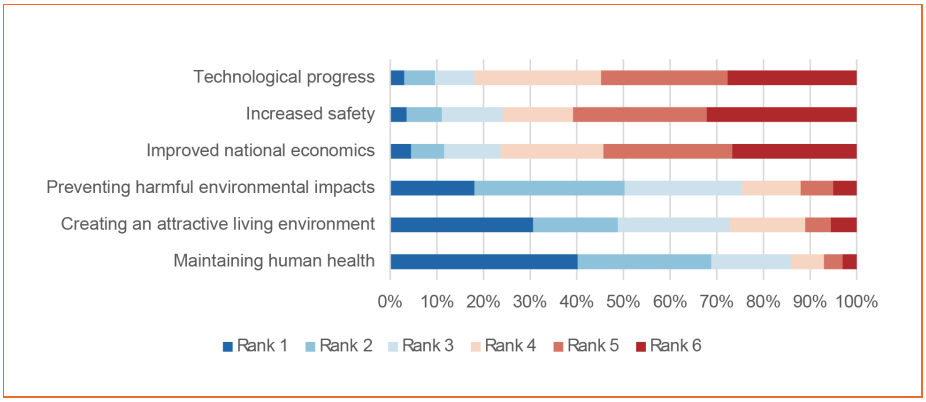

Figure 2: Assessment of the societal relevance of key topics related to outdoor lighting; ranking task; sorted in ascending order according to the mean rating level.

Responsibilities and Environmental Awareness

To account for potential confounding factors, all survey participants were asked questions about their environmental awareness and the responsibilities of various stakeholder groups in achieving environmental protection goals. The aim was to assess both the level of support for environmental and species protection and how responsibility is assumed or assigned.

Societal Relevance and Climate Policy

Given that outdoor lighting involves multiple, sometimes conflicting demands, participants were asked to rank the societal relevance of related topics (**Figure 2**). Maintaining human health was ranked highest by nearly 70% of respondents, highlighting growing awareness of health impacts, despite it being a relatively new issue in lighting. Preventing environmental harm and creating attractive living environments followed closely, each ranked highly by about 50%.

In contrast, areas like economic improvement, crime reduction, safety, and technological progress were rated significantly lower. Surprisingly, safety (traditionally considered a key criterion in outdoor lighting) received a relatively low priority. Environmental concerns, by contrast, were seen as equally or more important than human-related factors and were ranked well above economic and technological goals. This reflects increasing public consensus on the importance of environmental protection, supported by scientific research and communication.

On the topic of climate policy, about 75% of respondents believed Austria should take a leading role, while only 15% favored aligning with other countries' pace. Around 10% chose a neutral stance.

Responsibility and Trust

When asked to rank institutional responsibility for environmental goals (**Figure 3**), the federal government or legislative bodies were rated highest, with 85% ranking them first or second. The manufacturing industry followed with nearly 50%, and institutions responsible for creating technical guidelines came third. Private individuals, research institutions, and planning professionals were assigned lower levels of responsibility.

The low ranking of planning professionals is noteworthy, given their key role in environmentally conscious implementation (e.g., selecting appropriate technologies and applying expert knowledge). Interestingly, planners rated their own responsibility significantly higher than other groups did. Especially local authorities perceived planners' contributions as minimal, possibly reflecting a lack of awareness or reliance on in-house planning in smaller municipalities. Regarding trust across groups under challenging conditions, scientists received the highest trust scores. Respondents also showed moderate trust in the expertise of manufacturers and evaluators. However, trust in current norms and planners' knowledge was only average, aligning with earlier findings of low assigned responsibility.

A further key finding of this part of the stakeholder survey is that trust collapses when financial limitations arise. Costly but environmentally friendly solutions were seen as unrealistic, and the manufacturing industry was not trusted to pursue sustainability without profit incentives, despite their claims. Overall, the survey suggests that environmental goals often fail when they imply tax increases or financial trade-offs.

Thematic Challenges

The topic-specific questions of the stakeholder survey focused on key areas relevant to outdoor lighting, which, as part of a multifunctional field of requirements, include not only sustainability and environmental issues but also safety-related, psychological, and health-related factors. The aim of these questions was to quantify participants' awareness of the topics, assess current market conditions, and estimate potential developments over the next 10 years, in comparison to a scientific perspective on the individual areas.

Safety, Security, and Urban Attractiveness

Lighting significantly affects visual perception, particularly object recognition and visual performance metrics such as visual acuity and contrast sensitivity [8]. These aspects are critical for maintaining objective safety standards in traffic, as reflected in current regulatory guidelines. However, lighting also has considerable influence on subjective factors such as perceived safety and urban attractiveness. Although these aspects are often included in lighting recommendations, they are currently not addressed sufficiently in legal regulations.

Scientifically, perceived safety in urban areas is closely tied to studies on crime. A 1995 systematic review [9] found no clear link between lighting and crime reduction in studies up to the late 1980s. More recent findings remain mixed. For example, one study found that turning off street lighting increased burglaries and vehicle crime but decreased violent crime [10], while another found a reduction in violent crime following lighting upgrades [11]. The complexity stems from multiple interacting factors such as urban design, escape routes, and witness visibility, which obscure the isolated impact of lighting. As such, the direct effect of lighting on crime rates remains inconclusive, though its impact on fear of crime is clearer.

According to the theory of place characteristics [12], features like visibility and concealment opportunities influence fear levels. A follow-up study emphasized lighting's role in reducing fear, with darkness and shadows increasing it, and good lighting offering reassurance [13]. However, lighting mainly restores the level of perceived safety people expect during daylight [14], and its effectiveness can be further limited by architectural features. In general, uniform lighting and increased brightness are seen as beneficial for perceived safety. Therefore, warm white light is not recommended for safety perception due to its lower scotopic-photopic ratio. While no optimal lighting levels are currently defined for facial recognition, lighting has been shown to improve perceived safety through enhanced spatial awareness and aesthetic experience [15].

In addition, lighting also enhances nighttime aesthetics. Although attributes like uniformity, brightness, and spatial light dis-

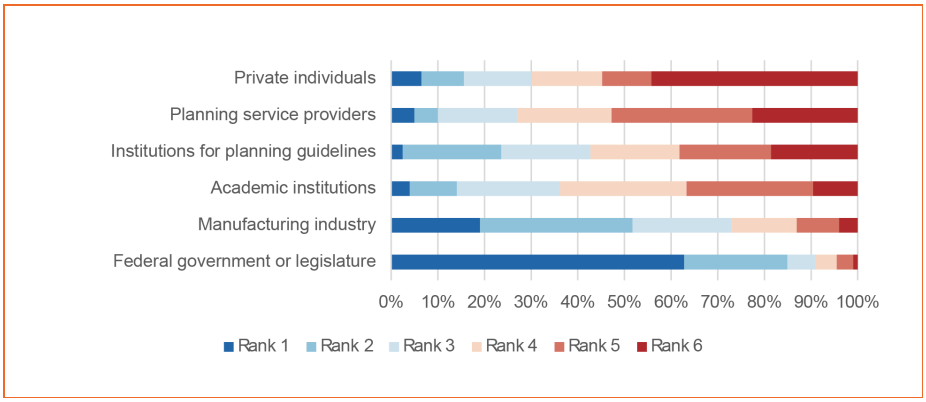

Figure 3: Usable and non-usable survey responses by stakeholder group normalized by total survey responses.

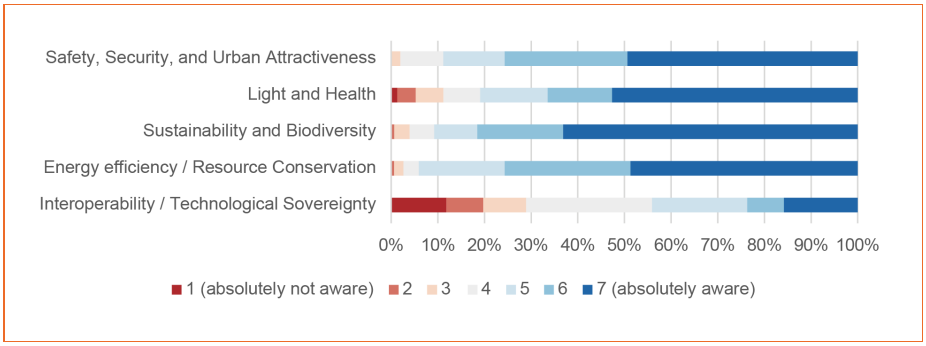

Figure 4: Assessment of the societal relevance of key topics related to outdoor lighting; ranking task; sorted in ascending order according to the mean rating level.

tribution influence perception, light color appears to have the strongest impact on emotional and environmental responses. White light increases both perceived safety and aesthetic preference [16]. Addressing subjective safety and attractiveness thus presents a valuable opportunity for lighting design.

While higher lighting levels benefit traffic safety and perceived security, they raise concerns in other areas. Increased brightness contradicts health recommendations aimed at minimizing circadian disruption, leads to higher energy consumption, and likely harms nocturnal wildlife. Furthermore, higher correlated color temperatures may also intensify negative effects on humans and ecosystems.

Today, these trade-offs are well recognized. Stakeholders rated awareness of this topic as high to very high (**Figure 4**). Solutions are pursued even with limited public acceptance. Normative regulations and planning guidelines are viewed as adequate, and both the availability of products and the demand in planning are strong. Investment in safety-related lighting is widely seen as justifiable.

Looking ahead, the importance of addressing lighting-related challenges concerning safety, security, and urban attractiveness is expected to grow (**Figure 5**). However, 35% of respondents foresee little or no change, likely due to confidence in existing regulations and their continued effectiveness over the next decade.

Light and Health

Outdoor lighting inherently involves significant health-related aspects by directly contributing to traffic safety and thereby reducing the likelihood and severity of accidents. These effects are primarily driven by visual perception factors, rooted in the visual processing of sensory information. Beyond visual mechanisms, however, light also exerts major effects through non-visual pathways, which mainly influence long-term health. These underlying connections have increasingly been studied in recent years.

It is now widely accepted that non-visual effects of light are linked to the sensitivity of intrinsically photosensitive retinal ganglion cells (ipRGCs), which are especially responsive to short-wavelength light and differ significantly from the sensitivity curves associated with brightness and color perception [17]. The strength of these effects is determined not only by illuminance levels but also by spectral composition. These relationships are currently described through the concept of melanopic equivalent daylight illuminance (MEDI), where photopic brightness is weighted against daylight-based biological effectiveness [18].

Studies on the effects of nighttime lighting point to associations with several health concerns. The most frequently cited non-visual mechanism affecting health is the suppression of melatonin, a hormone closely associated with circadian rhythm regulation. Artificial light at night disrupts melatonin secretion, impairing the body's ability to maintain its natural sleep-wake cycle [19]. This disruption can lead to shorter and poorer-quality sleep [20], resulting in fatigue and reduced performance the next day.

In addition, long-term circadian disruption is suspected to contribute to serious health conditions, including cancer, particularly breast cancer [21]. Melatonin suppression is also associated with inflammatory processes, increased fat accumulation, and impaired immune function [22]. Today, these effects are recognized by organizations such as the International Commission on Illumination (CIE) and the World Health Organization (WHO), and public awareness of health risks linked to lighting is steadily growing. As a result, the American Medical Association (AMA) issued recommendations in 2016 warning against the use of blue-rich LED streetlights [23].

Beyond hormonal effects, neurological and psychological impacts of nighttime lighting are also a growing concern. Studies have shown associations between light exposure and depressive symptoms, cognitive impairments, and even an increased risk of autism spectrum disorder [24]. Inadequate lighting has further been linked to stress-related physiological changes, including reduced cardiovascular regulation, which may contribute to heart disease over time. Although some studies suggest outdoor lighting may have negligible health effects, the potential harm of nighttime lighting is widely acknowledged. Leading lighting organizations now recommend minimizing melanopic-effective illuminance at night, with adverse effects potentially occurring from as little as 1 lx MEDI.

While these health-focused goals often align with objectives in energy efficiency and environmental protection, current health-based lighting recommendations may conflict with safety requirements. Practical implementation is therefore limited by the need to ensure minimum lighting levels for visibility and safety, especially in outdoor environments.

Despite being a relatively recent research area, awareness of health-related lighting impacts showed to be high across all stakeholder groups (**Figure 4**). However, while current guidelines are viewed as sufficient, product availability still lags behind demand due to the novelty of these standards. Moreover, justifying higher costs for health-optimized lighting was rated as challenging, as there are few robust evaluation mechanisms to clearly demonstrate their long-term benefits.

Looking ahead, most stakeholders expect the importance of addressing these health impacts to increase (**Figure 5**). However, some foresee stagnation, driven by the difficulties in demonstrating long-term effects in real-world applications and the challenges of gaining user acceptance for the associated higher costs.

Sustainability and Biodiversity

For a long time, artificial lighting systems primarily addressed human needs, especially those related to visual perception. However, as awareness of the potential negative effects of nocturnal lighting has grown, increasing attention is now being paid to environmental impacts, particularly light pollution. These effects are not limited to humans but extend to other living beings and have proven to be highly

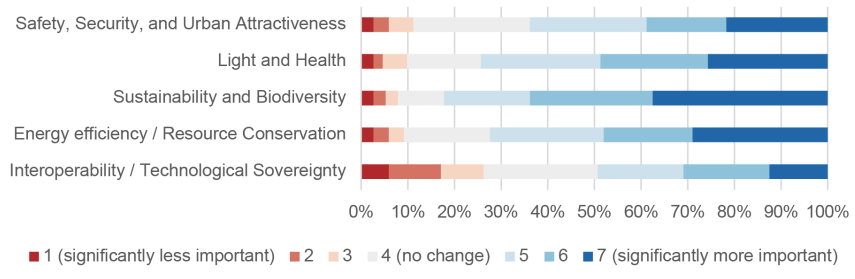

Figure 5: Assessment of the future importance of key topics relevant to outdoor lighting over the next 10 years; 7-point Likert scale (1 – significantly less important; 4 – no change; 7 – significantly more important).

complex due to the varying sensitivities of different species. At a broader level, greater environmental consideration regarding the preservation of biodiversity in urban areas is now seen as essential. A recent report on SDG 15, which concerns the sustainable use of shared ecosystems, illustrates this need. The report notes a significant decline in biodiversity, with extinction rates dropping from 0.82 in 1993 to 0.73 in 2020, and further projected to fall to 0.69 by 2030 [25]. This decline is largely attributed to habitat destruction, and light pollution must therefore be recognized as an additional threat to biodiversity. As SDG 15 is considered one of the six most at-risk goals, urgent action is needed to reduce anthropogenic impacts on terrestrial ecosystems.

The non-visual effects of light on animals are now well-documented across both terrestrial and freshwater environments. For example, based on systematic reviews, melatonin suppression in birds, rodents, and ungulates has been observed at light levels of just 0.3 lx, 0.03 lx, and 2.3 lx, respectively [26]. In amphibians and reptiles, nighttime lighting has been shown to affect reproduction [27] and nocturnal activity [28]. Evidence also points to disorientation in frogs, lizards, and snakes in urban settings.

Negative effects have also been observed in invertebrates, which are crucial for biodiversity and ecological balance. Early studies indicate that artificial lighting affects insect migration, growth, feeding, predation, and reproduction [29]. This decline in insect populations has adverse consequences for pollination, pest control, and nutrient cycling. Economically, these effects are significant. Bees, for instance, are essential pollinators and central to agriculture and biodiversity. Their global population decline is largely due to habitat and floral loss [30], to which light pollution contributes substantially. Environmental impacts must therefore be evaluated not only by direct effects on individual species but also through a broader systemic perspective. Since many plants rely on insects for pollination, disruptions in insect behavior indirectly affect plant reproduction. Studies have shown that artificial lighting can reduce pollination success through cascading effects between host plants, predators, and prey [29] and influences plant-insect interactions [31]. Additionally, exposure to low-intensity street lighting can delay flowering and reduce crop yields by 20–40%, particularly when plants are illuminated by decorative lighting with high levels of photosynthetically active radiation [32].

Translating such complex findings into actionable lighting guidelines remains a challenge. Assessing the full environmental impact of outdoor lighting is difficult due to the diversity of species sensitivities and the need to account for ecosystem-level interactions. Addressing this requires in-depth knowledge of spectral sensitivities and ecological interdependencies. Many current biological studies lack technical lighting data or rely on lux, which is inadequate for species with different spectral sensitivities.

As a result, defining lighting requirements for diverse urban species remains difficult. While individual studies identify specific mechanisms, current regulations primarily focus on reducing light intensity and switching off lights at night. These goals generally align with goals for energy savings and public health, but they often conflict with safety requirements and are therefore limited by regulatory constraints.

Although awareness of these environmental issues has grown in recent years (**Figure 4**), existing recommendations remain broad, and detailed planning guidance is still lacking. In line with this, the stakeholders surveyed report high awareness but note a lack of regulatory support, inadequate species data, limited product availability, and a resulting difficulty in justifying additional costs.

Looking ahead, most stakeholders expect growing importance for this issue over the next decade (**Figure 5**). However, due to the lack of comprehensive standards, the potential for fully addressing the problem remains uncertain.

Energy efficiency and Resource Conservation

The technological transition of lighting systems to LED sources has significantly contributed to reducing energy consumption. At the same time, however, the production of LED lighting products requires more energy, and recycling has become increasingly challenging due to the complexity of the necessary electronic components. To better assess and address the environmental impacts of electrical and electronic equipment, these products have been subject to legal regulation worldwide in recent years. The regulations adopt a life cycle approach to adequately address the manufacturing process, material use, and operation of products. While this approach is also relevant for lighting products, they represent a unique case among electronic devices. The long lifespan of LEDs, combined with their high energy use during operation, means that the usage phase overwhelmingly dominates their environmental impact. Multiple life cycle assessment (LCA) studies confirm that the use phase accounts for approximately 99% of environmental burdens associated with lighting products [33]. From a sustainability standpoint, optimizing product operation is therefore significantly more important than optimizing production or disposal.

Resource consumption during use is primarily determined by the overall efficiency of the luminaire. This efficiency is influenced by thermal management as well as the combined performance of the light source, driver or ballast, and optical system. In recent years, LED efficacy has improved dramatically, and advances in power electronics have also led to efficiency gains in LED drivers, with up to 92% efficiency reported in outdoor lighting applications as of 2019 [34]. By 2035, target values include 95% efficiency for drivers and optics, overall efficiency of 86%, and luminous efficacy of 214 lm/W for outdoor LED systems [34]. In comparison, conventional lighting achieves only 85 lm/W [35], underscoring the resource-saving benefits of LED-based systems. Additionally, LEDs offer a key advantage over traditional lighting: as electronic components, they enable software-based control and advanced regulation strategies. Energy savings of up to 84% compared to uncontrolled systems have been demonstrated in outdoor contexts [36], far exceeding gains achievable solely through improved component efficiency. Control approaches can be categorized into scheduled (time-based), zonal (group-based), and demand-driven strategies, often linked to daylight availability.

Many market solutions today mostly use basic time or dimming controls, with time-based systems being mostly common due to their simplicity and compatibility with legacy infrastructure. These systems can be preprogrammed to switch off during specific nighttime hours. Where complete shutoffs are not feasible due to safety or visibility concerns, dimming is typically used to reduce energy use while meeting regulatory requirements [37]. Even basic implementations can yield major benefits. A retrofit project at the University of Palermo, Italy, used time and dimming controls in public LED lighting and achieved energy savings of 84%, equivalent to 163.2 tons of CO□ [36]. Despite this potential, adoption remains limited: only about 20% of outdoor systems use time-based controls, and fewer than 1% use sensor-based systems [35].

As a color central concern of the lighting industry, the awareness of those issues

was unsurprisingly rated highly across all stakeholder groups (**Figure 4**). While product availability and planning are considered very good, regulatory frameworks are viewed as only moderate, aligning with previous assessments of regulatory institutions.

The importance of addressing these challenges is also expected to grow over the next ten years (**Figure 5**), reflecting both the topical relevance and the inherent connection between lighting and energy use. Increased product efficiency is seen as a key competitive advantage, and fewer than 10% of respondents expect the importance of this issue to decline in the future.

Interoperability and Technological Sovereignty

Considering the growing technologization and the opportunities arising from data generated through the use of sensors and enhanced system networking, strategic sovereignty is becoming increasingly important in both economic and regulatory contexts. The overarching goal is not only to maintain a country's innovative capacity but also to preserve technological capabilities and assets. Many related concepts revolve around privacy protection, trust, and the reliability of digital content **[38]**. Additional challenges stem from the activities of certain tech companies **[39]**, especially in relation to artificial intelligence, cybersecurity, access to critical technologies, and technological dependencies in public procurement.

In general, identifying strategic technologies is far from straightforward. This task becomes even more complex within multilateral geopolitical bodies such as the EU, where sovereignty is understood as a function of achieving shared goals. Strategic decisions must therefore closely align with European priorities for a sustainable, digital, and healthy society. Addressing these challenges requires significant technological and innovative breakthroughs in digital domains (e.g., edge computing, artificial intelligence, cloud infrastructure, and Internet of Things technologies), environmental fields (e.g., sustainable production, biologically engineered materials, energy efficiency), and healthcare (e.g., e-health solutions and preventive care).

Lighting, in particular, holds significant potential to contribute to strategic sovereignty. As discussed in other sections, artificial lighting is a key factor in environmental impact and energy consumption and also plays an important role in supporting human health. However, lighting technology remains relatively underdeveloped in terms of digital integration. Although emerging applications such as the Internet of Things (IoT) and Smart Cities show promise, and some system solutions already exist, current markets are still dominated by proprietary systems with poor interoperability.

Given that many of these technologies are developed and operated by European companies, the growing digitalization of business models and services in the lighting sector suggests considerable potential at the European level. To realize this potential in the long term, existing challenges must be addressed, particularly through regulatory measures concerning data usage. Ensuring a progressive, secure, and competitive European digital space for data collected via lighting systems in Smart Cities will require not only coherent policies but also the removal of barriers to establishing a digital single market and competitive cloud infrastructures. A clear and consistent legal framework, particularly on cybersecurity and data transfer, must also be established. The EU has already demonstrated its leadership in this area through the General Data Protection Regulation (GDPR), which compelled companies worldwide to comply with European data standards.

Moreover, broader adoption of standardized, open interfaces is necessary for IoT-based solutions to support open and accessible information exchange. Technological sovereignty does not imply complete independence, but rather the ability to retain a degree of autonomy in key technologies and avoid one-sided dependencies, especially on less reliable international partners. In this context, recent efforts to revive European industrial policy **[40]** should incorporate economic objectives into political instruments to achieve a shared understanding of sovereignty at both national and EU levels.

Although system interoperability can promote future-oriented digital business models and policy interventions can support technological sovereignty, this thematic area is relatively isolated from others. As a result, awareness of this topic remains low (**Figure 4**). Around 30% of survey participants reported little to no familiarity. Market demand and regulatory frameworks were also perceived as weak, likely due to the complexity of digital solutions and their limited attractiveness in project planning.

Also, the future importance of this topic is perceived with mixed opinions, although there is a slight trend toward increased relevance (**Figure 5**). The lighting industry is known for its slow adoption of innovations, especially in outdoor applications where multiple stakeholders with differing priorities are involved. As a result, simple, low-tech solutions have typically prevailed. The added complexity of digitalized systems may explain why experts familiar with these barriers are skeptical about significant progress in the next decade.

Conclusion

As this article has shown, modern outdoor lighting systems are embedded in a complex field of interrelated challenges, ranging from energy efficiency and resource conservation to human health, biodiversity, safety, and digital sovereignty. Meeting these challenges in the long term requires a fundamental shift in how lighting is designed, regulated, and implemented.

The findings of the stakeholder survey confirm a high level of awareness across most professional groups regarding the ecological, health-related, and societal implications of public lighting. At the same time, the survey reveals systemic barriers that limit the practical implementation of sustainable solutions. These include a lack of interdisciplinary cooperation, fragmented regulatory frameworks, insufficient technological interoperability, and persistent cost concerns. Particularly striking is the sharp decline in trust when financial trade-offs are introduced. Even stakeholders who express strong environmental commitment often view sustainable solutions as unrealistic if they entail higher costs, highlighting a gap between values and actionable outcomes.

From a technical perspective, the lighting industry is well positioned to contribute meaningfully to sustainability goals. Innovations in LED technology, control strategies, and life-cycle optimization already offer substantial potential for reducing environmental burdens. However, these gains are not automatic. They require deliberate planning, supportive regulations, and clear guidance tailored to specific applications and urban contexts.

On the societal side, the survey underscores the evolving understanding of lighting's broader functions. Public lighting is increasingly recognized as a determinant of environmental quality, psychological comfort, and long-term health. Topics such as melatonin suppression, circadian disruption, and the effects of artificial light on biodiversity are gaining prominence and are expected to play a greater role in future planning. Yet, integrating these diverse concerns into cohesive design strategies

remains a major challenge, particularly when traditional safety norms are still prioritized in public discourse and regulation. Crucially, the results also point to gaps in institutional trust and perceived responsibility. While federal authorities and industry actors are seen as having the greatest responsibility for environmental protection, key contributors such as lighting planners and researchers are undervalued by many stakeholders. This disconnect may hinder progress, especially in smaller municipalities where in-house expertise is limited and external planning resources are not fully utilized. To address these multifaceted issues, a systemic and inclusive approach is needed. This includes establishing clear, cross-sectoral goals that align technological development with ecological and social imperatives. Regulatory frameworks must evolve to integrate health and biodiversity considerations alongside established criteria such as energy efficiency and safety. Moreover, interoperability and data sovereignty must be strengthened to ensure that the growing digitalization of lighting systems supports rather than hinders sustainability objectives.
Public engagement will also play a critical role. Current decision-making processes remain dominated by regulatory and political forces, with minimal public input. A more participatory approach, grounded in transparent communication and accessible data, can enhance trust and foster acceptance of innovative solutions, even when they involve complex trade-offs.

In summary, sustainable public lighting is a deeply interdisciplinary challenge. It demands technical innovation, regulatory reform, ecological sensitivity, and a societal shift in expectations and practices. The path forward lies not in isolated advancements, but in coordinated efforts that recognize lighting as both a technical infrastructure and a cultural asset. In this sense, the first part of the article series lays the groundwork for future action. The upcoming second part will explore technological strategies and implementation pathways in greater detail to help translate technological potential into measurable progress. ■

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About Bartenbach

Light is a powerful instrument. It designs spaces – and creates quality of life for the people in them. Increasing well-being, making tasks easier, enriching the atmosphere, promoting social interaction: holistic lighting design does it all. And much more. In this way, energy-efficient lighting solutions can make a direct contribution to your company's sustainability strategy and save costs.

As the market leader for international lighting design, Bartenbach designs and implements sophisticated daylight and artificial lighting solutions from a single source. What makes it special is that all of our concepts are science-based and draw on the in-depth lighting know-how of our research and development. "The Lighting Innovators" – this is not only our claim, but also our promise to our customers.

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Bartenbach

About the Austrian Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology (BMK)

A key field of action of the BMIMI (former BMK) is transport policy. This includes, in particular, hydraulic engineering with regard to waterways and transport regarding the railways, shipping and aviation. This also comprises the regulation of access to railway infrastructure, ship verification, shipping-specific affairs of hydraulic engineering with regard to waterways, air traffic control, aeronautical meteorological services, advertising for passenger and freight transport, automotive engineering and affairs of the traffic police, accident research, road construction and the construction and maintenance of federal roads.

The BMIMI is also responsible for the management of the equity of the Federal Government in the Autobahnen- und Schnellstraßen-Finanzierungs-Aktiengesellschaft (ASFINAG), and in the Alpen Straßen Aktiengesellschaft and the Österreichische Autobahnen- und Schnellstraßen Aktiengesellschaft, as long as the Federal Government is a shareholder of these companies.

The BMIMI is responsible for hydraulic engineering with regard to the navigable rivers Danube and Morava as well as the Thaya from the state border and other waterways, as well as the water supply and sewerage system, insofar as they do not fall within the scope of a different Federal Ministry, or also for the administration of the Marchfeld Canal.

Issues of commercial passenger and freight transport including the commercial carriage of goods in pipelines with the exception of water pipe affairs are also handled by the BMIMI. Its competence also comprises affairs of the carriage of passengers and goods in plant traffic, the Austrian Federal Railways including the construction and administration of structures and properties of the Federal Government dedicated to the purposes of the Austrian Federal Railways, affairs of the management of the Federal Government's equity in other railway undertakings and in the Schieneninfrastrukturfinanzierungs-GesmbH or affairs of companies that exist for the interests of the rail infrastructure, as long as the Federal Government is a shareholder.

Another focal point for the BMIMI is research and technology development. This includes economic and technical research, insofar as it does not fall within the affairs of the Austrian Research Promotion Agency and the Austria Wirtschaftsservice-GesmbH. The BMIMI also focuses on industrial property rights, particularly the patent and utility model system. Last but not least, outer space affairs also fall within the scope of the BMIMI.

From Calm Technology to Ambient Communication – Part II: Exploring Poet Creator; A Real-Time System for Visual Environments

Tapio Rosenius, Designer and Technologist, and Co-Founder and CEO of Poet Creator Software

In the first part of this series, we outlined the conceptual groundwork for ambient communication. A vision shaped by decades of research into calm technology, peripheral interaction, and behavioral nudging through light, media, and rhythm. In this second part, we take a more technical view, unpacking how Poet Creator software turns theory into functioning, real-time environments.

Poet Creator is a control and content system developed specifically for the built environment. It allows lighting, projections, LED surfaces and even sound to respond to human activity and contextual data, live, intelligently, and autonomously. It has been deployed in offices, stadiums, cultural institutions and public spaces. Its purpose is to enable spaces that communicate meaningfully and enable instrumental benefits for the end users and building operators.

For more information visit
https://poet.software

A Self-Regulating Loop

At the heart of the system is a closed-loop model: **Data** → **Content** → **Output** → **Sensing**.

1. **Data** is collected via sensors, APIs or internal inputs. This can include crowd density, weather, calendar triggers, demography, and even emotional state.
2. **Content** is the visual output generated or modified in real-time by Poet's internal engines. These include intensities, tonalities, generative animations, and live video layers.
3. **Output** refers to how the content is expressed in physical space. Poet can send content to light fixtures (via DMX, DALI, sACN, Art-Net), LED video screens, video projections, and sound systems.
4. **Sensing** is not passive. It closes the loop. People tracking, noise, and behavioral patterns are captured and fed back into the system to influence the next round of output.

This feedback architecture allows spaces to continuously adapt and optimize without manual programming. The result is an environment that can evolve over time, respond to subtle human cues, and remain meaningful.

Key Features

Map Behaviors

Poet's behavior-mapping feature enables the software to distinguish movement types and patterns, including crowd density and flow direction, and even to differentiate between adults and children. This allows content to adjust not just to presence, but to the type of presence. For example, playful animations for children in a museum setting, or calming light patterns during peak-hour stress periods in a workplace.

Crowd Responsive

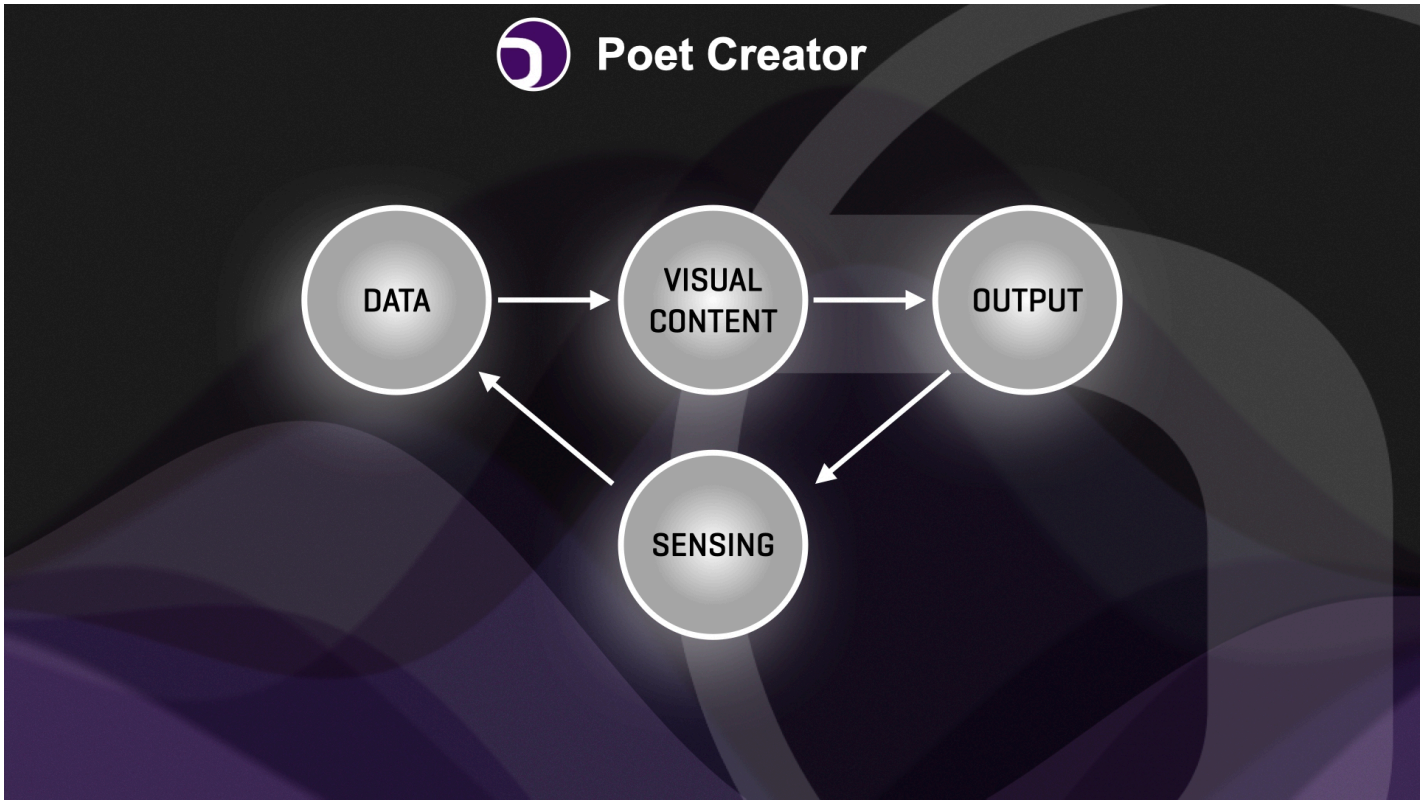
AI-integrated sensors and microphones allow Poet to read crowd energy in real time. Cheering, clustering, or dispersed quiet zones can all trigger different ambient modes. This is deployed in stadiums where the media facade and interior lighting respond dynamically to crowd behavior, shifting the entire mood of a venue in milliseconds.

Live With Emotion

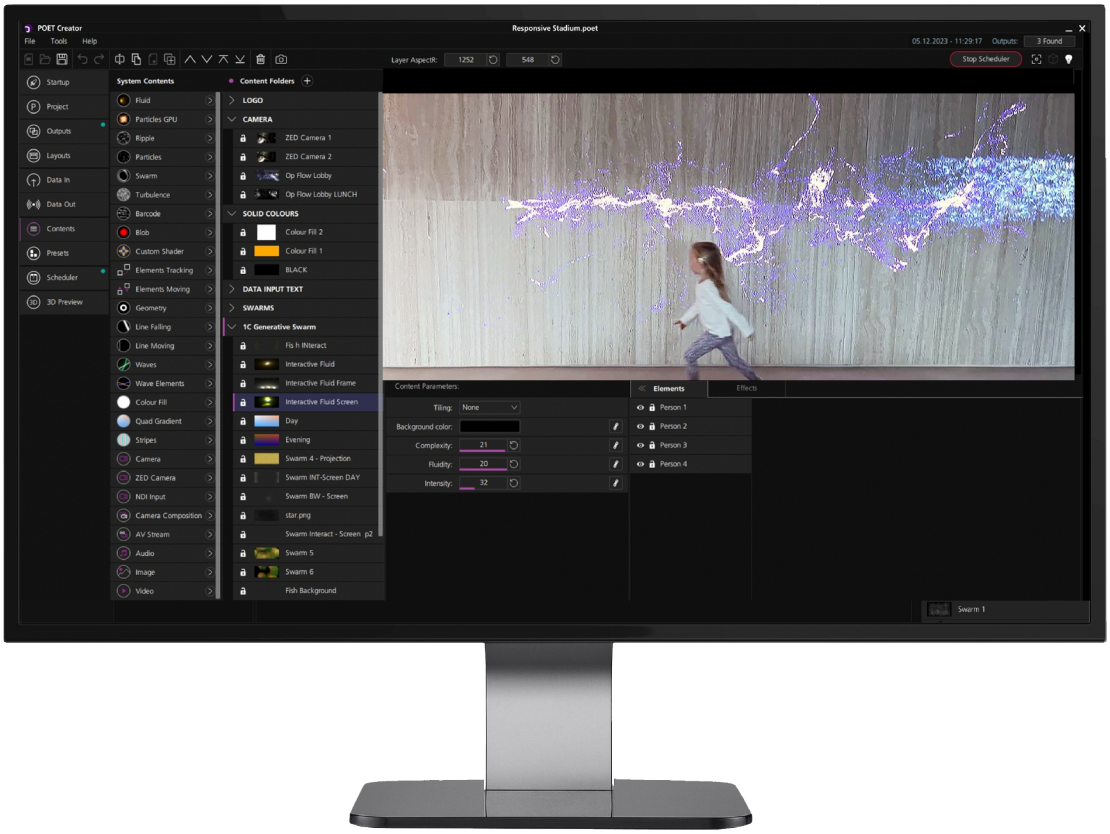
For sports and live event contexts, Poet integrates with real-time data feeds: goals, red cards, and more, to trigger emotional responses across media systems. This synchronization between live events and spatial expression helps audiences feel more connected and immersed in the moment.

The same mechanism is now being tested in care and executive settings. Our emotion detection module, currently in beta, allows spaces to adjust based on the detected emotional state. For example, calming light scenes during high-tension discussions, or subtle supportive gestures when stress is detected in a care setting. Early test results show surprising accuracy and promise.

Poet Creator is a control and content suite developed specifically for responsive environments. The user interface includes a 3D preview and a full suite of tools to manage lighting, video projections, and screens, as well as to create interactive and generative visual content.



Poet Creator operates on a closed-loop system: Data → Content → Output → Sensing; enabling continuous, autonomous adaptation. This feedback-driven architecture allows environments to evolve contextually, respond to human behavior, and remain relevant without manual reprogramming.



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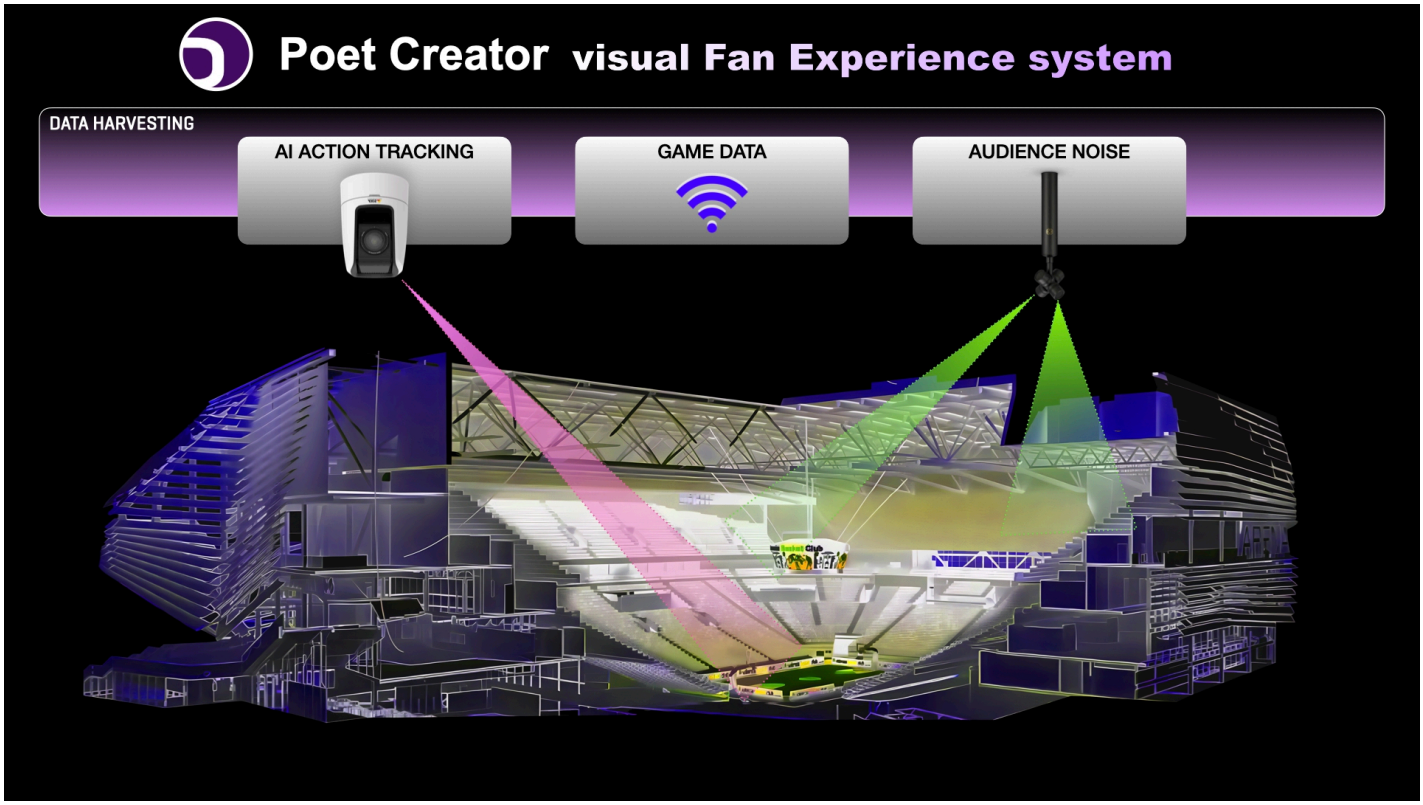
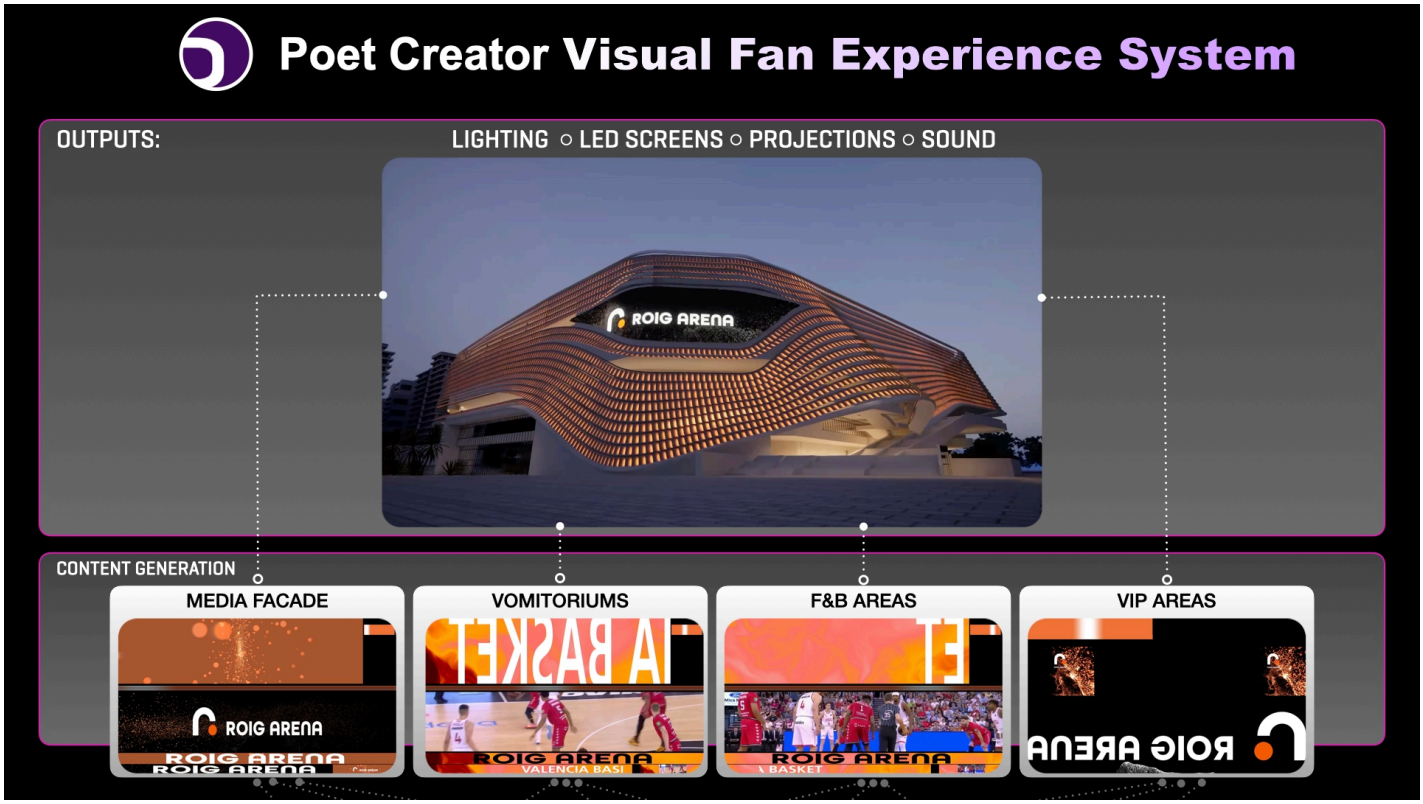


Poet Creator delivers a fully integrated Visual Fan Experience System, transforming venues into dynamic, responsive, and monetizable environments. The system collects behavioral and sensory data directly from the bowl using AI-driven action tracking and real-time game statistics.



A single system processes live data to drive adaptive content across multiple output areas and medias such as media facades, vomitoria, F&B, and VIP zones, all reacting to cheers, crowd flow, and client profiles in real time.

For sports and live event contexts, Poet integrates with real-time data feeds: goals, red cards, and more, to trigger emotional responses across media systems. This synchronization between live events and spatial expression helps audiences feel more connected and immersed in the moment.

ISO 27001-compliant remote access enables secure, real-time updates and control. This eliminates the need for costly on-site reprogramming and allows integrators and clients to manage their environments from anywhere, securely and efficiently.

How It's Used

In workplace settings, Poet Creator serves as a central nervous system for ambient lighting and communication. It links lighting to behavioral goals, contextual data such as weather, time of day and human behavioral patterns. This unlocks new opportunities for wellness related interventions, measurable behavioral change and gamification. In high-performance environments such as boardrooms and customer experience centers the system becomes a live engine for ambient data visualization on ceilings, walls, and embedded surfaces. It enhances focus while reducing cognitive overload.

In stadiums and arenas, Poet Creator delivers a fully integrated Visual Fan Experience System, transforming venues into dynamic, responsive, and monetizable environments. The system collects behavioral and sensory data directly from the bowl using AI-driven action tracking and real-time game statistics. This data is processed live and used to generate adaptive content across multiple zones, including the media facade, vomitoria, F&B areas and VIP zones. For instance, the lighting on the facade may intensify with crowd cheers, while vomitorium projections shift based on crowd flow and match tempo. F&B zones stay connected to the game action, and VIP lounges can be individually tailored to client profiles, all from a single system. For operators, the benefits are clear: automated content creation, reduced staffing needs, improved crowd experience, and enhanced safety through dynamic wayfinding.

Operational Benefits

Poet Creator is designed with the operator in mind. The solution includes a secure, ISO 27001-compliant remote access system that enables point-to-point encrypted connections for software updates, content deployment, and real-time control. This eliminates the need for on-site reprogramming and allows integrators and clients to manage their environments from anywhere, securely and efficiently.

The real strength lies in its unified control of lighting, screen content, projections and sound, allowing the entire visual experience of any architectural space to be updated in minutes. Whether introducing a new design theme for a special occasion, adapting to a changing employee or tenant profile, or reacting to seasonal events, operators and owners can shift the entire tone and content landscape of a building without technical delays or excessive cost.

This agility ensures that spaces remain dynamic and relevant. Instead of becoming visually stale over time, environments powered by Poet Creator retain their expressive potential, delivering new experiences continuously. For clients, this means a longer design lifespan, lower operational costs, and a constant alignment between spatial communication and evolving business goals.

Conclusion

Poet Creator demonstrates how intelligent systems can be embedded in architectural environments without compromising their spatial or aesthetic integrity. By integrating real-time sensing, adaptive content, and unified control, it enables designers to create environments that remain relevant, functional, and emotionally attuned over time. Rather than designing for a fixed moment, we begin designing for continuous interaction, where content evolves alongside people and purpose.

As lighting and media systems become more complex, the demand for operational clarity increases. Poet Creator offers a rare combination: a system that supports creative expression while meeting the rigorous demands of building operation. Its real-time adaptability, secure remote management, and behavioral responsiveness turn architectural media from a static asset into a dynamic tool, one that supports both the people using the space and those maintaining it. ■

For more information visit
https://poet.software

Tapio Rosenius is a Finnish designer, technologist, and co-founder and CEO of Poet Creator Software. His work explores the intersection of light, data, and human behavior in architectural environments. Together with the team at Poet Creator software, he is on a mission to bring ambient communication to the everyday spaces we live, work, and move through.

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deLIGHTed Talks: Good Light – Good Sleep

Learn how light affects your sleep in presentations by Dr. Renske Lok and Dr. Jeffrey Hubbard and moderated by Dr. Virginie Gabel.

In our fast-paced, technology-driven world, where artificial light dominates our environments, the relationship between light and sleep has never been more critical. Exposure to the right type of light at the right time is essential for regulating our circadian rhythms—the internal clock that governs sleep and wakefulness. Insufficient light exposure in the morning or excessive light in the evening can disrupt sleep, impair alertness, and reduce productivity during the day. Join us as we explore how good light can optimize melatonin production, support restful nights, and enhance overall well-being.

Talk: How daytime light exposure shapes nighttime sleep quality by Dr. Renske Lok.

Light is more than just a visual stimulus—it plays a fundamental role in regulating various physiological and behavioral processes beyond vision. These non-image-forming effects include maintaining alertness, enhancing cognitive performance, and regulating melatonin production. While many people recognize the importance of light for wakefulness, its impact on sleep is often overlooked.

Sleep is fundamental to overall health and well-being, playing a critical role in immune function, cognitive performance, and emotional regulation. Our research, spanning both controlled laboratory experiments and real-world field studies, reveals that daytime light exposure has a profound impact on nighttime sleep quality. Specifically, exposure to high-intensity light during the day enhances sleep depth, minimizes nighttime awakenings, and improves overall sleep efficiency. These effects not only promote more restorative sleep but also reduce next-day sleep inertia, leading to greater alertness upon waking.

These findings have important implications for both public health and personalized sleep strategies. Given modern lifestyles, where many individuals spend the majority of their day indoors under artificial lighting, understanding how light exposure shapes sleep can help inform better lighting designs, workplace policies, and behavioral interventions to improve sleep health.

Talk: The opposing forces of light and darkness on sleep and waking behavior: Lessons from nocturnal and diurnal animals by Dr. Jeffrey Hubbard.

Light is a powerful regulator of sleep and wakefulness in most animals, exerting both acute and sustained effects on these behaviors. Although the influence of light exposure on circadian rhythms is well-characterized, its direct, non-circadian effects on sleep and waking have been less explored. In fundamental neuroscience, animal models allow for detailed investigations on how light and darkness impact sleep and waking using both nocturnal species, such as laboratory mice, and day-active species, such as the Sudanian grass rat, Arvicanthis ansorgei. This talk will explore how light—and darkness—modulate sleep and wakefulness through direct effects on distinct neurobiological systems and can reshape sleep/wake architecture. By comparing the effects in these two species, we can examine how the same environmental cues can produce divergent behavioral and physiological responses, depending on the temporal niche of the animal. As artificial lighting increasingly blurs the boundaries between day and night in our societies, uncovering how exposure to light shapes fundamental biological processes is crucial. By deepening our insight as to whether light can support or disrupt natural sleep in these animals, this provides context as to how we consider our living circumstances in a world that is never completely in darkness.

https://youtu.be/mG_Y62eea5Y

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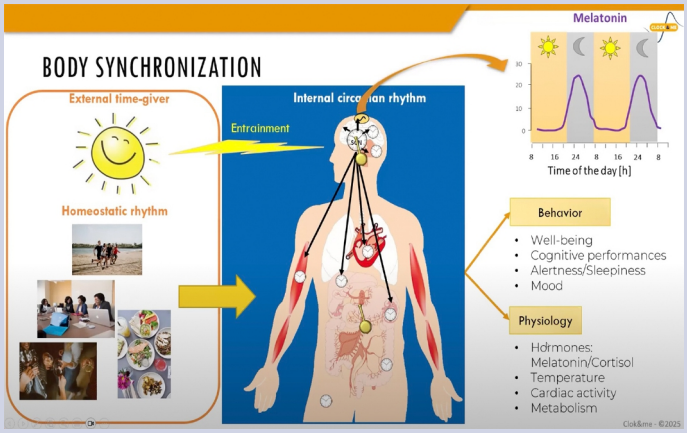

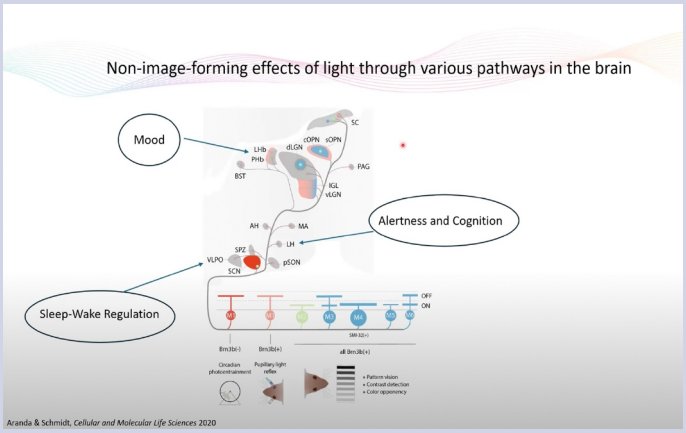

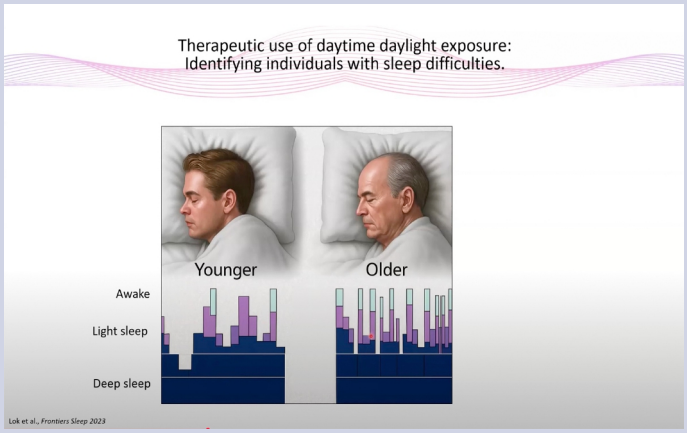

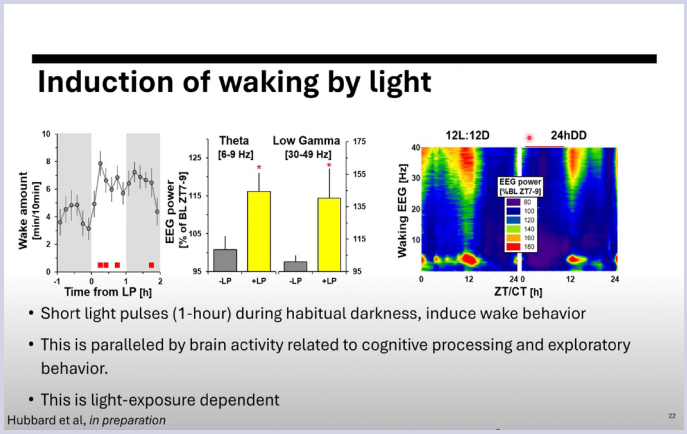

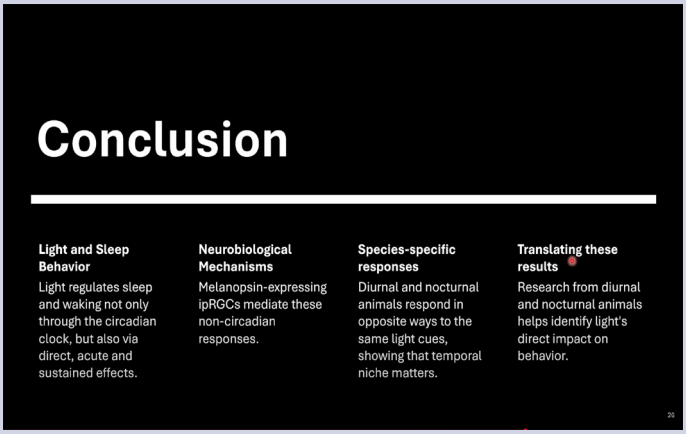

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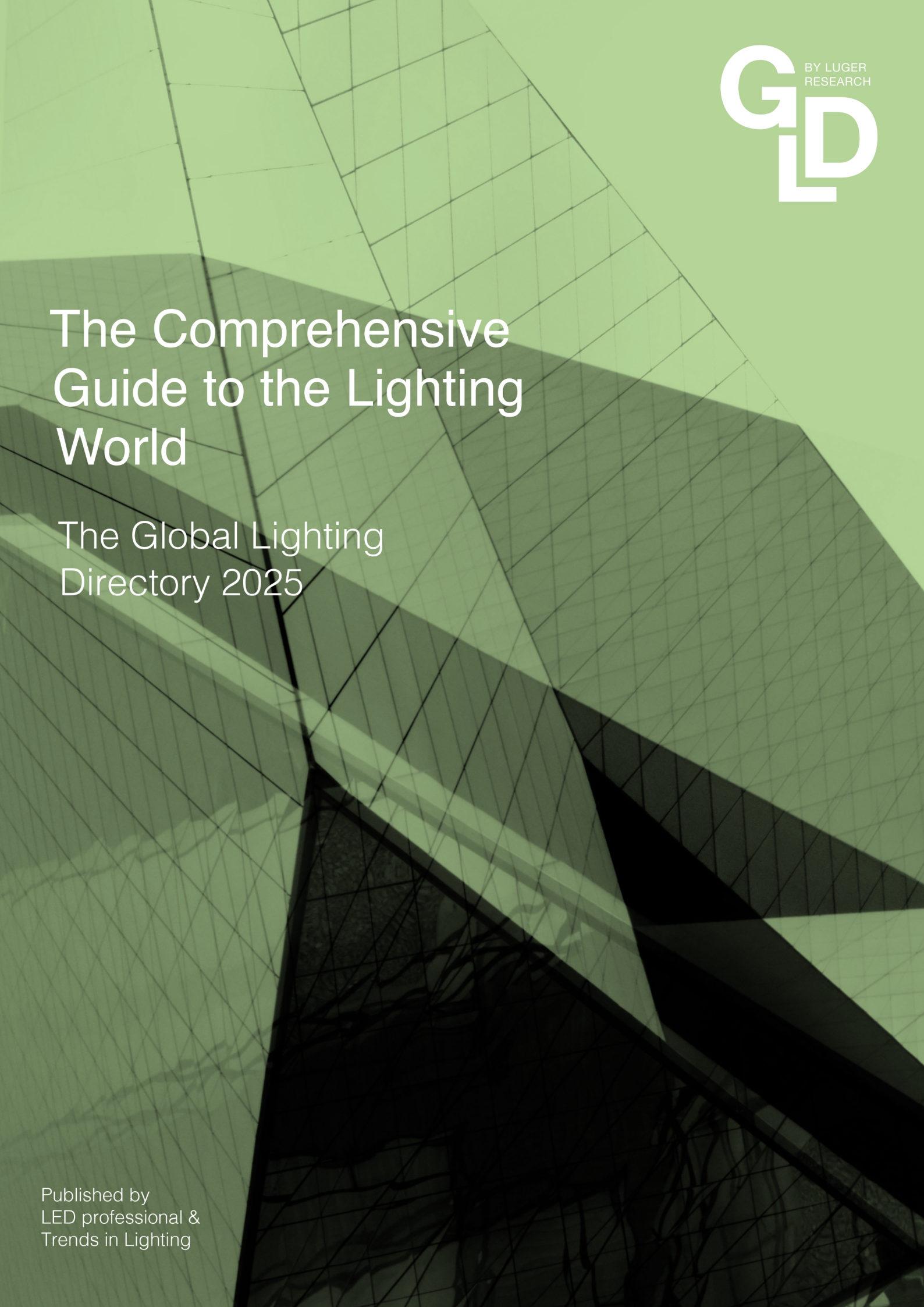

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