SIGHTLINES

Leora Radetsky and Scott Lind

Rethinking LED Retrofits: S/P ratios, sky glow, and smarter specifications

LEDs, long heralded for their energy efficiency, now comprise well over half the global commercial lighting market. Yet, their environmental impacts, especially from outdoor LEDs with bluish-white spectra, are increasingly scrutinized. Mounting evidence reveals unintended ecological consequences: diminished star visibility, disrupted circadian rhythms in wildlife, and altered nocturnal behaviors across taxa. To mitigate these impacts and to comply with voluntary and regulatory criteria, the lighting industry has developed lower CCT LED products as a promising solution.

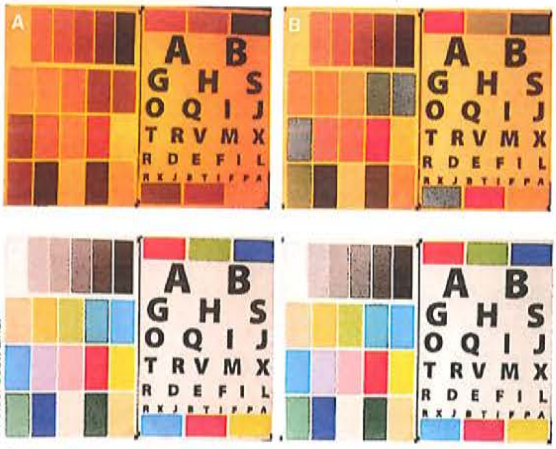
Nothing is absolute, however, and recent light pollution research has shown that relying on CCT values alone isn't the best way to reduce sky glow. A study by Hung et al. with the National Park Service (NPS)[1] found that 3000K zero-uplight luminaires increased sky glow significantly compared to legacy high-pressure sodium (HPS) luminaires. In 2023, a paper by Esposito and Radetsky[2] found that the Scotopic-to-Photopic (S/P) ratio was the strongest predictor of a luminaire's likely spectral impact on relative sky glow.

This insight became a catalyst for our collaboration. As a lighting scientist (Leora Radetsky) and a master electrician and dark-sky advocate (Scott Lind), we've pooled expertise to address how technical specification, installation, and ecological awareness can converge in effective outdoor lighting strategies. At LightFair 2025, we co-presented a session, The Hidden Cost of Light: Specifying controllable low CCT and amber outdoor lighting to combat light pollution, and shared specification language, case studies, and DesignLights Consortium (DLC) resources to help lighting practitioners implement lighting that respects both human and environmental needs.

Outdoor Illumination Discourse

As further study and real-world experiences continue to inform best practices related to outdoor illumination, we offer our thoughts on some pertinent issues.

> Manufacturers who prioritize developing low-output luminaires and extend their low-CCT choices might be able to stand out in a crowded marketplace



Photos: Scott Lind.

Color chart illuminated by a) HPS, b) 1800K LED, c) 2200K LED, and d) 2700K LED luminaires. Individual color panels were visually distinct and identifiable under all LED spectra.

Lind: After reading the NPS study, I contacted Leora at the DLC to learn more about research she had done with Tony Esposito of Lighting Research Solutions. That connection led me to reassess my entire approach to exterior lighting. I became particularly interested in the DLC's LUNA program and the rigorous performance validation it provides for night-sky-friendly products. Understanding that S/P ratio offers a better proxy for sky glow than CCT was a turning point.

One year later, I've overseen retrofits in multiple communities, replacing HPS and 5000K wall- and pole-mounted luminaires with selectable low-CCT luminaires set to 1800K. These installations span a range of public building types and incorporate onboard dimmers to align output levels with ANSI/IES RP-43-22 recommendations. Limiting the controls to photosensors—without motion sensors or scheduled dimming—has nonetheless reduced the predicted energy use and sky glow by roughly 80%.

Radetsky: Lighting practitioners familiar with the DLC usually associate it with rebates tied to increasing product efficacies. While energy efficiency is of critical importance to our mission and our efficiency program members, it's also balanced with comprehensive

lighting quality, dimming, and controllability requirements. This is especially true for outdoor lighting, where early generation, high-CCT LED installations often exacerbated sky glow due to their spectral power distributions. Light pollution is an increasing problem globally, affecting humans and other organisms across all habitats. As first- and second-generation LED installations are nearing the end of their product life, we can make better decisions with LED-to-LED replacements.

Lind: My motivation stems from a desire to protect wildlife from the disruptive negative impacts of anthropogenic light at night. That's why I've volunteered to relight buildings at cost, often with pro bono labor. The luminaires I specify are lumen- and CCT-selectable (1800–2700K), reducing risk if end-users initially dislike the goldish hue. So far, providing an option to increase CCT has proven unnecessary. Client feedback has been universally positive, even among those initially uninterested in sky-glow reduction. These clients were thrilled with the energy savings enabled by this lighting. It became clear to me that, just as customers accepted high CCTs by default during the initial LED transition, they may be equally amenable to low CCTs when they're presented as standard. No one has yet asked to raise the luminaire settings above 1800K, and actively asking my customers about the low CCT has only elicited positive feedback.

Radetsky: This shift is also reflected in product availability. In 2024, DLC-Listed outdoor luminaires with CCTs of 3000K or lower accounted for 37% of our Qualified Products List, surpassing the 28% share held by products with CCTs of 5000K or higher.

Our forthcoming SSL V6.0 and LUNA V2.0 technical requirements for product qualification introduce specifications for low CCT (1800K and 2000K) and

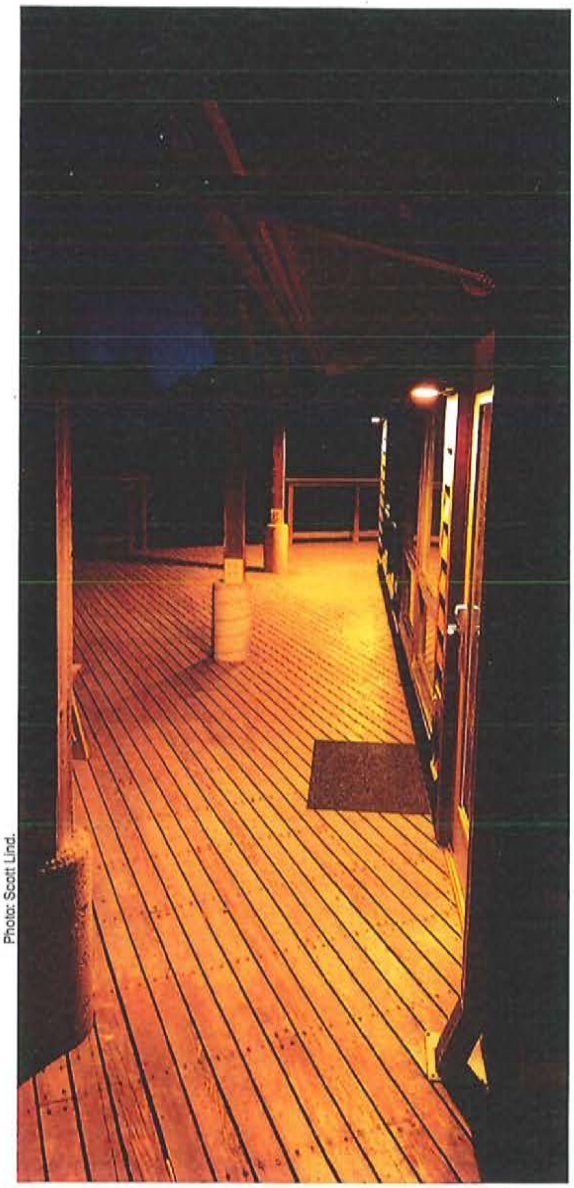


Photo: Scott Lind.

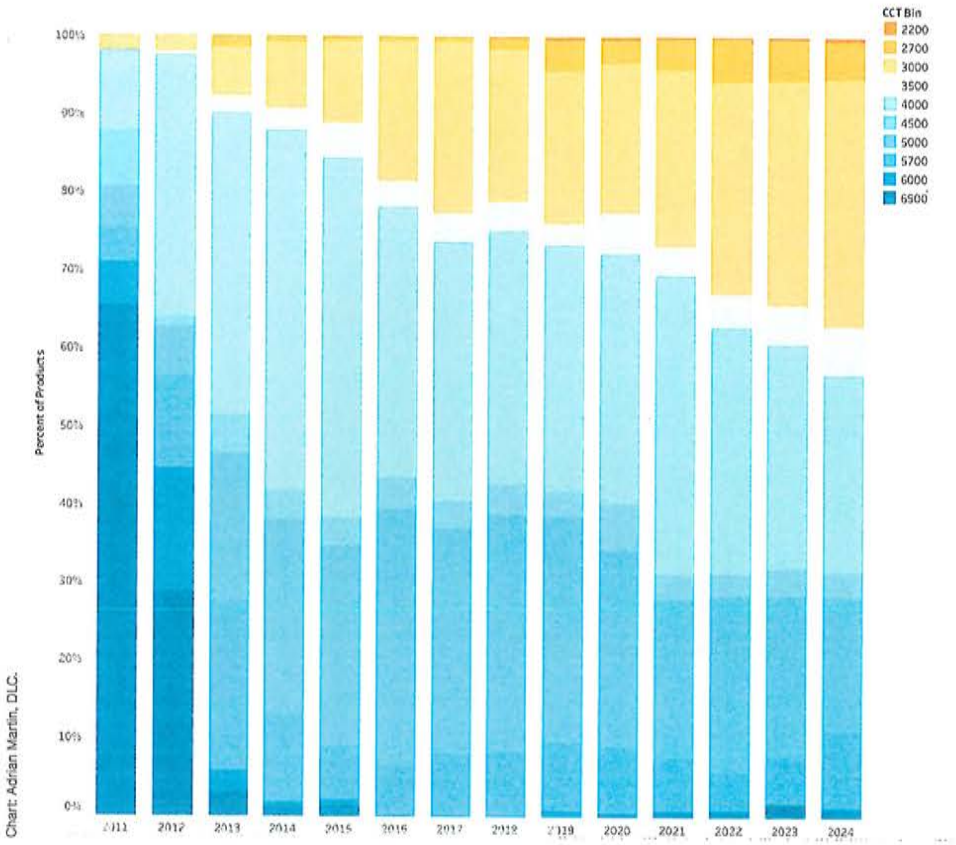
A cedar deck and structure at Kickapoo Valley Reserve Visitor Center in La Farge, WI, illuminated with nominal 1800K, U-0 wall packs dimmed to approximately 300 lumens.

amber LED products, balancing luminaire efficacy, lighting quality, and light pollution mitigation requirements. Direct emission (de-amber, i.e., narrowband amber) and phosphor-converted amber (pc-amber) LEDs are less efficacious than phosphor-converted white LEDs, with median luminaire efficacies of 30 and 70 lm/W, respectively. Tradeoffs with color rendition and lumen maintenance are also typical but, we believe, justified in ecologically sensitive areas. Meanwhile, LED chip manufacturers are developing innovative 1800K to 2000K phosphor-converted LED products that significantly reduce short-wavelength emissions. While some of these chips are quite efficacious (with reported luminaire efficacies of 130 lm/W), there are tradeoffs in lighting quality. To support product diversity, we've proposed significant efficacy allowances for DLC listing of low-CCT products.

Comprehensive performance requirements for low-CCT and amber LED lighting equipment also enable informed decision making, especially in areas with sensitive ecological needs. For the past three years, the DLC has supported light-pollution mitigation efforts in Oahu, HI. Seabird fledglings nesting on nearby islands and islets are attracted to and disoriented by coastal lighting, resulting in fallout, injury, and mortality. Sea turtles are also nesting more frequently on Oahu beaches and both hatchlings and adults are attracted inland toward electric lighting instead of toward the surf. A lack of understanding concerning ecological needs has sometimes resulted in inadequate retrofits that often focus on spectrum alone without considering distribution changes. Concurrently, a lack of lighting knowledge among ecological stakeholders has sometimes resulted in poorly informed retrofits that often focus on using direct-emission amber LED luminaires unnecessarily, without regard to distribution requirements or understanding how much energy these products use. LUNA V2.0 seeks to help markets like these by incorporating a broader range of metrics, including those required by the Hawaii and Maui County codes. We are also creating new turtle lighting product categories, to enable stakeholders to make informed, multifactorial choices.

Lind: Convincing others isn't always easy. Many electricians favor 4000K or 5000K products, dismissing 3000K products out of hand. However, in-person mock-ups of the 1800K and 2200K luminaires often changed their minds. One contractor is replacing an outdoor 4000K wall-mounted luminaire at his own facility after participating in an 1800K retrofit project. The luminaires I have been installing also have a 2200K setpoint, which yields good color rendition at reasonably high efficacies (about 124 lm/W). Moreover, the modeled relative sky glow from the specified vendor is about 75% higher at 4000K versus 2200K and nearly 200% higher at 4000K compared to an 1800K luminaire. For me, 2200K is an optimal CCT for outdoor parking lot and roadway lighting, and I am eager to share these impacts with others so they can make informed choices. Some of my electrical engineering and lighting design colleagues are beginning to consider using 2200K for area lighting and building-mounted secondary exits and 2700K for main building entrances.

Additionally, too often, LED retrofits don't give serious consideration to how much light is needed for specific applications, resulting in light levels that exceed IES recommendations.



A tableau stacked-column chart illustrating relative changes in DLC-Listed outdoor luminaires by year and nominal CCT. DLC-Listed outdoor luminaires with low CCTs (≤ 3000K) have become increasingly common, while those with higher CCTs (≥ 5000K) have declined in prevalence.

Lumen inflation is also a concern, where newer models often offer equivalent wattage instead of lumen output. This trend contributes to overlighting instead of reduced energy use. Lastly, while 1800K LED luminaires may not be as efficacious as higher CCT luminaires, the additional energy used by the luminaire is small when the light output is tuned for the application and when you consider the positive environmental impact. Even 1800K luminaires can save a lot of energy and money when applied with due diligence. And advanced controls strategies will further reduce energy use and light pollution.

Radetsky: Manufacturers who prioritize developing low-output luminaires and extend their low-CCT choices might be able to stand out in a crowded marketplace. Field adjustability in both light output and spectrum (CCT) can help right-size installations and support energy conservation goals. Clear information about controls and sensors also enables further energy savings and can help mitigate overlighting.

Finally, SPDX data and comprehensive reporting provide invaluable insights into the tradeoffs between spectrum, efficacy, and light-pollution mitigation. This is especially important for amber LEDs and low-CCT products, where design decisions often hinge on site-specific ecological or community requirements.

Room for Improvement

In closing, while the community preferences and regulatory landscape around outdoor lighting continues to evolve, so too does the opportunity to improve both performance and environmental stewardship. From luminaire specification to field application, aligning performance with the needs of local wildlife and environments is no longer an ideal, it's an essential best practice.

For more information about these topics, Scott and I reprised our LightFair presentation in a September webinar, which is available to view on the DLC website (*https://designlights.org/news-events/on-demand-past-events/*).

Leora Radetsky is the senior lighting scientist and LUNA program director at the DesignLights Consortium.

Scott Lind is a master electrician and consulting electrical engineer with Mead & Hunt, where he focuses on designing sustainable and reliable electrical systems for commercial, industrial, and public facilities.

References

1 Li-Wei Hung et al., "Changes in night sky brightness after a countywide LED retrofit," *Journal of Environmental Management*, vol. 292, Aug. 15, 2021.

2 Tony Esposito and Leora Radetsky, "Specifying Non-White Light Sources in Outdoor Applications to Reduce Light Pollution," *LEUKOS*, vol. 19, no. 3, Jan. 2023.