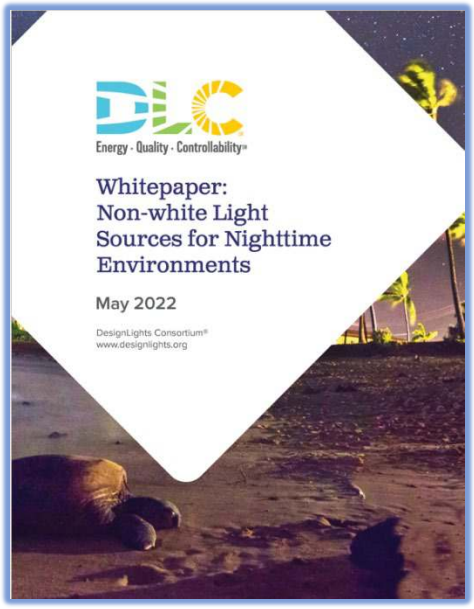

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Whitepaper: Non-White Light Sources for Nighttime Environments

Executive Summary

Background

The DesignLights Consortium (DLC) recently introduced the first version of its LUNA Technical Requirements. The policy offers a streamlined way to identify and select LED products that meet the efficacy thresholds necessary for inclusion on the DLC's Solid-State Lighting (SSL) Qualified Products List (QPL) while also limiting sky glow and light trespass and helping to mitigate light pollution. LUNA sets performance requirements for specific categories of outdoor LED fixtures so that municipalities, energy efficiency programs, and other outdoor lighting decision-makers can better support their energy reduction goals and abide by dark sky policies and ordinances. LUNA will also help specifiers to fulfill the light pollution and trespass requirements of LEED and WELL building programs, and help projects follow application guidance in the joint International Dark Sky Association-Illuminating Engineering Society Model Lighting Ordinance.

A subset of the DLC's SSL Technical Requirements, the LUNA V1.0 Technical Requirements apply only to white light LED outdoor products with correlated color temperatures (CCT) between 2200K and 3000K, and do not include non-white light (NWL) LED luminaires deemed appropriate for settings such as environmentally sensitive wildlife areas. During development and implementation of the first iteration of LUNA V1.0, stakeholders asked the DLC to consider allowing NWL LED sources, such as phosphor-converted- (pc-) amber and direct emission (de-) amber products, to be eligible for LUNA qualification.

This whitepaper provides an overview of the state of the science and current recommendations for NWL light sources in outdoor lighting applications, as well as why the DLC is not addressing NWL LED luminaires in LUNA at this time. The paper suggests next steps to address gaps in existing research, standards, and guidelines that would make qualification feasible in the future.

Environmental impacts of white light vs. NWL products

Outdoor LED lighting offers a range of benefits over incumbent technologies (such as high-pressure sodium (HPS) and low-pressure sodium (LPS) fixtures), including higher efficacies and improved optical and temporal control. The increased amount of short wavelength (violet-blue) radiation in these LED spectral power distributions (SPD), however, has been linked to several deleterious impacts, particularly if applications use high CCT products and/or areas are excessively lit. The known negative impacts from light at night, at meaningful doses and times, can include:

- Disruption in the circadian systems of animals and plants;

- Disorientation of wildlife such as sea turtles and migrating birds (the latter suffering significant mortality from collisions with illuminated buildings);
- Harm to both diurnal and nocturnal insects; and
- Increases in pathogenic risks.

Against this backdrop, NWL sources that eliminate short wavelength radiation have surfaced as a potential strategy to limit light pollution and other negative effects of anthropogenic/artificial light at night (ALAN). While HPS and LPS lamps have been common for outdoor lighting historically, two types of "amber" outdoor LED fixtures - phosphor-converted amber (pc-Amber) and direct emission amber (de-Amber) - are becoming readily available, and a third market category of "amber" LED chips with better color rendition (pc-LEDs) is emerging.

Lack of standardization

As researchers and stakeholders seek to describe the capabilities and features of these products, however, lack of standardization in metrics and measures is glaringly apparent.

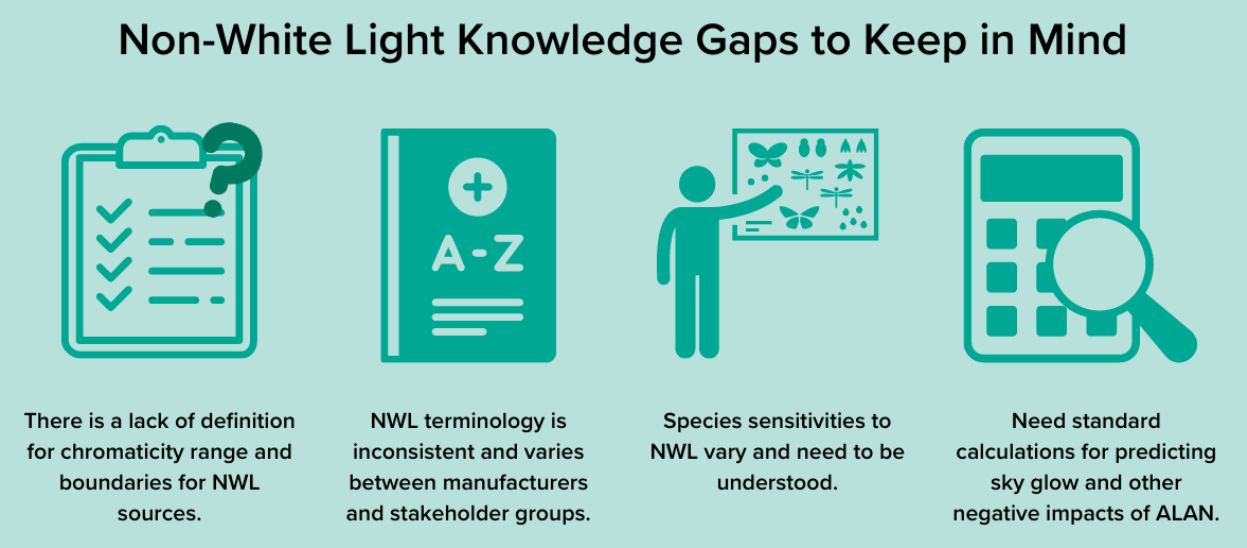

Figure 1: Non-white light knowledge gaps to keep in mind.

Findings

With regards to efficacy performance, the DLC found that:

- Very few pc-Amber products could meet DLC's threshold efficacy requirements.
- No de-Amber products could meet the DLC's threshold efficacy requirements.

With regards to spectral reductions in relative sky glow, the DLC found that:

- LPS and de-Amber sources, as well as evaluated pc-Amber sources, all produced lower relative sky glow than HPS.
- Pc-LED products had better color rendition than other NWL sources, but increased relative sky glow.
- The scotopic/photopic (S/P) ratio was the strongest predictor of relative sky glow.

- Relative sky glow is not predicted by color fidelity metrics such as CRI R_a or TM-30 R_f.
- There are spectral tradeoffs for each type of NWL product evaluated, and specifiers will have to find a balance between reducing relative sky glow and having good color rendition. No NWL light source outperformed all of the others in every aspect.

In addition to a need for standardization of NWL nomenclature, the whitepaper identifies several research tasks that the DLC must undertake before inclusion of NWL LEDs can be considered. Importantly, these include:

- Evaluation of more data from de-Amber LEDs products, particularly regarding susceptibility of lumen output and lumen and color maintenance to temperature fluctuations.
- Evaluation and development of appropriate luminaire efficacy, color rendition, and color maintenance thresholds for pc-Amber and pc-LEDs.

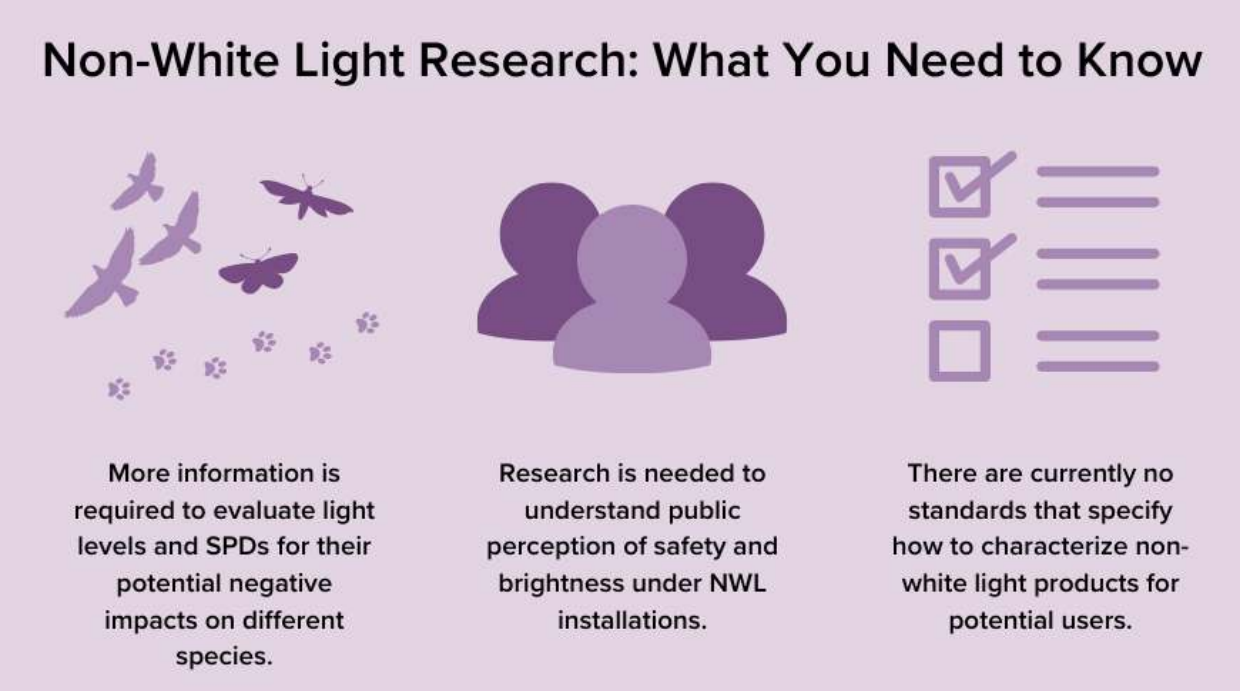

Figure 2: What you need to know about the state of non-white light research.

Calls to action

The lighting industry needs an integrated approach to solving the unintended negative consequences of light pollution on the natural environment. This whitepaper seeks to describe the landscape for a small but promising part of the solution: NWL LED light sources. Since the DLC uses standards to ensure that LED luminaires qualified under DLC technical requirements can be reliably and consistently measured and evaluated worldwide, existing lighting standards must be updated to include NWL sources so that the DLC and other stakeholders can evaluate these products using a consistent framework. To address these types of products in the future, necessary developments include:

- Standardized chromaticity boundaries for NWL products, including “amber,” “red-orange,” “red,” etc.;

- Standardized terminology and naming conventions;
- Standardized nomenclature that encompasses the totality of optical radiation to which non-human taxa are sensitive;
- Guidance on color rendition thresholds for NWL sources;
- Standardized reporting requirements for light source spectral power distribution; and
- Standardized calculation procedures for computing astronomical sky glow and other negative impacts of ALAN.

As efforts get underway to develop uniform standards for NWL LED products aimed at mitigating the negative impacts of ALAN, the DLC looks forward to continued engagement with stakeholders across the industry.