DLC LUNA RESOURCES:

Seven Strategies to Minimize Negative Impacts of Outdoor Light at Night

The DLC's LUNA V1.0 Technical Requirements for outdoor solid-state lighting products establish criteria to enable the use of high-quality outdoor lighting at night to minimize light pollution, provide appropriate visibility for people, and limit negative impacts to the environment. In addition to these benefits, LUNA products can help capture energy savings by using the right type and amount of light, and only where and when it is needed. But even the best outdoor lighting product can fail to meet these objectives if not applied correctly.

This resource provides high-level application strategies that go beyond the LUNA product requirements for energy efficiency program staff, contractors, distributors, and lighting practitioners who are interested in using outdoor lighting that is both energy efficient and reduces light pollution.

HIGHLIGHTS

- Overview of the types of light pollution that affect outdoor environments.
- High-level information for energy efficiency program staff, contractors, distributors, and lighting practitioners on outdoor lighting application strategies beyond the DLC LUNA product requirements.

What is light pollution?

Light pollution includes the following three components: sky glow, light trespass, and glare (see **Figure 1** below).

Sky glow is a result of light scattering in the atmosphere directly from light fixtures and from ground and object reflections. Ground surface reflectance values can reach 35% for asphalt and concrete; 25% for grass and tree foliage; and can vary between 5 - 80% for exterior building surfaces. Scattered and reflected light results in sky glow that travels well beyond the illuminated site.

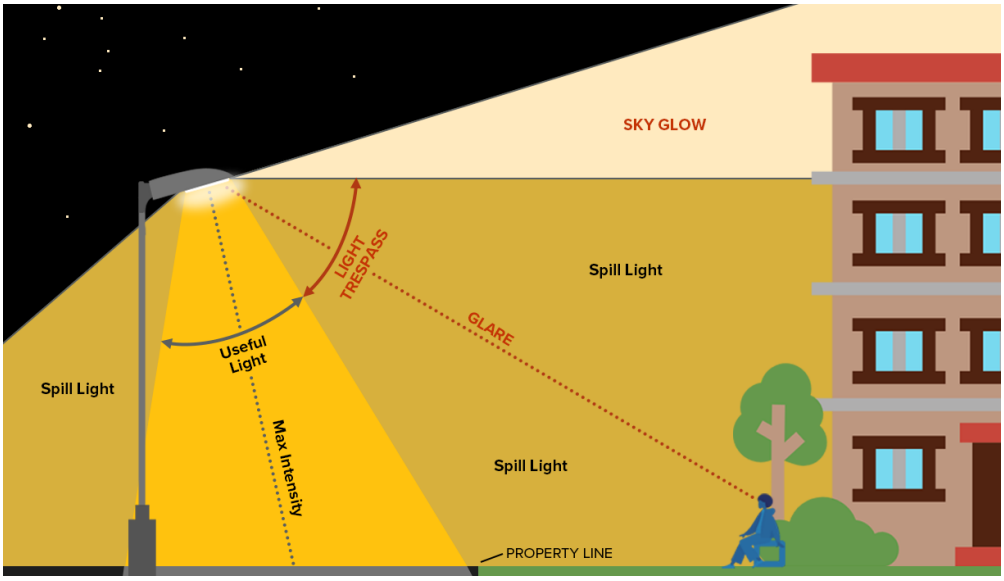


Figure 1: The three components of light pollution – sky glow, light trespass, and glare – are shown in red.

Light trespass is spill light that extends beyond a property boundary and may cause annoyance, loss of privacy, and other nuisance to people. It can also disrupt nocturnal rhythms of wildlife and plants.

Light reaching the eye can produce different types of **glare**, which can be uncomfortable or even dangerous.

- **Disability glare** is light scattering in the eyes that interferes with visibility.
- **Discomfort glare** is overly bright light that causes people to squint or avert their eyes (and may even cause pain).
- **Nuisance glare** is light that is distracting or unwanted (e.g., from a light shining in a window).

Using LEDs for outdoor lighting

The Five Principals for Responsible Outdoor Lighting from the Illuminating Engineering Society (IES) and International Dark Sky Association (IDA) state that outdoor lighting should do the following:

1. **Be useful.** All light should have a clear purpose (refer to IES standards for lighting).
2. **Be targeted.** Light should be directed only where needed.
3. **Provide low light levels.** Light should be no brighter than necessary.
4. **Be controlled.** Lighting should only be used when it is useful.
5. **Have a warmer color.** Use warmer white or amber lights where possible.

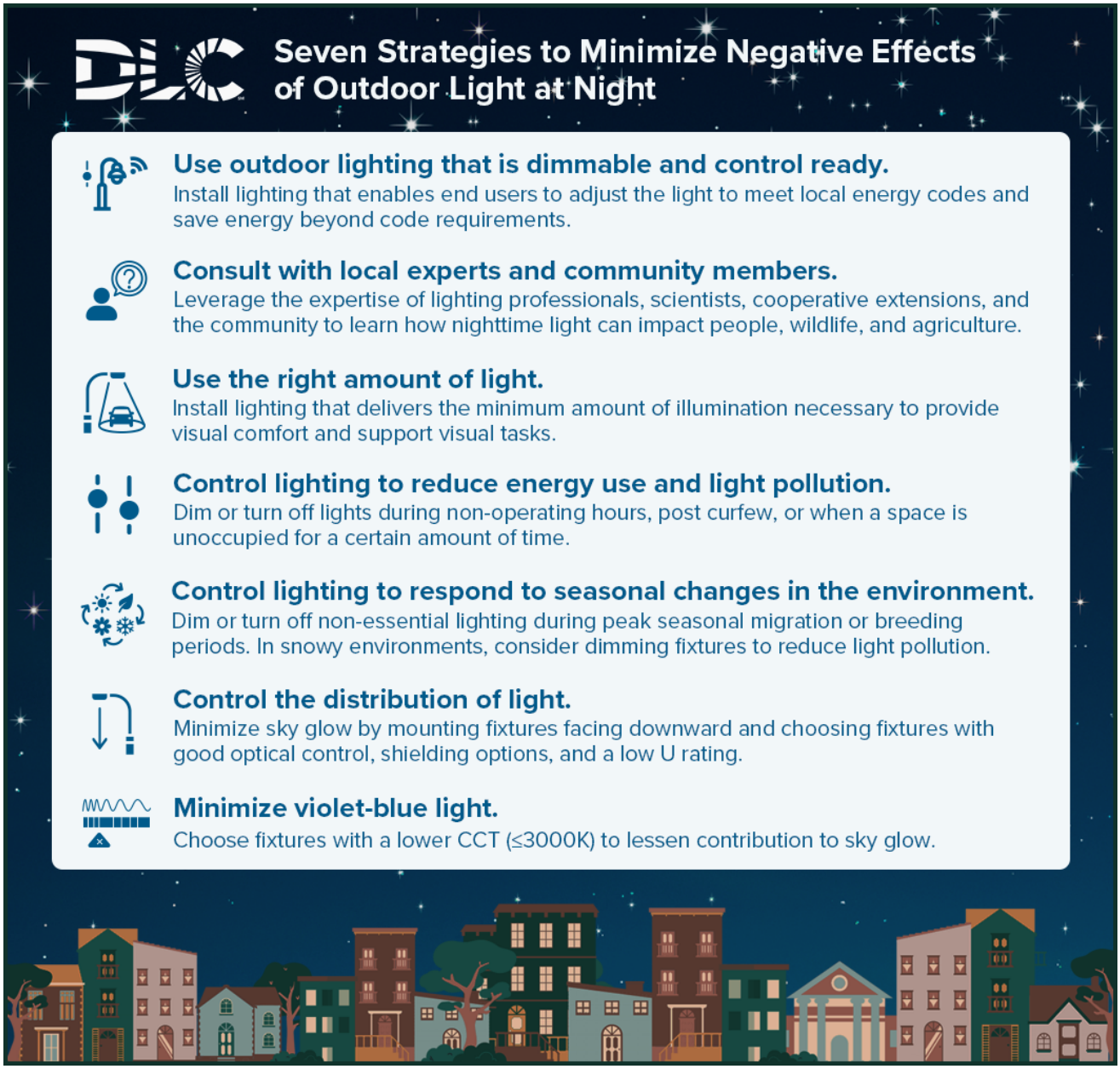
LED lighting offers many benefits over high-intensity discharge (HID) lighting,[1] including improved energy efficiency, better optical control, and more dimming capabilities. When thoughtfully applied, these benefits can help avoid the unintended consequences of light pollution. However, the increased amount of violet and blue wavelengths from LEDs producing white light has been linked to potentially harmful effects on humans, plants, insects, and marine and land-based animals, especially when the illuminated areas are overlit and/or are lit with high CCT products. Therefore, application is critically important to ensure the best results.

Seven strategies for outdoor lighting

The *Five Principals* from the IES and IDA can be translated into the following seven simple strategies for outdoor lighting projects, presented in order of importance. The LUNA V1.0 reporting requirements for dimmability and controls and thresholds for optical and spectral distribution enable the strategies listed in blue below. The method of installation and usage of the light is critical to ensuring these seven strategies are effective.

1. **Use outdoor lighting that is dimmable and control ready.**
2. Consult with local experts and community members.
3. Use the right amount of light.
4. Control lighting to reduce energy use and light pollution.
5. Control lighting to respond to seasonal changes in the environment.
6. Control the distribution of light.
7. **Minimize blue-violet light.**

[1] Types of HID lighting include high-pressure sodium (HPS) and metal halide (MH).



Explanation of the seven strategies

Use outdoor lighting that is dimmable and control ready.

LED lighting is the most sustainable choice for exterior lighting in terms of energy efficiency, and conversions from (HID) fixtures result in financial and energy savings. Dimming and controls capabilities enable end users to adjust lighting to meet local energy codes and to save additional energy beyond local code requirements. For example, adaptive lighting schedules can reduce light levels during low occupancy periods (e.g., from 11:00 pm to sunrise).

Outdoor fixtures that meet the DLC's LUNA V1.0 Technical Requirements have a minimum luminaire efficacy of 105 lm/W, with efficacy allowances given for products with warm white CCTs , shielding, and/or excellent color rendition. Bollards that meet the LUNA requirements are provided with an efficacy allowance of 25%. These allowances help offset the tradeoff between efficacy and quality that may be needed to achieve the best results for the application.

Consult with local experts and community members.

Consultation with lighting professionals is critical to ensure that installed lighting is appropriate for the application. However, wildlife experts, social scientists, and community members also have important input that should be carefully considered before making lighting decisions.

Wildlife experts: Illuminated areas impact plants and wildlife, especially nocturnal wildlife. Lighting installed in areas adjacent to protected wildlife habitats (i.e., sea turtle nesting grounds) should follow best practices for minimizing negative impacts on these organisms. The resources below provide information on the types of lighting deemed least harmful for wildlife-adjacent applications. Other nocturnal wildlife may also benefit from light pollution mitigation, even if not formally protected.

For example, in addition to selecting appropriate spectral distribution for local wildlife, lighting in a public park or a walkway adjacent to a beach requires careful selection of optical and dimming controls to keep these areas as dark as possible. Any design where spill light impinges on undeveloped areas would benefit from additional expert consultation. This DLC webinar provides examples and information on the impacts of light on wildlife from two experts. Additional resources to start with include:

- **Artificial light and sea turtles** *(Florida Fish and Wildlife Conservation Commission)*
- **Bird migration and collision with buildings** *(Cornell University BirdCast)*
- **Firefly preservation** *(Xerces Society for Invertebrate Preservation)*
- **Lighting on protected lands** *(National Park Service)*

Cooperative extension agents from a state land-grant university or local extension office can also provide guidance on nighttime lighting's impact on local crops. Find National Institute of Food and Agricultural college partners here.

Other experts and community members: Light pollution also has a social impact on humans, from limiting views of dark skies in urban and suburban areas, to creating uncomfortable (or even harmful) conditions due to improper installations in underrepresented communities. Consultation with social scientists with expertise in cultural and social impacts and with community members is essential to minimize light pollution and improve the quality of outdoor lighting in these spaces. The following resources provide a starting point:

- **With Good Lighting and Justice for All** *(Illuminating Engineering Society (IES))*
- **Tackling Social Inequalities in Public Lighting** *(The London School of Economics and Political Science)*
- **Responsible Lighting at Night: Bridging the Inequality Gap (Webinar)** *(DLC)*

Use the right amount of light.

If uplight and reflected light are not managed, exterior lighting can result in visible sky glow up to 200 miles away, which can disrupt wildlife and degrade the view of the night sky. To minimize these impacts, lighting should deliver the minimum amount of illumination necessary to provide visual

comfort and support visual task needs of pedestrians and drivers. The IES publishes Recommended Practices with extensive guidance by area type for outdoor and site applications (see ANSI/IES RP-8-22 and ANSI/IES RP-43-22). The best way to define and specify the right amount of light is to design for the maintained average or minimum illuminance or luminance criteria as noted in these Recommended Practices, *and no higher*. Maintained illuminance levels include light loss factors; therefore, there is no need to increase light levels above the noted value. Because light-colored surfaces are more reflective than dark-colored surfaces, it may be possible to illuminate certain light-colored surfaces equally as brightly using lower light levels; this will also help mitigate sky glow.

Replacing light fixtures or lamps on a one-for-one basis (e.g., replacing metal halide floodlights with LED flood lights based on input power or lamp or luminaire lumens) may seem less expensive, but without consideration of the required and actual illumination levels, this approach does not optimize the benefits of LEDs and may result in a less efficient and effective design. Consequently, light pollution mitigation and energy savings from one-for-one replacements may not be as comprehensive as that achieved through the design process.

Control lighting to reduce energy use and light pollution.

Many energy codes require exterior lighting in specific areas to be controllable, and to be dimmed by a minimum percentage or turned off during non-operating hours or when the space is unoccupied for longer than a certain period. ASHRAE 90.1-2019 specifies that most exterior lighting is turned off or reduces power by at least 75% during non-operating hours. Turning off or dimming lighting late in the evening (post-curfew) reduces light pollution by a commensurate amount (e.g., if exterior lighting fixtures are dimmed by 75% during non-operating hours, light trespass and local contribution to relative sky glow is reduced by 75%).

The IES Recommended Practices mentioned herein recommend dimming levels ranging from 0% to 50% depending on the application area, lighting zone, and safety considerations. Some application areas are not recommended to be dimmed, while others, like landscape lighting, are recommended to be switched off post-curfew. Refer to the ANSI/IES Recommended Practices for detailed guidance. If interested in lighting streets and roadways, refer to the recommendations for these specific applications in ANSI/IES RP-8-22.

Control lighting to respond to seasonal changes in the environment.

Seasonal events such as bird migrations, sea turtle nesting, salmon spawning, and firefly mating occur during nighttime hours. Light pollution, including light trespass onto water and adjacent landscape areas, can disrupt these natural behaviors and lead to high mortality among the affected species. When possible, during peak seasonal migration or development times, non-essential lighting should be turned off or dimmed post-curfew or during non-operating hours. In snowy environments, consider dimming fixtures to account for the higher reflectance values of snow-covered roads. Turning fixtures off or dimming them to address seasonal concerns also reduces sky glow and saves energy.

Control the distribution of light.

Sky glow is caused by light reflecting off surfaces and from light emitted directly from the luminaire in a horizontal and upward direction. The more uplight a fixture produces, the more sky glow increases (see **Figure 3**). To limit the direct component of sky glow, it is best to minimize uplight as well as horizontal light. This can be achieved in multiple ways:

- Select fixtures with a low U rating in the BUG rating system. A value of U1 or lower is appropriate for most exterior lighting, with some exceptions.[2]
- Rather than aiming or tilting luminaires vertically, select luminaires with good optical control. Aimed luminaires without additional shields or baffles can produce more uplight and increase sky glow, glare, and light trespass.
- As much as possible, direct the light downward instead of upward. Fixtures should be mounted facing down instead of up or angled. LUNA V1.0 requires pole and arm-mounted luminaires to have mounting hardware that limits tilt to +/- 10 degrees.

Figure 3, below, shows that tilting luminaires up vertically towards the horizon increases light output at high angles, thereby increasing relative sky glow (RSG) and the chance that the light will cause discomfort from glare.

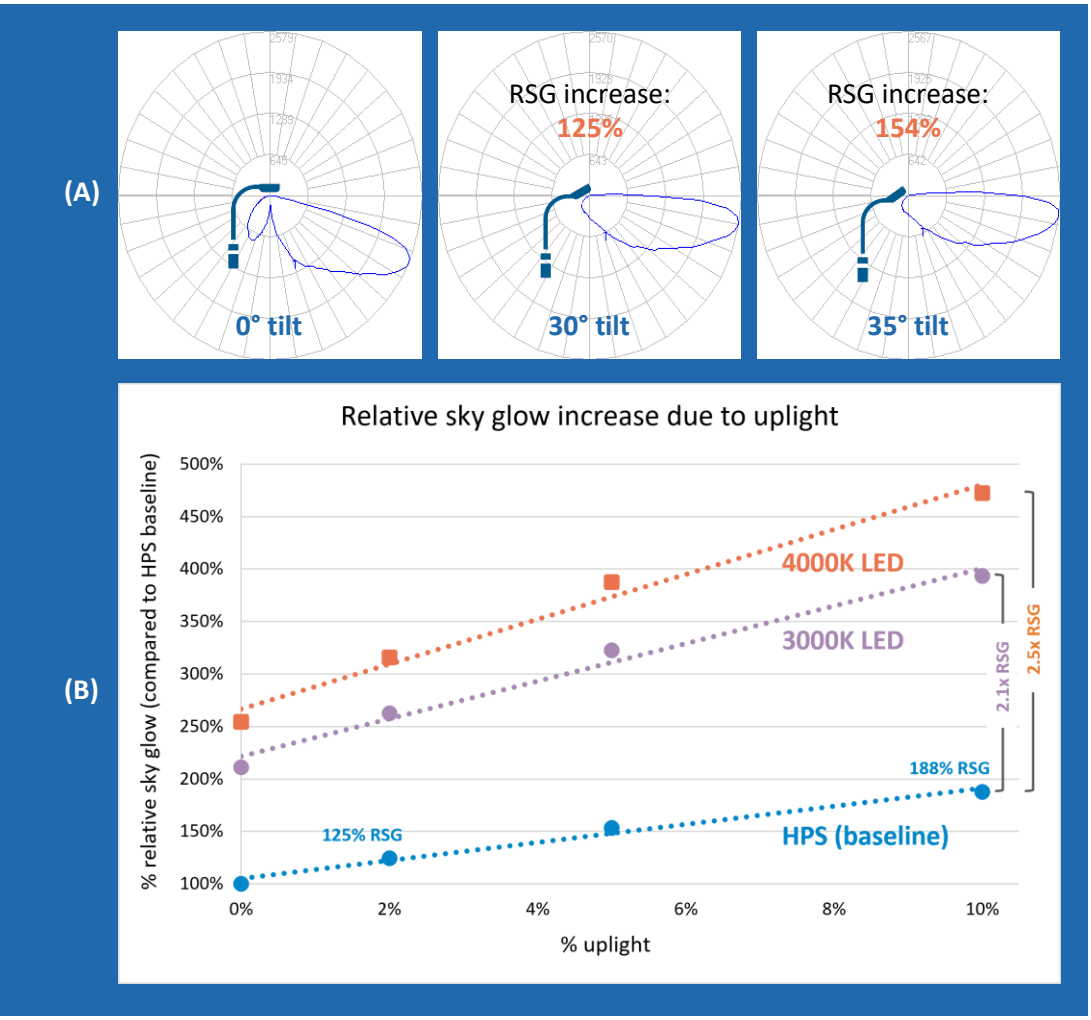


Figure 3: An illustration of two scenarios where uplight increases light pollution.

The distributions in the top three plots (A) show that a 30-degree tilt increases relative sky glow by 125% compared to a non-tilted luminaire. Tilting the luminaire an additional five degrees (to 35 degrees) increases the relative sky glow to 154% compared to the non-tilted luminaire.

The bottom graph (B) shows that additional uplight increases relative sky glow by a much higher rate than the increase in uplight, and the effect is heightened with higher CCTs (e.g., with more violet and blue radiation). For example, compared to an HPS luminaire with 0% uplight, HPS luminaires with 2% and 10% uplight increase relative sky glow by 125% and 188%, respectively. Compared to an HPS luminaire with 10% uplight, 3000K and 4000K LED luminaires with equal uplight produce a relative sky glow that is 2.1 and 2.5 times higher, respectively. LUNA V1.0 limits CCT to a maximum of 3000K to mitigate this effect.

[2] Decorative lighting that emits a soft glow may be desirable in some urban contexts. For these luminaires, select products with a low U rating. Lighting fixtures mounted under canopies or other ceiling surfaces may also have a higher U rating as long as the uplight does not escape beyond the canopy boundary. LUNA V1.0 limits the U rating of these types of fixtures to a U2.

Light trespass and glare are also caused by fixtures that are not optimized for the application area. Lighting distributions should light the application area only and should minimize spill light beyond this area. It is also helpful to have additional shielding options available from the manufacturer, so that spill light in the forward or backward direction can be further reduced if needed. In **Figure 4** below, a school parking lot adjacent to a residential housing development is illuminated to meet the maintained minimum horizontal illuminance criteria of 0.2 fc in ANSI/IES RP-8-22. The difference between Type 5 fixtures, Type 2 fixtures, and Type 2 fixtures with house side shields is illustrated by the decreasing light trespass on the outer walls of the houses.

Example 1

Type 5 LED fixtures (light distribution shown in the inset image) are used throughout. There is a lot of spill light, or light trespass, on the adjacent green spaces and into the backyards of the adjacent houses.

Example 2

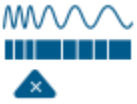
The fixtures closest to the residential properties are replaced with Type 2 (light distribution shown in the inset image) to eliminate some of the back light. There is some spill light, or light trespass, onto the properties, but less than occurs when Type 5 fixtures are used.

Example 3

The fixtures closest to the residential properties are changed to a Type 2 with a house side shield (light distribution shown in the inset image) to eliminate most of the back light. There is some spill light, or light trespass, onto the properties, but it is reduced even more than in example 2.

Figure 4: A parking lot adjacent to a residential housing development is illuminated to meet the maintained minimum horizontal illuminance criteria of 0.2 fc in RP-8-22. The difference between Type 5 fixtures, Type 2 fixtures, and Type 2 fixtures with a house side shield is illustrated by the decreasing light trespass on the outer walls of the houses.

The IES facilitates the Discomfort Glare in Outdoor Nighttime Environments (DGONE) committee, which is developing a new method for predicting discomfort glare in outdoor environments. Until this method is finalized, ANSI/IES RP-43-22 recommends maximum Glare rating (G) values of G1-G3 using the BUG system, depending on the application and lighting zone. To help manage glare, luminaires that meet the DLC's LUNA Technical Requirements must have mounting hardware that limits the aiming angles to 10 degrees or fewer (depending on the primary use designation (PUD)). In addition, pole and arm-mounted PUDs must have at least one shield type available for specification.



Minimize blue-violet light.

The last strategy to reduce light pollution is to minimize blue-to-violet radiation from the LED products selected. Even though CCT is not intended to predict the contribution of blue-violet light to sky glow, it is the current industry standard metric to characterize color appearance from a light source. When all else is equal (e.g., same light output, distribution, and mounting height), one can minimize the amount of blue-violet radiation by choosing a lower CCT fixture (3000K or lower).

Some lighting manufacturers are also designing outdoor fixtures using amber LEDs. These fixtures may be described as "amber" or with a low CCT (2000K or lower). At this time, the DLC does not allow non-white light (NWL) LED products, such as amber, to be qualified under LUNA V1.0 because of the lack of standards for this technology. More information on how to compare amber products is provided in the DLC's 2022 whitepaper, Non-white Light Sources for Nighttime Environments.

Additional Reading

Resource	Description
ANSI/IES RP-8-22 – Recommended Practice: Lighting Roadway and Parking Facilities	Recommended practices for lighting roadway and parking facilities.
ANSI/IES RP-43-22 - Recommended Practice: Lighting Exterior Applications	Illumination recommendations for the reassurance, safety, comfort, amenity, and enjoyment of people in outdoor environments in lighting zones LZ-1 through LZ-4.
ANSI/IES TM-15-20 - Technical Memorandum: Luminaire Classification System for Outdoor Luminaires	A classification system for outdoor luminaires that provides information to lighting professionals regarding the lumen distribution within solid angles of specific interest.
DLC Solid-State Lighting Technical Requirements V5.1	The DLC's requirements and reporting standards that improve the quality and controllability of high performance, energy efficient commercial lighting products.
DLC LUNA Technical Requirements V1.0	The DLC's requirements and reporting standards for light distribution, spectral characteristics, and controllability to mitigate negative impacts of outdoor lighting at night.
DLC Whitepaper: Non-white Light Sources for Nighttime Environments	Describes the scientific landscape for non-white light LED sources as a part of the solution to the consequences of light pollution on the natural environment.
DLC Report: Choosing Both Energy Efficiency and Light Pollution Mitigation for Commercial Outdoor Lighting	A DLC study which found that LUNA qualified luminaires, when paired with proper design and controls programming, can provide greater energy savings than LEDs luminaires focused solely on energy efficiency.