Evaluating sensors in smart lighting systems

UL Solutions

Safety. Science. Transformation.™

Executive summary

Sensors in smart lighting systems have become essential to the efficient management and control of lighting systems in consumer, commercial, industrial as well as public infrastructure applications. Sensors serve a critical function in the optimization of performance and energy efficiency of lighting. They also facilitate timely maintenance by signaling lighting component performance issues, failures and outages. Furthermore, sensors contribute to the overall safety and security of buildings through their integration with building automation and security systems.

As the science behind artificial intelligence (AI) and machine learning (ML) continues to progress, it has become easier and more cost-efficient to use AI/ML technologies. These technologies are finding increased utility across a variety of applications. As a result, sensors will become even more important in generating crucial data needed by AI/ML algorithms to enable automation and further optimization in lighting.

For these and other reasons, the implementation of advanced sensor technology as part of smart lighting systems represents a significant and growing market for manufacturers. At the same time, however, standardized methods for evaluating the performance of sensors used in such systems have been slow to emerge. In this vacuum, sensor manufacturers and integrators evaluate and test sensors to their own specific requirements, potentially leading to significant variations in the characteristics, quality and reliability of sensors. Standardization is necessary to ensure a seamless customer experience and improve interoperability between products and systems.

This UL Solutions white paper discusses the use of sensors in smart lighting systems and presents a case for the standardization of sensor performance. Beginning with a review of sensor technology and an overview of its growing importance, the paper then examines a sampling of current sensor standards and identifies key considerations for future technical standards for sensors used in smart lighting systems. The white paper concludes with information about UL Solutions' contributions to the current and future development of Standards and protocols for lighting sensors and other connected technologies.

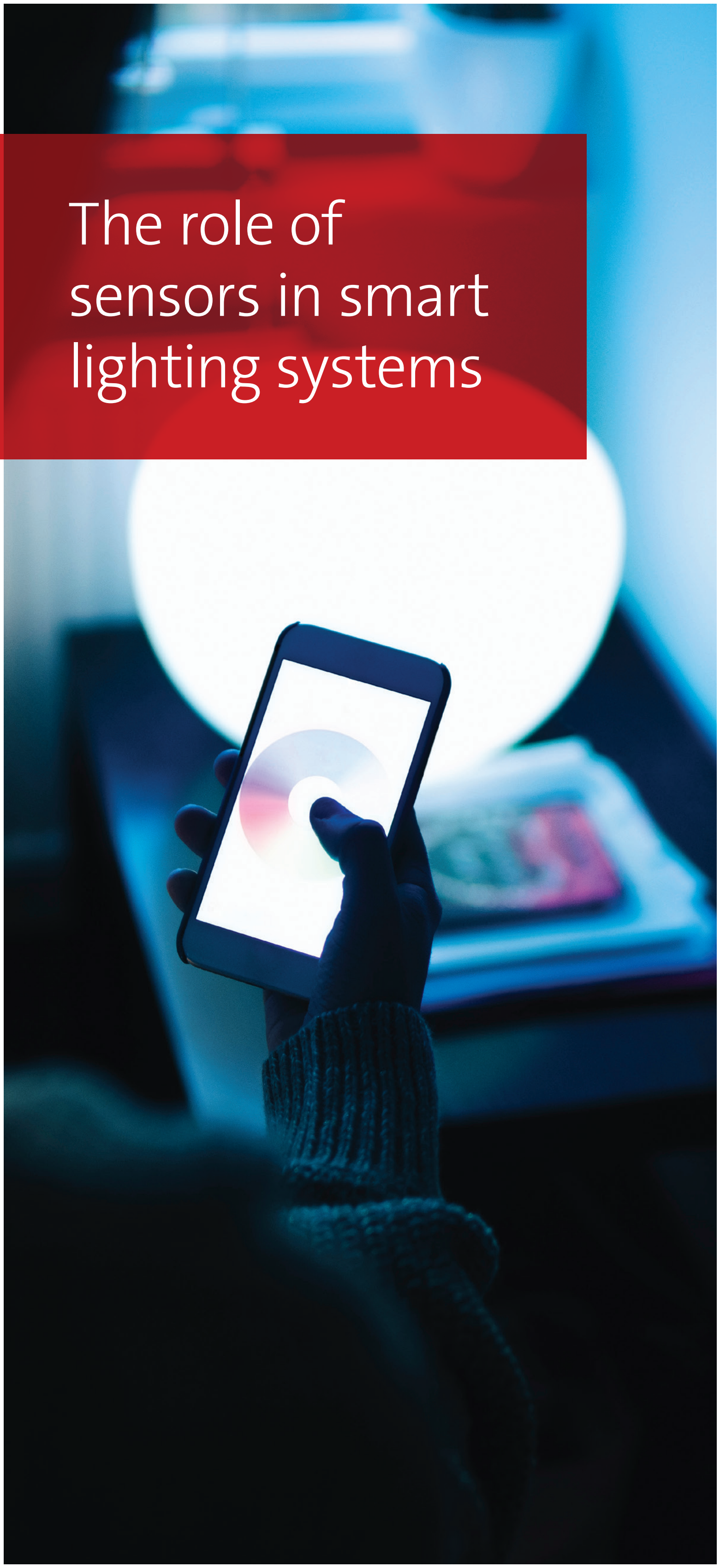
What are sensors?

Sensors translate the characteristics of the physical world into information that can be used to monitor, control and optimize the performance of other devices and systems. Sensors are the driving force behind such 21st century advancements as smart homes, building and cities, autonomous vehicles, and intelligent systems in automated factories and production facilities, i.e., Industry 4.0.

Sensors used in lighting systems are generally low-powered, often microelectronic elements designed to detect one or more specific physical, electrical or chemical properties. A sensor can be a simple, single-function device designed for a specific application, such as a photoelectric device used with a switch to turn on or turn off a piece of lighting equipment. It can also consist of multiple sensing elements to make it a multi-sensor and be integrated into more advanced equipment, such as a controller used in consumer, commercial, or industrial applications for monitoring and control. When packaged with wired or wireless connectivity, the resulting connected sensor can transmit data on changes in these properties to facilitate further centralized analytics to identify actionable intelligence.

Sensors used in smart lighting systems can be of a variety of types. These include photosensitive sensors, infrared sensors, ultrasonic sensors, microwave sensors, temperature sensors, acoustic sensors and many others. New microelectromechanical system (MEMS) technology makes sensors smaller and even more sensitive, accurate and versatile than conventional ones. All of these make sensors essential components in the development and widespread deployment of interconnected devices and technologies that make up the Internet of Things (IoT) and need to be evaluated for cybersecurity risks.

The increasing utility of the smart phone, as well as the growth and expansion of the IoT and the Industrial Internet of Things (IIoT) will fuel dramatic increases in the market for sensors. Global sales of sensor elements and devices, estimated at approximately $156.6 billion (USD) in 2021, are projected to exceed $249.6 billion (USD) in 2026, at a compound annual growth rate (CAGR) of more than 9.8%.[1] Separately, Gartner predicts that sensor-dependent IoT/IIoT-connected devices will grow globally from 14.4 billion in 2022 to more than 27 billion by 2025.[2] These projected trends strongly correlate with the IoT's/IIoT's dependence on sensor technology, which subsequently increases the need for quality benchmarks around this product category.



The role of sensors in smart lighting systems

IT IS ESTIMATED THAT *SENSOR-DEPENDENT IOT/IIOT-CONNECTED DEVICES* WILL GROW GLOBALLY FROM 14.4 BILLION IN 2022 TO MORE THAN 27 BILLION BY 2025

According to the U.S. Energy Information Administration (EIA), energy usage related to lighting products has dropped dramatically in recent years, from about 18% of U.S. electrical consumption in 2013[3] to just 5% in 2021.[4] While economic growth in the U.S. and elsewhere in the world continues to drive an overall increase in the demand for energy, today's advanced lighting products consume significantly less energy than comparable products from just a few years ago, making important contributions to overall energy savings. LED lighting products and other advanced lighting technologies used in both commercial and residential applications have been important factors behind these savings.

In addition to reducing energy consumption, the widespread adoption of LED lighting has also paved the way for the integration of sensors into lighting systems. For millions of consumers, this integration has enabled users to dynamically program sophisticated residential lighting systems, permitting manipulation of illumination through an almost unlimited range of output levels, intensities and colors, all from a smart phone or tablet.

Due to the ubiquitous presence of lighting, smart lighting systems can serve as a platform for sensors to support a host of broader capabilities in all types of settings and applications. Here are just a few examples:

ENERGY EFFICIENCY

Sensors can be used to detect ambient lighting levels to power down lighting during daytime hours ("daylight harvesting") or to detect motion, sound or even body heat to adjust lighting systems based on occupancy. In a building, data from sensor-enabled lighting products can be uploaded into cloud-based building management systems and analyzed for specific occupancy and usage patterns, enabling infrastructure, building and plant operators to more easily monitor and control energy usage associated with lighting systems. These sensor data from lighting systems can also be used to program heating, ventilation and air-conditioning (HVAC) systems to coordinate additional potential energy savings. In public applications, motion sensors can also be used to detect vehicles, cyclists and pedestrians to control the level of dimming to balance energy conservation and public safety.

FACILITIES MAINTENANCE

Sensors in lighting systems can signal when repair or maintenance of a lighting system or component is required or imminent. For example, sensors can measure lighting system performance parameters (e.g., illuminance, energy consumption and temperature) against theoretical specifications to enable asset managers to proactively plan servicing and maintenance.

SECURITY

Sensor-enabled lighting systems can be programmed to contact security services when lighting is unexpectedly activated or when other localized activity (such as a window breaking or loud noises) signals a potential intrusion. Smart lighting systems can also be equipped with cameras or infrared motion detection sensors that can be integrated into building monitoring systems to provide more comprehensive security.

BUILDING AUTOMATION

The operation of smart lighting systems can be integrated with other infrastructure operations, such as plant and equipment activation, elevator operation, access control, as part of an orchestrated effort to manage building and infrastructure operations more effectively.

HUMAN-CENTRIC LIGHTING

The emerging lighting technologies that focus on the impact of light on health and well-being are growing rapidly. In addition to medical and healthcare applications, human-centric lighting (HCL) solutions that measure circadian stimulus, color rendition, and other factors designed for homes, offices and commercial spaces are becoming more prevalent in the lighting industry. In recent years, acceptance of the link between the lighting we are exposed to each day and its effect on our circadian rhythm has increased interest in measuring circadian effectiveness. High-precision sensors that measure ambient light and color deliver useful data for maintaining a balanced environment.

HORTICULTURE/VERTICAL FARMING

Lighting and grow systems designed for food production and other horticultural applications are a critical technology to fuel optimal plant development and growth. The need for reliable sensors in lighting systems to verify lighting outputs are optimized according to specific plant needs is a critical in maximizing the return on investment from the facilities and driving toward more sustainable ways to grow crops.

ULTRAVIOLET (UVC)

UVC radiation has sanitizing properties and has many uses in commercial, healthcare and consumer settings. UVC has germicidal benefits, depending on exposure dose (based on strength, proximity and time). However, there are serious risks to UVC exposure, so safety precautions are essential. UVC containment in both consumer and professional settings is critical. While integrated proximity and orientation sensors and connected sensors (e.g., door open sensors, facilitate containments), there are continued concerns with the accuracy and reliability of these safeguards as well as opportunities for misuse or bypass that could result in personal injury.

OTHER CUSTOMIZED APPLICATIONS

The current technology behind sensor-enabled lighting products provides a platform for the development of a wide range of customized lighting applications. And future advances in sensor technology and photonics is likely to offer new ways to monitor the use environment and share data, supporting additional applications for smart lighting systems.

Current sensor standards

The development of standards applicable to sensors used in smart lighting systems has not kept pace with their growing importance and future potential. Instead, many currently available sensor-related standards focus generally on sensor technology or on sensors intended for use in specific applications. Some industry and professional organizations, such as the National Electrical Manufacturers Association (NEMA), the Institute of Electrical and Electronics Engineers (IEEE), as well as the International Electrotechnical Commission (IEC), have contributed to the standardization of sensor technology by developing industry-accepted standards that sensor manufacturers and integrators have adopted.

Here is a sampling of current sensor-related standards:

- **IEC 61757 series, fiber optic sensors**
  This international standard series covers sensors that measure a physical or electrical quantity, property, or condition as it applies specifically to fiber optic sensing applications.
- **IEC 62047-1, semiconductor devices – microelectromechanical devices – Part 1: Terms and definitions**
  This IEC standard defines terms for microelectromechanical systems (MEMS) and devices, including the process of producing such devices.
- **IEEE 2700, IEEE standard for sensor performance parameter definition**
  Presents a common framework for sensor performance specification terminology, units, conditions and limits.
- **NEMA WD-7, occupancy motion sensors**
  Developed by the National Electrical Manufacturers Association, NEMA, WD-7 provides a reference definition and measurement characteristics for the use and application of occupancy motion sensors.
- **NEMA WD-9, dimmers, photoelectric controls, presence sensors, and multi-outlet bars energy consumption testing and labeling**
  Another NEMA standard, WD-9 provides a standardized testing method to measure and label the standby energy consumption of dimmers, photoelectric controls, presence/motion sensors and multi-outlet bars.
- **NFPA 72, national fire alarm and signaling code scope**
  Developed by the National Fire Protection Association (NFPA), NFPA 72 covers the installation, performance, inspection and testing of fire alarm systems, fire warning equipment, emergency communication systems and their components.

- **ANSI/UL 217, the Standard for Smoke Alarms**
  This Standard covers electrically operated single and multiple station smoke alarms and remote accessories intended for open area protection in indoor locations, as well as portable smoke alarms.
- **ANSI/UL 268, the Standard for Smoke Detectors for Fire Alarm Systems**
  UL 268 establishes requirements for smoke detectors and accessories, such as releasing device controls like electromagnetic door holders and fire and smoke dampers, in accordance with NFPA 72.
- **ANSI/UL 639, the Standard for Intrusion-Detection Units**
  UL 639 addresses the performance of intrusion detection units intended to be used in burglary protection signaling systems.
- **ANSI/UL 1434, the Standard for Thermistor-Type Devices**
  This Standard covers thermistor-type devices that may be used as temperature sensors for various products.
- **ANSI/UL 1484, the Standard for Residential Gas Detectors**
  This Standard covers electrically operated gas detectors intended for installation in residential occupancies and recreational vehicles.
- **ANSI/UL 2075, the Standard for Gas and Vapor Detectors and Sensors**
  This Standard covers toxic and combustible gas and vapor detectors and sensors intended for portable, indoor or outdoor use.
- **UL 8802, Outline of Investigation for UV Germicidal Equipment and Systems**
  These requirements apply to ultraviolet germicidal irradiation (UVGI) equipment and systems emitting uncontained UV, intended for use in commercial and industrial environments. The fourth edition of UL 8802 introduces a new annex to the Outline of Investigation that addresses the use of motion detectors as a safeguard for UV germicidal systems.
- **UL 60730-2-101, Outline of Investigation for Automatic Electrical Controls - Part 2-101: Particular Requirements for Electrical Sensors and Sensing Elements**
  This part of UL 60730 applies to the safety of electrical, electro-mechanical and electronic sensors, including sensing elements and any conditioning circuitry. Discrete sensors covered under the scope of this document serve only to transform an activating quantity into a usable output and do not perform a control operation as defined in Part 1.

Absent from these lists are standards specifically applicable to the newer and more complex sensors used in smart lighting systems. Without the availability of such standards, individual sensor manufacturers are left to develop new sensors based on proprietary technical specifications and protocols. This approach may help to support technical innovation and strengthen first-to-market advantages, but it does little to promote sensor-enabled smart lighting technology in general since it introduces new challenges concerning compatibility, interoperability and interchangeability.

Specific areas for future sensor performance standardization

Sensor standards development will become increasingly necessary as the marketplace depends more and more on the performance of sensors. It must address more than just the safety performance of detector-type sensor technology. Indeed, as the market for smart lighting systems expands, buyers and specifiers will be concerned about a broader range of sensor-specific issues, including performance and reliability, functional integration, battery life and vulnerability to cyberattacks. Increased marketplace reliance on sensors to achieve results can be expected. Therefore, future standards development activities will need to take a holistic approach in addressing technical requirements for sensors for smart lighting systems and evaluating sensors in the context of system-wide integration, which have more impact than individual sensors.

Some specific performance expectations to be considered in the development of new standards for sensors used in smart lighting systems include:

Safety
Manufacturers of sensors are requesting safety certification specific to sensors since they often do not know the type of system their sensors will be utilized in. From a safety point of view, safety- certified sensors can help to reduce the need for sensor redundancy in designs to comply with the deterministic approach to functional safety. At the current moment, a sensor-specific safety standard does not exist.

Parametric measurement accuracy and reliability
Sensors should be evaluated against industry and other stakeholder standardized accuracy and reliability metrics to enable pre-selection for an intended application, simplify installation calibration and commissioning, and increase expected and actual consistency in operational accuracy and reliability.

Energy economy

Many sensors rely on batteries to provide a backup energy source in cases where a primary source of energy is unavailable (e.g., a power outage) or to provide developers with maximum flexibility regarding their installation and use. Sensor designs that have low power demands can support their continued operation for extended periods, reducing maintenance and unanticipated downtime.

Interoperability

The seamless interoperability of individual and bundled sensors is essential for their effective deployment in connected lighting products. Interoperability is facilitated by the adoption of non-proprietary industry communications standards and protocols, along with product designs that foster easy performance and physical integration with connected lighting systems and other smart infrastructure systems.

Interchangeability

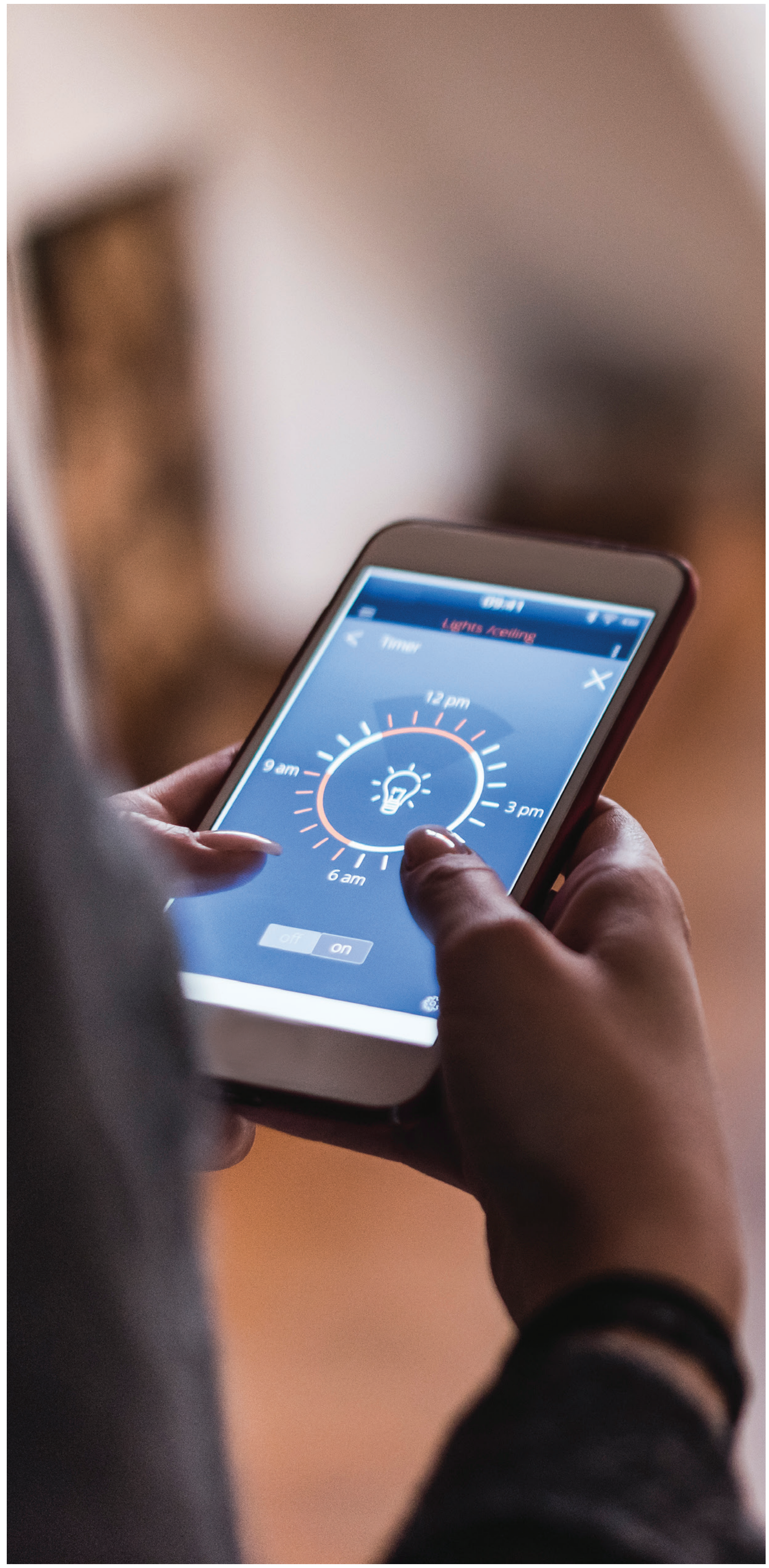
Because many advanced lighting products and luminaires can have a useful life of 15 years or more, the adoption of standardized sensor interfaces will support the ability to continually upgrade lighting system performance to keep pace with new and more advanced sensor technologies. Over time, sensor interchangeability can also help foster the more widespread use of connected lighting systems, increasing their value.

Spectrum efficiency

Commercial and industrial settings equipped with smart technologies may have dozens of different connected systems, devices and applications operating simultaneously, potentially increasing the risk of interference in the wireless spectrum. Therefore, sensor devices designed for use in connected lighting products will need to make the most efficient use of the available spectrum to minimize the risk of interference with other connected devices.

Security and privacy

Like all connected technologies, sensors are potentially vulnerable to hacking and other forms of cyberattack, originating from both external sources as well as other connected systems and components. As such, sensors in connected lighting products must be rigorously evaluated and tested for cybersecurity vulnerability.



Development of standards for smart products

From the earliest beginnings of the Internet of Things, we have been actively supporting the development and widespread deployment of smart technologies that make up the IoT ecosystem, including sensors. Our technical experts serve in key standards development efforts, including those addressing lighting system and component safety, power, control, compatibility and interoperability. We participate in numerous domestic and international technical fora, including committees and working groups involved in the development of standards for IoT technologies.

UL Solutions is an authorized and experienced IoT testing laboratory for DALI, KNX, Bluetooth SIG, Thread Group, Matter from the Connectivity Standards Alliance (CSA) and Qualcomm Quick Charging. We provide Bluetooth and WiFi compatibility and performance testing services for the leading automotive companies, wireless device producers and wireless carriers. In addition, leading IoT and technology companies have entrusted UL Solutions with their customized interoperability programs to confirm products connect and function as intended. Our IoT and interoperability services became an integral part of a product's pre-launch to assess whether products meet consumer expectations for connectivity.

Addressing a potential impediment to the ubiquitous deployment of IoT, UL Solutions has developed the security framework UL MCV 1376, Methodology for Marketing Claim Verification: Security Capabilities Verified to level Bronze/Silver/Gold/Platinum/Diamond, that takes a holistic approach in mitigating cybersecurity risks in connected products and components. It outlines the specific requirements and testing methodologies that are aligned with global industry frameworks and best practices. This approach can help to minimize the vulnerability of sensors and other connected technologies to cyberattacks and provide device manufacturers with greater assurances regarding the performance and security of their products. UL MCV 1376 is a recognized cybersecurity service by the DesignLights Consortium (DLC) to meet their NLC5 Technical Requirements for network lighting controls (NLC). In addition to UL MCV 1376, we also provide testing services for other cybersecurity standards, including ETSI EN 303 645 Cybersecurity Standard for Consumer IoT Devices.

Overall, this broad involvement in the development of standards and testing of sensors and IoT components complements and informs our comprehensive portfolio of standards and testing services. Taking what we know about evaluation and testing for safety, performance, usability and sustainability, we seek to be a catalyst for standards development for lighting sensor technologies so that the sensors our world relies on can provide optimized, reliable and resilient performance.

Summary and conclusions

Sensor-enabled smart lighting systems and those that serve as a platform for other building and infrastructure systems will be significant contributors to the advancement of smart homes, smart buildings, smart industries and smart cities. However, to maximize their potential, there is a critical need for the development of standards for these applications that address performance, reliability, compatibility, interoperability and interchangeability, among other considerations. UL Solutions is actively working with the lighting industry, professional associations and other organizations involved in driving the adoption of IoT technologies. One of our objectives is to facilitate the development of comprehensive, stakeholder-supported, lighting-specific sensor standards that will bring consistency and predictability to sensor performance and contribute to the continued growth in the deployment of smart lighting products and systems.

For more information about the evaluation of sensors in smart lighting systems, and our ongoing contributions to the development of sensor Standards and protocols, visit www.UL.com/lighting.

END NOTES

1. Sensors: Technologies and Global Markets, BCC Research, April 2022.
https://www.bccresearch.com/market-research/instrumentation-and-sensors/sensors-technologies-markets-report.html.

2. State of IoT 2022: Number of connected IoT devices growing 18% to 14.4 billion globally, IoT Analytics, May 18, 2022.
https://iot-analytics.com/number-connected-iot-devices/.

3. "Energy Savings Forecast of Solid-State Lighting in General Illumination Applications," a report prepared for the U.S. Department of Energy, August 2014. Web. 1 June 2017.
https://energy.gov/sites/prod/files/2015/05/f22/energysavingsforecast14.pdf.

4. "Frequently Asked Questions: How much electricity is used for lighting in the United States?" from the website of the U.S. Energy Information Administration (EIA), last updated May 23, 2017. Web. 1 June 2017.
https://www.eia.gov/tools/faqs/faq.php?id=99&t=3.

5. The DesignLights Consortium® (DLC) released the final version of Networked Lighting Controls Technical Requirements Version 5 (NLC5). NLC5 focuses on strengthening the value of NLC technology and contains a new cybersecurity requirement to encourage market acceptance and customer confidence. June 23, 2020.
https://www.designlights.org/news-events/news/new-dlc-policy-networked-lighting-controls-technical-requirements-v5-nlc5-released.

Contact Us

In the Americas: LightingInfo@UL.com
In Europe: AppliancesLighting.EU@UL.com
In China: GC.LightingSales@UL.com
In Australia and New Zealand (ANZ): CustomerService.ANZ@UL.com
In the Association of Southeast Asian Nations (ASEAN): UL.ASEAN.AHLSales@UL.com
In Japan: ULJ.AHL@ul.com
In South Korea: Sales.KR@UL.com
In the Middle East and Africa: UL.MEA@UL.com
In South Asia: Sales.IN@UL.com

UL.com/lighting

TC:AHL22CS467850