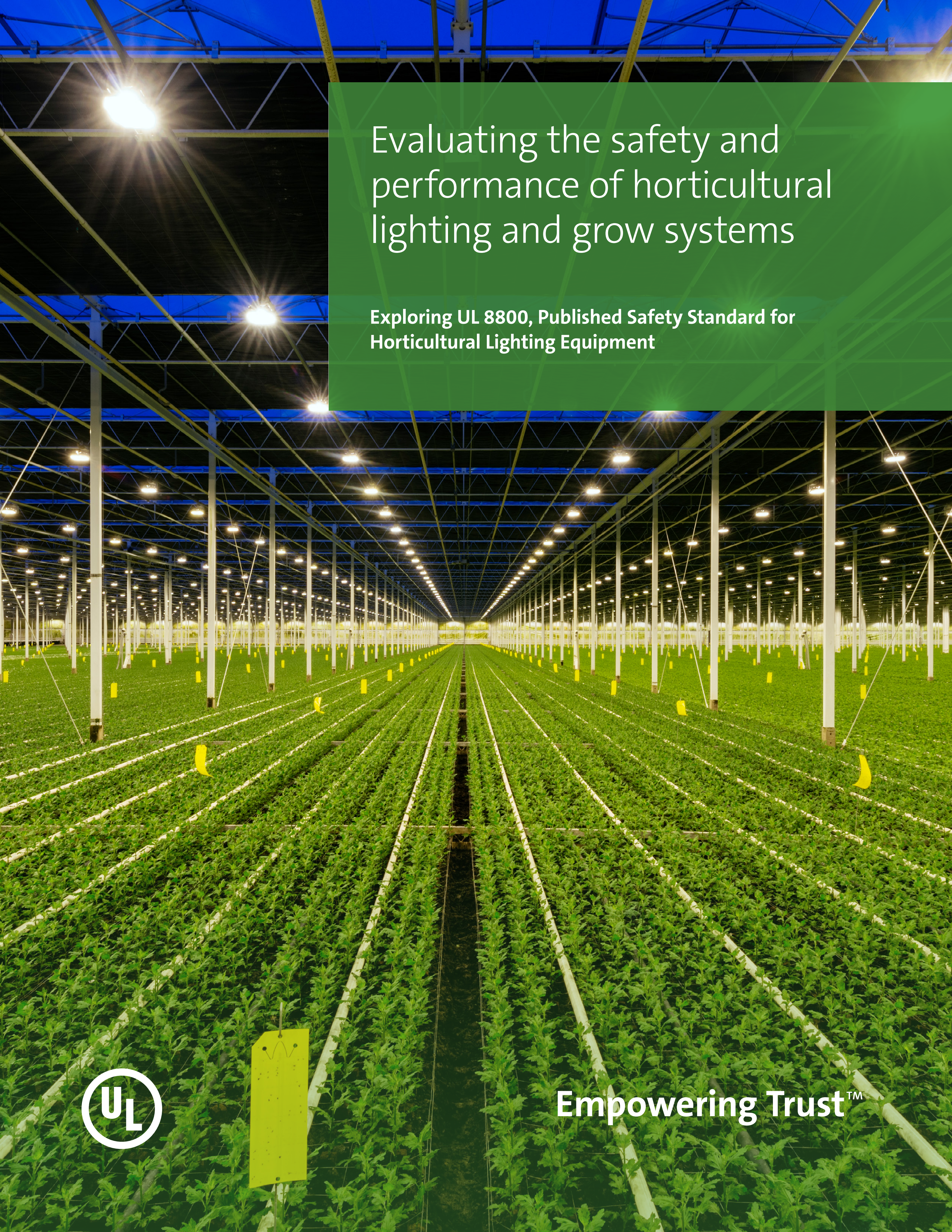


Evaluating the safety and performance of horticultural lighting and grow systems

Exploring UL 8800, Published Safety Standard for Horticultural Lighting Equipment

Empowering Trust™

Executive Summary

As concerns grow about the long-term sustainability of conventional farming and agricultural operations in meeting the world's future food requirements, increased attention is being given to the potential advantages of what some are calling controlled environment agriculture or indoor farming for short. Indoor farming facilities can operate throughout the year, dramatically increasing production yields within a given footprint, while also reducing the environmental impact associated with conventional farming operations. As such, these alternatives hold significant promise in helping to provide billions of people around the world with access to fresh and nutritious food, while also supporting global sustainability initiatives.

Luminaires and grow systems specifically designed for horticultural applications are a critical element in these innovative agricultural environments. Based on light-emitting diode (LED) technology, most of today's advanced horticultural lighting systems are highly customizable and can provide light with color and intensity characteristics calibrated to meet the specific growing requirements of individuals plants. This makes horticultural lighting essential for supporting plant germination, development and growth, as well as for optimizing overall agricultural productivity.

At the same time, previously available standards for evaluating LED luminaires and lighting systems did not fully address the unique safety issues that horticultural lighting and grow systems may be subject to. Further, these standards did not assess the performance characteristics of horticultural lighting, a critical factor in the evaluation and selection of luminaires and lighting systems suitable for a given agricultural application. The absence of relevant safety and performance requirements for horticultural lighting increases the challenges for operators of indoor farming facilities in selecting safe and effective lighting solutions for their enterprise.

In this UL white paper, we'll discuss the function of horticultural lighting in controlled environment agricultural operations, as well as the specific safety and performance requirements applicable to these specialized horticultural luminaires and systems. We'll also discuss the scope of safety evaluations available under UL 8800, Standard for Safety for Horticultural Lighting Equipment, and conclude with a summary of the potential advantages of UL 8800 horticultural lighting and grow system certification.

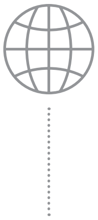
The rise of indoor farming

Thanks to significant technical advances, an expansion of the use of land, water and other natural resources, and a growing reliance on global food supply chains, agricultural production around the world has more than tripled since 1960.[1] Yet, widespread hunger and malnutrition continue to plague people in many parts of the world, with a reported 800 million people suffering from chronic hunger and an estimated 2 billion experiencing micronutrient deficiencies. And there are predictions that agricultural production will need to increase by 50 percent or more over the next 30 years in order to meet the food requirements of a projected world population of nearly 10 billion people by the year 2050.

In response to this challenge, scientists and agricultural experts are carefully examining multiple aspects of current food production and consumption practices for clues on how to meet the ever-growing need for food. To illustrate just one example, demand for meat products tripled in the developing world over the past four decades, while egg consumption increased sevenfold during the same period.[2] Yet, to support this demand, approximately 26 percent of the earth's ice-free land is being used for livestock grazing, while 33 percent of available croplands is used to produce feed for livestock.[3] To help meet the demand for meat now and in the future, innovators are rapidly developing and perfecting laboratory-based culturing technologies necessary to produce tasteful and nutritious meat equivalents that use a fraction of the environmental resources currently required to produce conventional meat products.

At the same time, substantial investments are being made in the development of controlled environment agricultural production facilities, such as large-scale greenhouses and indoor farms. According to one estimate, the global smart greenhouse market, which includes all types of indoor farming operations, is expected to reach $2.28 billion in sales by the year 2023, nearly double the $1.26 billion market size in 2018.[4] Indeed, the potentially disruptive innovation in agricultural production presented by controlled environment agriculture has attracted the attention of both well-established investment firms and high-profile individual investors alike.[5]

Vertical indoor farming operations hold particular promise. In vertical indoor farms, plants are grown in multiple vertically stacked beds installed in a controlled indoor environment. Vertical farming operations can be easily set up in vacant or underutilized warehouse spaces located in cities, significantly simplifying food supply chain activities and expediting the delivery of fresh foods to urban populations. Depending on their height, vertical farms can also produce crop yields significantly greater than what could be obtained from the required ground-level land area. And, because indoor vertical farms continuously maintain a controlled environment optimal for plant growth, they can operate 365 days throughout the year, further multiplying overall production.



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The role and the risks of horticultural lighting.

The growth of vertical indoor farming and all types of controlled environment agriculture is being driven, in part, by advances in a number of essential indoor farming technologies and methods. Of these, horticultural lighting is probably the most critical to the success of indoor agricultural operations. This is because photosynthesis, the essential process in plant germination, growth and reproduction, requires the presence of photosynthetically active radiation (PAR) that is available only through light. Accordingly, horticultural light is used as the primary source of light required for plant growth in indoor farming operations and as a supplement to natural light in greenhouse operations when geography, weather or overcast conditions affect the quality or amount of natural sunlight available.

However, in order to optimize plant development, horticultural lighting design differs from conventional lighting in several important ways. First, horticultural lighting products are designed to produce PAR in spectrums most favorable to plant growth, with the greatest emphasis on deep blue and red spectrums, while conventional lighting is generally designed to accommodate the response of the human eye, with the greatest emphasis on spectrums associated with green and yellow. Other factors critical to horticultural lighting include precise levels of both photosynthetic photon flux (PPF), which represents the number of photons of light that are emitted each second, and photosynthetic photon flux density (PPFD), which is an indication of the density of light photons distributed within a given surface area. And, since not all plants respond to light in the same way, horticultural lighting systems may feature different PAR, PPF and PPFD parameters, or permit the customization of these parameters to meet the requirements of a given plant type.

Running **300** *pages*
UL 1598 *addresses*
THE MECHANICAL AND ELECTRICAL CONSTRUCTION
requirements for luminaires
based on many types of lighting technologies.

Luminaires and lighting systems designed for operation in controlled environment agricultural facilities are also routinely subject to environmental conditions unlike those commonly found in conventional commercial or industrial applications.
For example, to foster plant development, indoor farming environments typically feature increased ambient temperature conditions and higher levels of humidity, requiring that horticultural lighting be designed to reliably operate under these conditions. Horticultural lighting must also be able to safely withstand exposure to increased levels of dirt and dust, as well as water and mist generated by plant irrigation systems. Plastics and other materials used in the construction of horticultural lighting systems must be designed to hold up under these conditions, as well as prolonged exposure to ultraviolet (UV) radiation.

Unlike conventional luminaires and lighting systems that are typically installed in fixed locations, the positions of horticultural lighting are frequently adjusted in order to optimize plant exposure to light. Therefore, horticultural lighting fixtures may be mounted via adjustable cables or chains, or installed on moveable racks. In either case, an abundance of cables, cords, connectors and plugs may be attached to the fixtures to facilitate movement and to provide the greatest degree of positioning flexibility. But this increase in the number of electrical connections can also create unique safety issues that must be addressed in the design of the lighting system itself.

Finally, as the use of LED-based lighting becomes the preferred technology behind most horticultural luminaires and lighting systems, considerations regarding the potentially harmful photobiological effects from exposure to LED lighting come into play. Photobiological effects can include skin irritation, as well as irritation of the front surface of the eye and the retina, and can lead to photokeratitis, ultraviolet erythema, cataracts or retinal thermal injury. Because employees in indoor farming operations routinely work in close proximity to lighting fixtures, thereby increasing the potential risk from exposure, LED-based horticultural lighting must thoroughly account for these risks.

Standards for luminaires and lighting systems: Their application to horticultural lighting

In this context, none of the previously available standards and other requirements for conventional luminaires and lighting systems fully address all of the unique safety and performance requirements applicable to horticultural lighting. Here is a brief summary of the standards and testing methods that are commonly used, along with their limitations in conducting a thorough assessment of horticultural lighting:

UL 1598 — UL 1598, the Standard for Safety of Luminaires, is widely used to evaluate safety issues applicable to many types of luminaires installed in nonhazardous locations and that are hard-wired in a fixed location. First published in 2000, UL 1598 has undergone several revisions, with the most recent edition, the Fourth Edition, published in August 2018. Running more than 300 pages in length, UL 1598 addresses mechanical and electrical construction requirements for luminaires based on many types of lighting technologies, including LED technology. However, the Standard does not directly address the unique aspects or requirements of horticultural lighting.

IEC 62471 — As its title suggests, IEC 62471, Photobiological Safety of Lamps and Lamp Systems, addresses photobiological safety of luminaires and lighting systems, including those utilizing LED technology. First published in 2006 and based on earlier work by the Illuminating Engineering Society of North America (IES) and the International Commission on Illumination (CIE), IEC 62471 defines exposure limits and measurement parameters for lighting-generated optical radiation. This standard is not applied to luminaires intended for general lighting throughout North America but has an extremely important application in horticultural lighting.

IES standards and testing methods

The IES is an accredited Standards development organization (SDO) in its own right and publishes a variety of standards, design guides, and testing and calculation guides applicable to lighting products. Three IES documents relevant to luminaires and lighting systems, and their limitations for horticultural lighting applications, include:

LM-79-08, Electrical and Photometric Measurements of Solid-State Lighting Products — Oriented toward photometric measures, but recommended test conditions are not realistic for horticultural applications.

LM-80-15, Measuring Luminous Flux and Color Maintenance of LED Packages, Arrays and Modules — Describes procedures for testing luminous flux maintenance or wavelength changes, but it isn't applicable to direct color LEDs used in horticultural lighting.

TM-21-11, Projecting Long Term Lumen Maintenance of LED Light Sources — Details a method for determining the anticipated useful life of an LED, but it does not include metrics for LEDs used in horticultural lighting applications.

ASABE standards and testing methods

The American Society of Agricultural and Biological Engineers (ASABE) is also an accredited SDO. The ASABE has published two standards applicable to LED lighting used in horticultural applications. The standards are:

S640, Qualities and Units of Electromagnetic Radiation for Plants (Photosynthetic Organisms) — Quantifies illumination metrics to determine the effectiveness of horticultural lighting on plant growth, but it does not address safety issues.

S642, Recommended Methods for Measurement and Testing of LED Products for Plant Growth and Developments — Describes specific methods for testing horticultural specifications for LED performance, but it does not address performance specifications for other lighting technologies or safety issues.

Design Lights Consortium technical requirements

The Design Lights Consortium (DLC) is a nonprofit organization with a focus on improving the energy efficiency of lighting products. Many utilities throughout the U.S. offer rebates on purchases of DLC-qualified luminaires and lighting fixtures as part of their energy conservation efforts. The DLC has recently published an updated draft of its Testing and Reporting Requirements for LED-based Horticultural Lighting, which can be used as the basis for qualifying horticultural lighting products for inclusion in the DLC's Horticultural Lighting Qualified Products List. However, the document applies specifically to LED-based lighting products and does not address safety issues.

About UL 8800

UL 8800, Standard for Safety for Horticultural Lighting Equipment, is intended to address the unique safety issues applicable to horticultural luminaires, lighting components and grow systems, and represents the first comprehensive set of standardized requirements specifically designed for horticultural lighting equipment. As a result, UL is certifying products using the requirements of UL 8800 to evaluate horticultural lighting equipment from manufacturers seeking the UL Safety Mark for their equipment and devices.

Published as s Standard of Safety, UL 8800 provides a published set of safety requirements for lighting equipment and grow systems intended for use in a horticultural environment and installed in accordance with the National Electrical Code (NEC), ANSI/NFPA 70. Lighting equipment covered under the scope of this Standard for Safety includes luminaires, grow systems and hardware specifically designed or intended for use in optimizing plant growth.

The requirements of UL 8800 set it apart from other lighting safety standards in several significant ways. Key differences include:

Targeted scope — The scope of other current safety standards for luminaires addresses safety issues for lighting equipment that is hard-wired in a fixed location and designed for the purpose of general illumination. In contrast, the scope of UL 8800 specifically covers luminaires and grow systems intended for use in the active development and growth of plants.

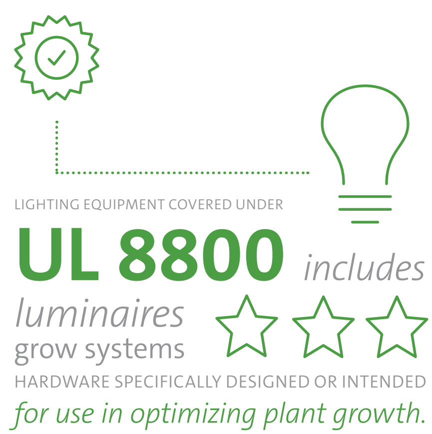
Photobiological effects — UL 8800 addresses safety considerations associated with the photobiological effects and potential hazards associated with human eye and skin exposure to light sources technology widely used in horticultural lighting systems. UL 8800 photobiological safety requirements are consistent with those found in IEC 62471, Photobiological Safety of Lamps and Lamp Systems, and provides the user with detailed information on what precautions to take regarding the potential exposure of the light output.

Wiring and connection methods — Unlike luminaires installed in conventional industrial and commercial settings that remain fixed throughout their useful life, horticultural lighting systems are typically designed to be frequently raised, lowered or repositioned in order to optimize plant growth. As such, UL 8800 allows for specialized wiring and connection methods that support the required positioning flexibility.

Environmental considerations — General environmental conditions within indoor horticultural operations can vary widely, with high humidity levels and temperature conditions. Under UL 8800, horticultural lighting systems are evaluated for their suitability in damp and/or wet environments, as well as in environments with elevated ambient temperatures. Lighting systems achieving UL 8800 Certification bear markings that verify these characteristics.

Ingress protection — Equipment used in indoor agricultural operations are also at greater risk of infiltration from dust, moisture and water that can compromise their reliability. UL 8800 addresses these risks with ingress protection (IP) testing that classifies and rates the degree of protection afforded by the equipment against both solid objects and water, consistent with the requirements of IEC 60529, Degrees of Protection Provided by Enclosures.

UV exposure of polymeric materials — Finally, in a grow environment, polymeric materials associated with the equipment can be exposed to UV from the sun, such as within a greenhouse. This exposure can cause polymeric materials to become brittle and more susceptible to breakage. UL 8800 sets forward requirements to address these concerns.



How UL supports horticultural lighting manufacturers

UL takes a holistic approach to the evaluation of safety and performance issues unique to horticultural luminaires and grow systems. We begin with a comprehensive assessment based on the requirements detailed in UL 8800, addressing electrical and mechanical safety issues as well as photobiological safety considerations applicable to horticultural lighting. Luminaires and systems certified in accordance with UL 8800 requirements also conform with the requirements of the NEC and are recognized by electrical inspectors and other authorities having jurisdiction (AHJs).

As previously noted, specific characteristics of lighting such as the quantity, distribution and spectrum of light play an important role in the performance of horticultural lighting when it comes to plant growth. Since these individual characteristics are unique to each type of plant, knowing the performance specifications of a lighting system is essential in selecting a system that will best optimize the growth of a given plant or plants. UL's performance testing of horticultural lighting measures key light characteristics that are essential to plant growth, helping to ensure that growers have the information they need to choose an appropriate lighting system for their specific growing operation. And our report of performance testing of horticultural lighting meets the requirements of ASABE standards, thereby facilitating qualification in accordance with the technical requirements of the DLC.

For lighting manufacturers, UL's holistic methodology to evaluating horticultural lighting safety and performance issues represents an efficient and cost-effective approach that can help them meet applicable regulations while also providing the greatest possible transparency for current and prospective customers. For growers, UL's testing and certification help provide a level of assurance that a horticultural lighting product will meet their specific growing requirements while also helping providing assurances regarding their safety in use.

Summary + Conclusion

Horticultural luminaires and grow systems represent an essential technology in the growth of controlled environment agriculture. However, currently available standards do not provide a comprehensive assessment of the safety and performance factors that are unique to these systems. The previous patchwork of standards meant that some horticultural lighting systems may fall short of essential safety requirements but may also fail to meet the performance expectations of growers, potentially leading to lower than expected agricultural yields.

As such, a more comprehensive approach to the assessment of horticultural lighting and grow systems is required; one that can provide both manufacturers and growers with assurances regarding their safety and their appropriateness in a specified growing operation. Manufacturers who achieve certification to the requirements of UL 8800 will have met the most rigorous safety criteria currently available for horticultural lighting and grow systems, while UL's performance testing services can aid in the selection of horticultural lighting products that are best suited for their intended use.

For more information on UL's testing and certification services for horticultural luminaires and grow systems, contact our team at LightingInfo@ul.com. Or visit us at UL.com/HorticulturalLighting.

End Notes

1. Statistics on global agricultural production and future population growth trends cited in this paragraph are taken from "The future of food and agriculture: Trends and challenges," a report by the Food and Agricultural Organization of the United Nations. 2017. Web. 22 November 2018. http://www.fao.org/3/a-i6583e.pdf.

2. "The Food Effect: Where Will We Find Enough Food for 9 Billion People," an article and photo essay prepared by the National Geographic Society. Web. 22 November 2018. https://www.nationalgeographic.com/foodfeatures/feeding-9-billion/.

3. "Livestock and Landscapes," an infographic produced by the Food and Agricultural Organization of the United Nations. Web. 22 November 2018. http://www.fao.org/docrep/018/ar591e/ar591e.pdf.

4. "Smart Greenhouse Market by Type, Technology and Geography—Global Forecast to 2023," a report by MarketsandMarkets, March 2018. Web. 22 November 2018. https://www.reportsnreports.com/reports/404679-smart-greenhouse-market-by-technology-hvac-led-grow-light-communication-technology-irrigation-system-material-handling-valves-pumps-control-system-and-others-type-hydroponic-non-hydroponic-and-geography-forecast-to-2020.html.

5. "Opportunities in Controlled Environment Agriculture," a report by the Food Institute at The George Washington University. May 2018. Web. 22 November 2018. https://cpb-us-e1.wpmucdn.com/blogs.gwu.edu/dist/a/122/files/2018/05/CEA-Final-Document-1i4su6u.pdf/.

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