Draft policy for stakeholder comment

Solid-State Lighting (SSL) Technical Requirements
Version 5.0

Draft 1: Conceptual Specification

Released for Comment: January 29, 2019

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Introduction

Since 2008, the DesignLights Consortium® (DLC) has established minimum quality and efficiency specifications for high-performance LED lighting. In partnership with utilities, manufacturers, and lighting stakeholders across North America, the DLC has raised the bar for quality and efficacy of LED lighting products, accelerating LED lighting adoption and helping to ensure the benefits of the technology are realized. The DLC's core mission is to drive efficient lighting by addressing quality, and this continues to be a central aspect of the DLC's proposals for updated Technical Requirements.

The Version 5.0 revision to the SSL Technical Requirements will continue to expand the value proposition and benefits of LED lighting by improving the quality of light and controllability of products on the SSL Qualified Products List (QPL). The DLC has proposed new quality of light requirements for color, glare, distribution, and flicker along with requirements for lighting control aspects of dimming compatibility and integral controls.

Quality of light encompasses the characteristics of lighting that impact productivity, performance, comfort, mood, safety, health, and wellbeing. New proposed lighting control requirements will support additional energy savings while advancing quality of light benefits through the control of lighting. This comprehensive approach will help ensure high-quality products are listed by the DLC, superior performing products can be differentiated, and additional energy savings can be realized.

***Figure 1**: SSL Version 5.0 Objective, Focus Areas, and Desired Outcomes*

Objective	Accelerate broad-scale **energy savings** by improving the **quality of light** and **controllability** of DLC listed products.
Focus	Increase efficacy requirements with an emphasis on: • Quality of light • Controllability • Policy and process improvements
Desired Outcomes	☑ High-performing products are listed on the SSL QPL ☑ The quality of light of listed products is well-understood and products with superior performance can be differentiated ☑ Lighting controls are more easily promoted and specified ☑ The efficacy of listed products is increased at the pace of technology without sacrificing quality of light ☑ The SSL QPL is more effective and easy to use for more users

High Level Objectives

A cornerstone objective of the V5.0 revision is to provide greater understanding of the quality of light and controllability performance of DLC listed products. New metrics and information on glare, color quality, and flicker are proposed along with new information on lighting control capabilities. This new information will provide more options for QPL users, enable differentiation of higher-quality products, and lead to new opportunities for lighting decision-makers to choose products appropriate to their needs. With this additional information on quality, the DLC will continue to drive adoption of high quality and controlled lighting, leading to better lighting environments for people and greater energy savings.

Figure 2: *Version 5.0 Outcomes by Audience*

Conceptual Level Specification

This first draft of the V5.0 requirements is issued as a conceptual level specification. It does not contain the detailed specification language and requirements that will appear in the final version. Implementation questions, such as when and how existing products will need to be updated to meet the new requirements, have not been determined or included in this draft. The DLC is seeking input at the conceptual stage from all stakeholders before developing the detailed specification and implementation requirements, which will be available in the next draft and released for a second round of comment.

When reviewing this draft, reviewers should note that each topic area includes a **Key Questions** section where the DLC identifies areas of desired feedback. The **V5.0 Comment Form**, provided with this draft, is pre-populated with these questions. The DLC requests that reviewers communicate their feedback on these specific questions and any additional topic areas of the V5.0 draft using the comment form provided. The DLC is looking to identify any major questions and complicating issues with this draft and ideas stakeholders have for solutions to address them. Comments from this first draft will be discussed in depth at the upcoming DLC Stakeholder Meeting April 1-3 in St. Louis, Missouri. Interested stakeholders should register for this event as soon as possible.

The DLC expects two or more iterations of stakeholder review as the specification develops from this conceptual level to a final version that will be used to qualify products.

Research Summary

In developing this V5.0 draft, the DLC conducted over one hundred interviews with topic experts and stakeholders, including manufacturers, designers, specifiers, researchers, utilities, and others. Online surveys for each topic (glare, distribution, color quality, flicker, controllability, and circadian wellness) were also distributed to large numbers of DLC stakeholders with several hundred responding. With each topic, the DLC sought answers to key questions:

- Is it useful and valuable for the DLC to address the topic? What are the potential benefits? Are there unintended consequences of the DLC addressing a topic?
- What is the current state of science and metrics for each topic? What are the potential benefits and shortcomings of any metrics? What has been the experience of using these metrics?
- How are metrics determined, tested, and reported? Is it feasible and appropriate for the DLC to include these metrics in its policies and QPL?

The requirements and metrics in this V5.0 draft are informed by the findings of this research and outreach. It should be noted that several of the topics addressed in this draft, including glare, distribution, flicker, color quality, and circadian wellness, continue to be researched. Existing metrics for these topics may have known shortcomings and in some cases the industry may not have settled on which metrics to use or on appropriate performance criteria.

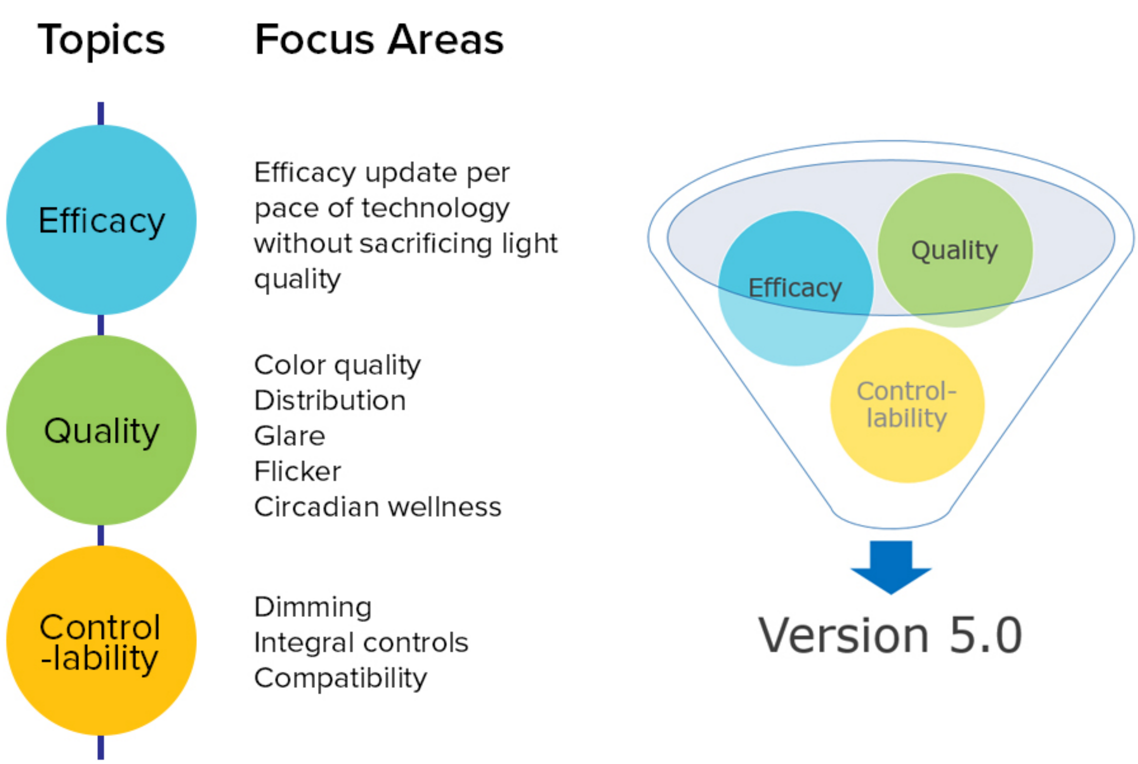
The DLC has carefully considered the feedback of experts in developing this draft. Each topic has been evaluated for the value, benefits, shortcomings, and state of the science and industry in what is proposed. Additional discussion of these issues and rationale is provided with each topic in this draft.

Specification Focus Areas

The DLC takes a holistic view of lighting product performance beyond efficacy. The DLC criteria for qualification have always included requirements for quality of light (light output, CRI, CCT, chromaticity, zonal lumen distribution), reliability (warranty, luminous flux maintenance, driver testing), and safety (third party safety certification). Version 5.0 builds on this comprehensive approach to incorporate new aspects of quality and performance.

The V5.0 revision focuses on three specific areas: efficacy, quality, and controllability. This V5.0 draft considers the trade-offs between and among efficacy, quality, cost, safety, and human-affecting factors of lighting. The DLC recognizes that quality must go hand-in-hand with efficacy if long-term energy savings are to be realized. The DLC also recognizes the risk of products that push efficacy at the expense of quality factors, which can leave customers unsatisfied and/or negatively impact human health or wellbeing. Incorporating quality aspects ensures that the market is not driven toward poor performing products, while at the same time saving energy through highly efficacious and controllable products.

Figure 3: *Version 5.0 is a comprehensive approach to the future of the SSL QPL*



Policy and Process Improvements

The DLC solid-state lighting product qualification program has driven change in the commercial lighting industry for both product design and LED performance, and has provided a basis for incentivizing the installation of energy saving products for more than ten years. During this period, the program has grown to include many new categories and product types, and as products have evolved, the policies have been updated to allow flexibility for qualification.

As the DLC looks to increase the impact of the program and drive better quality of light with policy additions and enhancements in Version 5.0, the SSL product qualification program will be streamlined where possible. The DLC is actively working to improve the submitter experience. This includes reducing application processing time, streamlining the program and policy documentation, and increasing manufacturer support resources, where appropriate.

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Draft Technical Requirements: Efficacy

SSL V5.0 Efficacy Update

Rationale

For SSL Technical Requirements V5.0, the DLC is proposing a smaller efficacy increase for most product categories relative to prior revisions. This is due to two primary factors: first, while LED package-level efficacy continues to improve, these improvements are occurring at a slower pace than in the past. Efficacy improvements of LED devices are expected to be more incremental going forward, barring major breakthroughs in technology.

Second, the DLC conducted extensive analysis and research to understand the relationship between efficacy, product cost, and quality of light. This research and analysis found that a large increase in efficacy requirements may have the unintended consequence of driving the market towards products that are higher cost and/or have higher glare and poor light distribution, both of which can slow the technology adoption and associated energy savings.

Table 1: *Average efficacy increases of previous revisions of the Standard SSL Technical Requirements*

Year	SSL Version	Average Efficacy Increase
2011	1.6	25%
2013	2.0	17%
2015	3.0	n/a
2016	4.0	27%
2019	5.0	9.6% (proposed)

It is important to understand that while higher efficacy levels will certainly lead to additional energy savings, the rate at which new savings are captured has decreased due to a maturing technology. In other words, as wattage decreases there are diminishing returns from gains in energy efficiency. While LEDs remain highly efficacious, the benefits realized from an increase in efficacy are less now than in the past, which was considered in developing these requirements. The DLC chose to focus on the additional energy savings and benefits that can be achieved by optimizing the quality of light and controllability performance of lighting.

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Draft Testing and Reporting Requirements

The SSL V5.0 proposal includes efficacy changes for Standard products as shown in **Table 2** and takes into account research, analysis, and outreach conducted by the DLC. At this time, the DLC has not proposed efficacy levels for DLC Premium. These recommendations represent a DLC Standard classified product-weighted average increase to efficacy of 9.6%.

Table 2: *Current and draft V5.0 efficacy levels for Standard products, by General Application*

General Application	Current V4.4 Requirements	V5.0 Draft Requirements	Rationale
Troffers	100 lm/W	105 lm/W	**≈ 5% efficacy increase**. Troffers and linear ambient products are very sensitive to changes in efficacy, based on DLC research and outreach. These categories would also suffer the biggest negative consequences from any tradeoffs in quality, particularly glare and CRI. As such, stakeholders indicated that efficacy requirements for indoor categories are among the most difficult to meet/exceed while also balancing quality of light and cost. Diminishing returns in efficiency have lessened the potential impact within these categories in particular. Finally, these categories are the most likely to include networked lighting controls, which can capture additional savings. These proposed levels will trail behind the DOE projection[1] (123 lm/W by 2020).
Linear Ambient	105 lm/W	110 lm/W	
Outdoor – Low Output	90 lm/W	100 lm/W	**≈ 10% efficacy increase**. DLC analysis indicates moderate room for improvement in the outdoor categories, and utility analysis showed similar or slightly less impact for these products market-wide than the QPL in terms of products delisted due to increasing requirements. Outdoor products may have a greater cost sensitivity to changes in efficacy, so a significant efficacy increase is not proposed. CRI is less of a concern for outdoor luminaires, however glare tradeoff could be a consequence should the efficacy levels increase considerably. These proposed levels for outdoor luminaires align with the DOE projections (105-115 lm/W by 2020).
Outdoor – Mid Output	95 lm/W	105 lm/W	
Outdoor – High Output	100 lm/W	110 lm/W	
Outdoor – Very High Output	100 lm/W	110 lm/W	

[1] Energy Savings Forecast of Solid-State Lighting in General Illumination Applications, DOE efficacy projection can be found in table D-4: https://www.energy.gov/sites/prod/files/2016/09/f33/energysavingsforecast16_2.pdf

General Application	Current V4.4 Requirements	V5.0 Draft Requirements	Rationale
Linear Replacement Lamps and 2G11 Lamps	110 lm/W (bare lamp)	120 lm/W (bare lamp)	**≈ 10% efficacy increase**. Lamp categories have a lower opportunity for efficacy increase and are reasonably sensitive in terms of delisting products, based on QPL analysis. A linear replacement bare lamp requirement 10 points higher than linear ambient (15 points higher than troffer) is reasonably consistent with the current approach. Glare tradeoff is less of a concern for these products since they typically rely on optics of the fixture they are eventually installed in. The proposed linear replacement lamp requirement would trail behind the DOE projection (137 lm/W by 2020). The proposed four-pin CFL replacement lamp requirement would be aligned with the DOE projection for a downlight retrofit lamp (81 lm/W by 2020).
Four-Pin CFL Replacement Lamps	75 lm/W (bare lamp)	85 lm/W (bare lamp)	
Mogul Screw-Base (E39) Replacements for HID Lamps	90 – 120 lm/W (In-luminaire)	In-luminaire efficacy requirements for mogul-based LED lamps will align with the General Application for which they are submitted (Outdoor Low, Mid, High, or Very High Output; or Indoor High-Bay)	
High Bay	105 lm/W	120 lm/W	**Considerable ≈ 15% efficacy increase**. Based on DLC analyses, the High Bay product category has a large share of products that overperform the current efficacy requirement by a wide margin. The incremental savings potential for high bay products is more significant given the typical longer operation hours and high lumen output. The requirement aligns with the DOE projection (121 lm/W by 2020).
Case Lighting	80 lm/W	95 lm/W	**High ≈ 20% efficacy increase**. Based on the distribution of qualified products, the current minimum efficacy requirements lag actual performance by a wide margin for case lighting and interior directional products. These categories will also experience very little impact from a dimming requirement since case lighting is recommended to be exempt and interior directional has the highest

General Application	Current V4.4 Requirements	V5.0 Draft Requirements	Rationale
Interior Directional	65 lm/W	80 lm/W	rate of dimming (87%) out of all product categories. Increasing interior directional to 80 lm/W brings the category roughly in line with what would be expected from a screw-base directional LED product (the ENERGY STAR specification for directional LED products is 70 lm/W, which was established in 2016). There is no DOE projection for case lighting. The DOE projection for an interior directional fixture (LED track) is 101 lm/W by 2020.

Note: Efficacy requirements for retrofits will align with the related luminaire General Applications.

Key Questions: Efficacy

1. Are the proposed efficacy increases reasonable, either generally speaking and/or specifically within a General Application?
2. The DLC is interested in further understanding the cost implication of the proposed efficacy increases. Can you provide any specific information or data as to how the cost of a product may or may not increase with the proposed efficacy levels?
3. The DLC performed analysis on trade-offs and interactions between efficacy and CRI and CCT to inform the levels proposed in this draft. However, the DLC did not have a dataset or metrics to analyze the tradeoffs between efficacy and glare or optical control. Can you provide any specific information or data on the trade-offs between glare and optical control and the proposed efficacy levels?

Please provide your responses to these key questions in the Excel-based SSL V5.0 Comment Form, under the Efficacy tab.

Draft Technical Requirements: Quality of Light

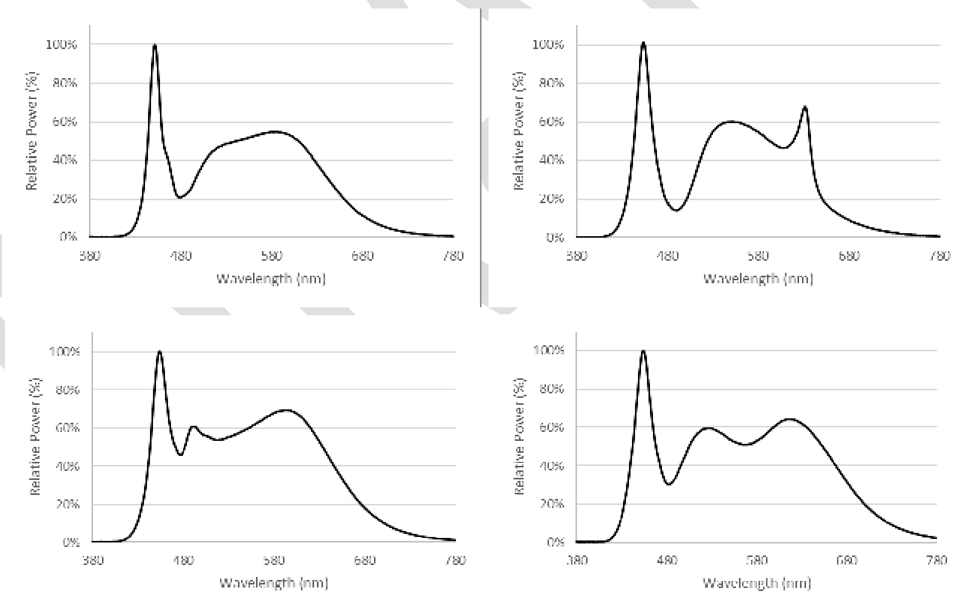
Spectral Quality

In this policy, Spectral quality describes the properties of a lighting product that result from the spectral power distribution (SPD; see examples in **Figure 4**) of the light emitted by the product. With the Spectral quality requirements, the DLC acknowledges and addresses the overall relevance of light source SPD as the basis for the calculation of many current (and future) metrics around color quality and visual comfort, as well as health and safety.

Solid-state lighting technology enabled customization and optimization of light source SPDs according to different criteria. Therefore, this section below is divided in two parts:

1. Color of Light and Color Rendering of Objects
2. Support for Alertness, Sleep, and Circadian Wellbeing

***Figure 4**: SPD examples of four different LED lighting products at a CCT of 5000 K*



Color of Light and Color Rendering of Objects

Rationale

Color quality, as defined in this document, relates to two crucial performance categories:

a) *The color of the light emitted by the product (Chromaticity)*
b) *The color of the objects illuminated by the light (Color Rendering)*

Assuring adequate lighting quality for the above aspects is important for:

- Task performance (color discrimination, visual performance) in many areas, such as workplace, retail, and healthcare
- Mood and wellbeing (ambiance, comfort, experience of the environment)

Luminaires that exhibit inferior color quality can have a range of negative impacts on occupants, from creating uncomfortable spaces to causing errors in judgements related to color discrimination. These impacts can impair productivity, and are annoying at best and dangerous at worst. Color quality standards for lighting are well developed and recent updates are well documented in the industry. The DLC's outreach indicated the need to update color quality considerations in the DLC's policy requirements to align with the state of the industry, maintain acceptable color quality in all products on the QPL, and enable differentiation of products with superior color quality.

Therefore, the Color of Light and Color Rendering draft policies contained herein introduce two tiers of requirements that will be used to distinguish between products that meet either a minimum acceptable level of performance (Tier 2), or a more rigorous level of performance aligning with the higher end of commercially available products (Tier 1). The intent of Tier 2 is to ensure that baseline color quality needs are met by all products on the QPL, while Tier 1 will enable differentiation of products that provide higher color quality for applications and projects that require it. In general, Tier 1 intends to align with requirements set forth by the International WELL Building Institute™ (IWBI™) in the WELL v2 rating system[2].

Definitions

Unless otherwise noted, the terms in this policy directly reference the definitions from the Illuminating Engineering Society (IES) *ANSI/IES RP-16-17: Nomenclature and Definitions for Illuminating Engineering*[3], and, where applicable, the International Commission on Illumination (CIE) *CIE S 017/E:2011 ILV: International Lighting Vocabulary*[4], with key deviations noted below. Explanations below reference the DLC's understanding of definitions as used by the industry. In some instances, the term "color" is used, where the more accurate term may be chromaticity of the light emitted by the product.

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[2] The lighting requirements of the WELL v2 rating system can be seen on their website: https://v2.wellcertified.com/v2.1/en/light
[3] ANSI/IES RP-16-17 Nomenclature and Definitions for Illuminating Engineering
[4] CIE S 017/E:2011 ILV International Lighting Vocabulary

- **Spectral Power Distribution (SPD)[5]:** Describes the power emanating from a light source as a function of wavelength. The information can be presented graphically or as a numerical table.
- **Color Rendering (of Objects):** Effect of an illuminant on the color appearance of objects by conscious or subconscious comparison with their color appearance under a reference illuminant
- **Color of Light**
    - **Chromaticity:** The aspects specified by the chromaticity coordinates of the color. It describes the color of the emitted light, independent of its intensity[5].
    - **D_{uv}[5]:** A signed measure of the distance from the blackbody locus in the CIE 1960 (u, v) color space. A positive D_{uv} indicates that the chromaticity of the light is above the blackbody locus (on the green side). A negative D_{uv} means the chromaticity is below the blackbody the blackbody locus (on the blue/pink/purple side).
    - **Correlated Color Temperature (CCT):** The thermodynamic temperature of a blackbody whose chromaticity most nearly resembles that of the light source. Expressed in kelvin (K).
    - **Color Consistency:** The initial product-to-product variation in chromaticity.
    - **Color Maintenance:** A product's ability to maintain a specific chromaticity over time. This is the spectral corollary to luminous flux maintenance, which describes depreciation in luminous flux over time.
    - **Angular Color Uniformity:** The variance in chromaticity throughout the intended light distribution, such as the beam angle, the angle where light intensity is 50% of the maximum intensity.

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[5] IES DG 1-16 Design Guide for Color and Illumination

Draft Testing and Reporting Requirements

The draft DLC Color Quality Technical Requirements for all SSL products are as shown in **Table 3** - Draft Testing and Reporting Requirements for Color Quality. Some explanation regarding each metric and/or reporting requirements follow below the table.

***Table 3**: Draft Testing and Reporting Requirements for Color Quality*

Metric or/and Data Set	Current V4.4 Requirements		V5.0 Draft Requirements*		Method of Measurement/ Evaluation
	Standard	Premium	Tier 2	Tier 1	
Chromaticity (CCT & D_{uv})	Unit under test shall exhibit chromaticity consistent with at least one of the basic, nominal, 7-step quadrangle CCTs ≤ 5000 K (indoor) and CCT ≤ 5700 K (outdoor & high bay) as defined by ANSI C78.377-2015[6] *Efficacy allowance of -3% for 2700 K < CCT ≤ 3000 K, and -5% for CCT ≤ 2700 K is allowed.*		Reporting of CCT and D_{uv}. Unit under test shall exhibit chromaticity consistent with at least one of the basic or extended nominal, 7-step quadrangle CCTs from 2200 K – 6500 K as defined by ANSI C78.377-2017[7]. *Efficacy allowances to align with V4.4.*	Reporting of CCT and D_{uv}. Unit under test shall exhibit chromaticity consistent with at least one of the basic or extended nominal, 4-step-quadrangle CCTs from 2200 K – 6500 K as defined by ANSI C78.377-2017. *Efficacy allowances TBD.*	IES LM-79-08[8] (Integrating Sphere / Spectroradiometer testing) ANSI C78.377-2017
Consistency (of Chromaticity)	No V4.4 Requirement		Chromaticity for 3 different units under test shall fall within the 7-step nominal CCT quadrangle, and within a circle with diameter of 0.006 on the CIE 1976 (*u*', *v*') chromaticity diagram.	Chromaticity for 3 different units under test shall fall within the 4-step nominal CCT quadrangle, and within a circle with diameter of 0.003 on the CIE 1976 (*u*', *v*') chromaticity diagram.	IES LM-79-08 (Integrating Sphere / Spectroradiometer testing) ANSI C78.377-2017

[6] ANSI C78.377-2015 (outdated)
[7] ANSI C78.377-2017
[8] IES LM-79-08: Electrical and Photometric Measurements of Solid-State Lighting Products, an update to IES LM-79 has yet to be published but is expected and will replace the 2008 version.

Color Rendering **	CRI (CIE 13.3-1995[9]): $R_a \geq 80$ (indoor) $R_a \geq 65$ (outdoor) $R_a \geq 70$ (high bay) *Efficacy allowances of -5% for CRI $R_a \geq 90$ (with requirement to report TM-30 test results).*	Products must be capable of meeting one of the following criteria, and must provide full report for both: ANSI/IES TM-30-18[10]: • IES $R_f \geq 70$ • IES $R_g \geq 89$ • $-12\% \leq$ IES $R_{cs,h1} \leq +23\%$ CIE 13.3-1995: • $R_a \geq 80$ and $R_9 \geq 0$	Products must be capable of meeting one of the following, criteria, and must provide full report for both: ANSI/IES TM-30-18: • IES $R_f \geq 78$ • IES $R_g \geq 95$ • $-1\% \leq$ IES $R_{cs,h1} \leq +15\%$ CIE 13.3-1995: • $R_a \geq 90$ and $R_9 \geq 50$ *Efficacy allowances TBD.*	IES LM-79-08 (ANSI/IES TM-30-18 Full Report and CIE 13.3-1995 complete Color Rendering Index Detail)
Spectral Power Distribution	No V4.4 Requirement	Required to report. Spectral range of 380 – 780 nm at 1 nm increments.		IES TM-27-14[11], and/or ANSI/IES TM-33-18[12]
Color Maintenance ***	No V4.4 Requirement	Chromaticity shift from 0-hour measurement to ≥6,000 hours shall be within a linear distance of 0.004 ($\Delta u'v' \leq 0.004$) on the CIE 1976 (u', v') chromaticity diagram.	Chromaticity shift from 0-hour measurement to ≥6,000 hours shall be within a linear distance of 0.002 ($\Delta u'v' \leq 0.002$) on the CIE 1976 (u', v') chromaticity diagram.	ANSI/IES LM-80-15[13], and/or IES LM-84-14[14]
Angular Color Uniformity	No V4.4 Requirement	*Optional to report*. Chromaticity variance throughout the beam and/or field angle; Vertical angular scanning resolution: 1° on the 0° and 90° vertical planes; $\Delta u'v'$ distance shall be reported for each vertical angle measured.	*Optional to report*. Chromaticity variance throughout the beam and/or field angle; Vertical angular scanning resolution: 1° on the 0° and 90° vertical planes; $\Delta u'v'$ distance shall be reported for each vertical angle measured.	LM-79-08 (Goniophotometer/ Spectroradiometer testing)

[9] CIE 13.3-1995: Method of Measuring and Specifying Colour Rendering Properties of Light Sources
[10] ANSI/IES TM-30-18: IES Method for Evaluating Light Source Color Rendition
[11] IES TM-27-14 IES Standard Format for the Electronic Transfer of Spectral Data
[12] ANSI/IES TM-33-18: Standard Format for the Electronic Transfer of Luminaire Optical Data
[13] ANSI/IES LM-80-15: Measuring Luminous Flux and Color Maintenance of LED Packages, Arrays, and Modules
[14] IES LM-84-14: Measuring Luminous Flux and Color Maintenance of LED Lamps, Light Engines, and Luminaires

*Tier 1 thresholds intend to be aligned with the WELL v2 color quality requirements.
**A TM-30-18 Full Report and a complete Color Rendering Index Detail must be included with the LM-79 report.
***The chromaticity coordinates at all measurement intervals during the life test must be provided in the LM-80 or LM-84 report.

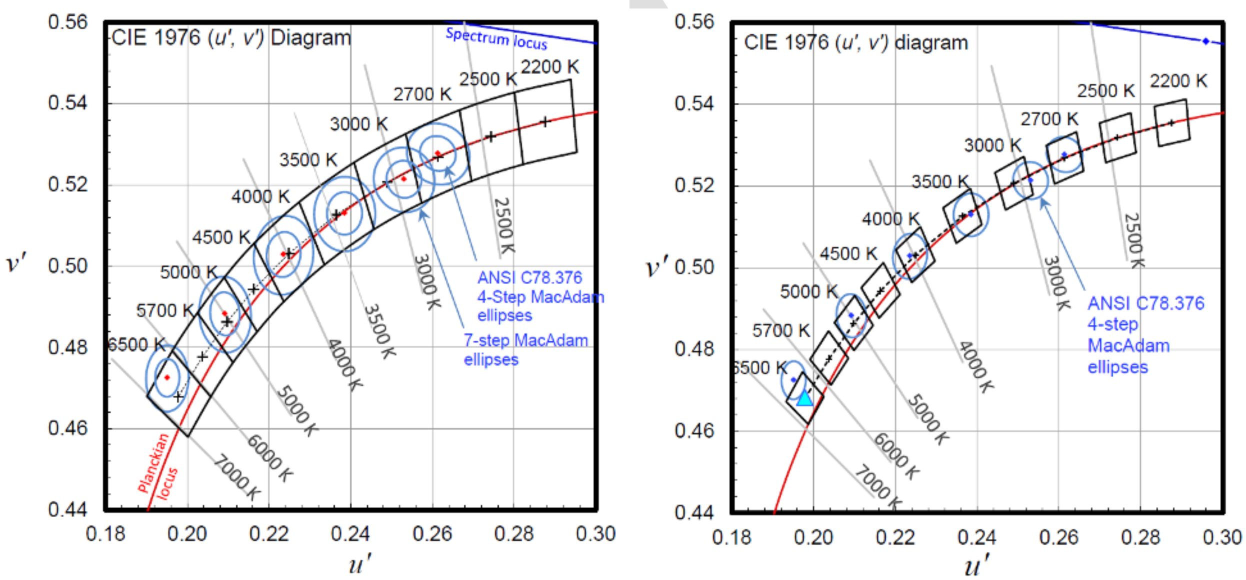
Considerations

Research and outreach to the industry on color quality revealed general alignment around the appropriate metrics and thresholds, as well as their limitations. The draft Technical Requirements have been developed with considerations in mind, some of which are described herein.

Color Consistency

ANSI C78.377-2017 is intended to specify and categorize a range of chromaticities recommended for general lighting. To establish alignment with the existing fluorescent lamp standards, 7-step and 4-step quadrangles (shown in **Figure 5**, below) were developed to categorize the chromaticity of the products. An additional consideration is that individual units of the same product line might have deviations in chromaticity due to limitations in consistency during the production process. These deviations could fall within a 4-step bin or 4-step MacAdam ellipse, without all falling within the 4-step CCT quadrangle. In general, SSL products are already reported to have a binning within 4-steps; adding DLC qualified product chromaticity to be within 4-step quadrangle (Tier 1) in addition to the current 7-steps of Tier 2 will help differentiate Tier 1 quality products. **Figure 5** below is a graphical representation of the basic nominal chromaticity specification of 7-step (left) and 4-step (right) quadrangles tolerances as defined in ANSI C78.377-2017 on the CIE 1976 (*u*', *v*') chromaticity diagram.

***Figure 5**:* Illustration of 7- and 4-step quadrangles for the basic nominal CCT definitions for LEDs in ANSI C78.377 with illustration of the MacAdam Ellipse classifications for fluorescent lamps in ANSI C78.376, reprinted with permission from NEMA, copyright 2017.



(Note: the apparent gaps between the 4-step quadrangles can be filled in by using the flexible nominal CCT definitions in ANSI C78.377.)

Chromaticity (CCT & D_{uv})

ANSI C78.377-2017 extends the designated chromaticity regions to include areas that have been shown to be suitable and preferred in some lighting applications. To keep alignment with the industry, the extended specifications are proposed as qualifying options for products that are being manufactured to meet specific applications needs. Similar considerations were made for the allowable CCT range. In V5.0 the upper bound for allowable CCT that existed in previous DLC Technical Requirements will align with ANSI C78.377-2017; refer to **Figure 5** (above) to see the range of allowable CCTs. This means that products with a CCT of 6500 K would now be eligible for the QPL. While it is not generally recommended that products with a CCT around 6500 K be used for general illumination, there may be appropriate use cases in interior lighting where a lighting professional might recommend such higher CCTs. Refer to design guide publications, such as the IES DG-1-16 (*IES Design Guide for Color and Illumination*[15]), for more information on the use of colored and white light of high/low CCTs.

Color Rendering

It is recognized that a single metric cannot adequately describe the color rendering capability of SSL products, and the lighting industry is incorporating new, updated metrics that address some of the known limitations of CRI. The metrics developed for current use are part of ANSI/IES TM-30-18, specifically the fidelity index R_f (which is also adopted by the CIE in CIE 224[16]), the gamut index R_g, and red local chroma shift $R_{cs,h1}$. Research findings[17] by Pacific Northwest National Laboratory (PNNL) describe three performance tiers that relate to user preference, naturalness, and acceptability. The “Acceptable” and “Best” thresholds, as identified by PNNL, have been used to inform Tier 2 and Tier 1 requirements in this policy draft, respectively. While these threshold values were developed through experiments and analyzed with currently available products, these metrics and the associated thresholds have not had adequate time to allow for industry experience or acceptance. Therefore, the DLC will also maintain a CRI R_a requirement with a proposed supplemental requirement for CRI R_9 red rendering as shown in **Table 3**. The CRI and R_9 values can be used as an alternate qualification path for products that do not yet meet the TM-30 requirements.

Color Maintenance

Currently, available color maintenance metrics provide limited insight into how products perform beyond the testing duration (i.e. just because a product shows negligible color shift over the first 6,000 hours of testing, does not mean that the product will perform similarly beyond the 6,000-hour mark). Because of this, proposed requirements have been set specifically around the measurable (testing) duration. Understanding chromaticity shift in LED packages and products is a complex undertaking because there are different factors at play, depending on package materials and construction. There are predictive patterns being identified to aid in the development of extrapolating techniques for color maintenance. Future revisions of this specification intend to align with eventual industry accepted methods for predicting color maintenance of SSL products.

[15] IES Design Guide for Color and Illumination (IES DG-1-16): Section 8.1.1 Selecting Colors of White Light

[16] CIE 224:2017: Colour Fidelity Index for Accurate Scientific Use

[17] https://journals.sagepub.com/doi/abs/10.1177/1477153517725974, and https://journals.sagepub.com/doi/abs/10.1177/1477153516663615

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Angular Color Uniformity

Angular color uniformity is important for certain use cases. In the early days of LEDs, manufacturing processes (among other things) created concerns around angular color uniformity (e.g., poor layering of phosphor created bluish-white light at center of beam and a yellow ring around the perimeter of the beam). Today, these concerns are less prevalent, however they still exist. In addition, multi-package LED light engines that use optics to mix the beam color can also produce unwanted variations. Because of this, the DLC has included optional reporting of angular color uniformity data for relevant Primary Use Designation (PUD) categories.

Spectral Power Distribution (SPD)

Reporting of SPD data enables calculation of current and future metrics of color quality, visual comfort, and/or health, safety, and wellbeing. Therefore, to allow for further evaluation and future-proofing of the QPL listings, the DLC V5.0 policy draft requires reporting of the SPD from 380 nm - 780 nm in 1 nm increments as per IES LM-79-08 in IES TM-27 or ANSI/IES TM-33-18 format. There will not be any qualification process around spectral composition.

Spectral quality information can be generated using the SPD in IES TM-27-14 and/or ANSI/IES TM-33-18 format. The DLC, therefore, considers simplifying the submission process by asking only for submission of the spectral data files, with the values on the QPL being autogenerated according to the listed industry metrics and procedures. The DLC is seeking feedback from the industry regarding this approach.

Key Questions: Color of Light and Color Rendering

1. The DLC has proposed reporting of the SPD according to IES LM-79-08 sphere testing in IES TM-27-14, or ANSI/IES TM-33-18 format. What are the major questions or complicating issues you have with this proposal and what are your suggestions to address them?
2. The DLC has proposed reporting of color rendering information in ANSI/IES TM-30-18 format (full report), as an alternative option to CRI R_a/R_9. What are the major questions or complicating issues you have with this proposal and what are your suggestions to address them?
3. The DLC has proposed expanding the CCT range to include all allowable CCT possibilities as defined by ANSI C78.377-2017 (2200 K – 6500 K). What are the major questions or complicating issues you have with this proposal and what are your suggestions to address them?
4. The DLC has proposed defining two tiers of color quality, one for baseline quality, the other for projects requiring higher color quality. Are two tiers appropriate, or should lesser or additional tiers be used?
5. The DLC is considering additional efficacy allowances for Tier 1. In consideration of your specific role in the industry, what are your suggestions to help determine allowances, (e.g., to determine efficacy trade-offs with color rendering, chromaticity and correlated color temperature)? How much should these allowance(s) be?
6. The DLC has proposed to require reporting of the spectral power distribution in IES TM-27-14 and/or ANSI/IES TM-33-18 format and additional separate reporting of the metrics specified in Table 3 that are derived from this information. As an alternative, to simplify and streamline the submission and review process, these additional metrics could be autogenerated by DLC using

the submitted spectrum (e.g., .spdx) file. Would you support this approach to generate QPL product information from manufacturer submitted spectral data? What are the major questions or complicating issues you have with this proposal, and what are your suggestions to address them?

Please provide your responses to these key questions in the Excel-based SSL V5.0 Comment Form, under the Color Appearance and Color Rendering tab.

DRAFT

Support for Alertness or Sleep, and Circadian Wellbeing

Rationale

Today, many people spend most of their time indoors under various electrical lighting conditions. This can result in limited exposure to bright light with radiant energy in the range of 460-520 nm, which is abundantly contained in daylight, and which, during morning hours, is required to entrain the human circadian system to a natural day-night cycle. This range of spectrum has also been shown to have an acute alerting effect supporting cognitive performance.

Conversely, to prepare for relaxation and sleep, such bright and 460-520 nm-rich light should be avoided in the evening (or several hours before sleep). Sleep disorders and other health impacts related to circadian disruption have been linked to the exposure of inappropriate light at the inappropriate time.

Therefore, designing lighting to support the sleep-wake cycle is relevant for:

- Increasing (daytime) alertness
- Wellbeing (use of light to support the sleep-wake cycle, and to decrease risk of any adverse impact to normal human biological clocks)

Luminaires can be designed to vary the impact on the occupants' daily sleep-wake cycle and alertness, especially when coupled with controls. Industry awareness has increased to understand that appropriate lighting solutions can support our daily biological rhythms (circadian rhythms). While research to develop refined metrics that consider all factors contributing to the effect of light upon the human circadian rhythm is still in process, some information is already available to assess lighting solutions and luminaires in their potential to have an impact. The DLC's proposed policy strives to promote awareness and ongoing education related to lighting solutions that support alertness, sleep, and the circadian system as well as projects that target WELL Building™ certification. The IES is working on related Recommended Practices, which will be referenced upon publication.

Definitions

The DLC references the following terms as defined in the Illuminating Engineering Society (IES) *ANSI/IES RP-16-17: Nomenclature and Definitions for Illuminating Engineering*[18], and the International Commission on Illumination (CIE) *CIE S 017/E:2011 ILV: International Lighting Vocabulary*[19]¸ with key deviations noted below. Explanations below reference the DLC's understanding of definitions as used by the industry, unless noted otherwise.

- **Circadian Rhythm:** From Latin circa, "around", and diem or dies, "day", meaning "around a day." Humans are inherently rhythmic beings, and body clocks regulate many bodily functions including feeding, sleeping, body temperature and hormone production. Light is the main signal that entrains the body clock to a daily cycle.

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[18] ANSI/IES RP-16-17 Nomenclature and Definitions for Illuminating Engineering
[19] CIE S 017/E:2011 ILV International Lighting Vocabulary

- **Lighting for Alertness and Circadian Wellbeing:** the capability of a lighting product to impact performance, mood, and the daily sleep/wake cycle by modulating the light spectrum around 460-520 nanometers.
    - Terms used in in the industry to describe this type of lighting include: "light for health and wellbeing," "biological lighting," "circadian lighting," and "human-centric lighting."
    - Please note that many additional factors such as site conditions (e.g. surface finishes), light output/levels, timing, and distribution play major roles in the impact of light on alertness and the daily sleep-wake cycle.
- **Melanopic Flux** as per CIE S 026/E:2018[20]: effective photobiological flux with the spectral flux spectrally weighted with the melanopic action spectrum (melanopic spectral weighting function).
- **Melanopic Daylight (D65) Efficacy Ratio** as per CIE S 026/E:2018: ratio of the melanopic efficacy of luminous radiation (for a source), to the melanopic efficacy of luminous radiation for daylight (D65).
- **Melanopic/Photopic Ratio (M/P Ratio)**, as per the International WELL Building Institute™ (IWBI™)[21]: The ratio of melanopic to photopic flux as per Lucas et al., 2014[22]. Given a spectrum of light, each equivalent α-opic lux is related to each other by a constant called Melanopic Ratio (R). To calculate the equivalent melanopic lux (EML), multiply the photopic lux (L) designed for or measured in a building by this constant (R): EML = L × R.
- **Circadian Light (CLA) and Circadian Stimulus (CS)**, as defined by the Lighting Research Center[23]:
    - CLA is the irradiance at the cornea weighted to reflect the spectral sensitivity of the human circadian system as measured by acute melatonin suppression after a one-hour exposure
    - CS is the calculated effectiveness of the spectrally weighted irradiance at the cornea from threshold (CS = 0.1) to saturation (CS = 0.7), assuming a fixed duration of exposure of 1 hour.

[20] CIE S 026/E:2018 CIE System for Metrology of Optical Radiation for ipRGC-Influenced Responses to Light
[21] International WELL Building Institute™ (IWBI™)
[22] Measuring and using light in the melanopsin age (Lucas et al, 2014)
[23] LRC Circadian Stimulus Calculator

Draft Testing and Reporting Requirements

Table 4: *Draft Testing and Reporting Requirements for Support for Alertness or Sleep, and Circadian Wellbeing*

Metric and/or Data Set	Current V4.4 Requirement	V5.0 Draft Requirement	Method of Evaluation
Spectral Power Distribution	No V4.4 Requirement	Required to report. Spectral range 380 – 780 nm at 1 nm increments.	IES LM-79-08 (per IES TM-27-14 and/or ANSI/IES TM-33-18)
Melanopic Flux *	No V4.4 Requirement	Required to report	As per CIE S 026/E:2018
M/P Ratio*	No V4.4 Requirement	Required to report	As per Lucas et al., 2014, and WELL v2, Appendix L1
Melanopic Daylight (D65) Efficacy Ratio *	No V4.4 Requirement	Required to report	As per CIE S 026/E:2018

*While this performance data can be reported at the luminaire level, ultimately the impact depends on design and site conditions.

Considerations

This policy was developed with consideration of the ongoing research into the impact of light on human physiology as it relates to promoting alertness, sleep and a healthful sleep-wake cycle. Outreach to researchers and industry experts on this topic revealed alignment around the reporting of product SPD to enable simulations and the calculation of future metrics. To encourage education and to support industry efforts that encourage health-conscious design, e.g. the WELL™ rating system, the DLC included in this draft the reporting of the melanopic/photopic (M/P) ratio as well as the melanopic daylight efficacy ratio at the product level. These metrics can be generated using the spectral power distribution in IES TM-27-14 and/or ANSI/IES TM-33-18 format. The DLC, therefore, considers simplifying the submission process by asking only for submission of the spectral data files, with the information on the QPL being autogenerated according to the listed industry metrics and procedures. The DLC is seeking feedback from the industry regarding this approach.

While these values can be calculated at the product level and inform product selection, many factors, including site conditions (e.g. finishes), light levels, timing, and distribution play major roles in the impact of light on alertness and the daily sleep-wake cycle. Therefore, any solution for application should be evaluated at the project level by a trained professional.

Circadian stimulus (CS) cannot be reported at the product level. SPD information can be used with the published calculator[23] to estimate the lighting impact in application.

This policy intends to set a reporting requirement for the applicable metrics so that knowledgeable users of the QPL have data available to evaluate an appropriate solution. This policy intends to align with future research updates.

Key Questions: Circadian Considerations

1. The DLC has proposed reporting of the SPD according to IES LM-79-08 sphere testing and IES TM-27-14 or ANSI/IES TM-33-18 format. What are the major questions or complicating issues you have with this proposal and what are your suggestions to address them?
2. The DLC has proposed reporting of Melanopic Flux and Melanopic Daylight Efficacy Ratio as per CIE S 026, and Melanopic-Photopic Ratio, as per WELL™ v2 Appendix L1. What are the major questions or complicating issues you have with this proposal and what are your suggestions to address them?
3. The DLC has proposed to require reporting of the spectral power distribution in IES TM-27-14 and/or ANSI/IES TM-33-18 format and additional separate reporting of the metrics specified in **Table 4** that are derived from this information. As an alternative, to simplify and streamline the submission and review process, these additional metrics could be autogenerated by DLC using the submitted spectrum (e.g., .spdx) file. Would you support this approach to generate QPL product information from manufacturer submitted spectral data? What are the major questions or complicating issues you have with this proposal, and what are your suggestions to address them?

Please provide your responses to these key questions in the Excel-based SSL V5.0 Comment Form, under the Circadian Considerations tab.

DRAFT

Distribution

Rationale

Light distribution refers to the photometric spatial characteristics of a luminaire or lamp, specifically the complete data set of luminous intensity produced in every direction. The optical design of luminaires can produce different beam distribution shapes with spatially-targeted intensity for a variety of indoor and outdoor use cases, applications and luminaire layouts. Designing targeted distribution patterns of lighting is important for:

- Energy consumption: minimizing wasted light either falling outside of the desired/target area or creating excessively illuminated areas
- Task performance: sufficient quantity and uniformity of light to optimize performance of the visual task
- Safety: visibility for navigation and detecting relevant obstacles
- Aesthetics: light patterns and directions of light that shape and enhance the observer's interpretation and appreciation of the architectural environment
- Wellbeing: mood, comfort, atmosphere, etc.

Distribution is the important link between the luminous efficacy values currently listed on the SSL QPL and the ultimate purpose of electric lighting: proper illumination of visual tasks and the environment. Luminaires whose distributions are well-matched to a specific application can provide excellent illumination with less energy consumption, less light trespass, and possibly less glare. However, there is not necessarily a best light distribution for a luminaire type or a DLC Primary Use Designation (PUD); much depends on the project design and application. Therefore, the proposed additional reported values in SSL Version 5.0 aim to provide more information for lighting specifiers and designers to be able to quickly select and compare the appropriate options.

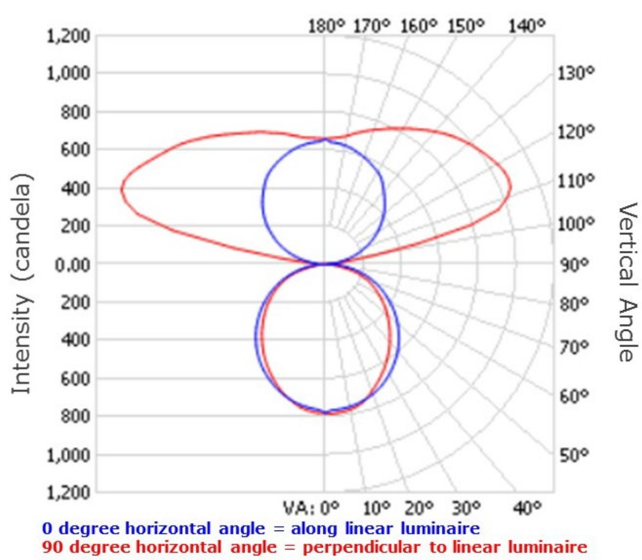


Figure 6: *Example of a Polar Plot, Candela Distribution*

Definitions

The DLC references the following terms as defined in the Illuminating Engineering Society (IES) ANSI/IES RP-16-17: Nomenclature and Definitions for Illuminating Engineering, and, if applicable, the International Commission on Illumination (CIE) CIE S 017/E:2011 ILV: International Lighting Vocabulary.

- **Luminous Intensity Distribution** data are stored and transferred in an .ies file as specified in ANSI/IES LM-63-02(R2008) Standard File Format Electronic Transfer of Photometric Data or ANSI/IES TM-33-18 Standard Format For The Electronic Transfer Of Luminaire Optical Data, and often displayed in a polar plot (see **Figure 6** above).
- **Beam Angle**: The angle between the two directions for which the intensity is 50% of the maximum intensity as measured in a plane through the nominal beam centerline. For beams that do not possess rotational symmetry, the beam angle is generally given for two planes at 90°, typically the maximum and minimum angles. Note that in certain fields of application, beam angle was formerly measured to 10% of maximum intensity (see **Figure 7** below).
- **Field Angle:** The angle between the two directions for which the intensity is 10% of the maximum intensity as measured in a plane through the nominal beam centerline. For beams that do not possess rotational symmetry, the field angle is generally given for two planes at 90°, typically the maximum and minimum angles. Note that in certain fields of application the angle between the 10%-of-maximum directions was formerly called beam angle (see **Figure 7** below).

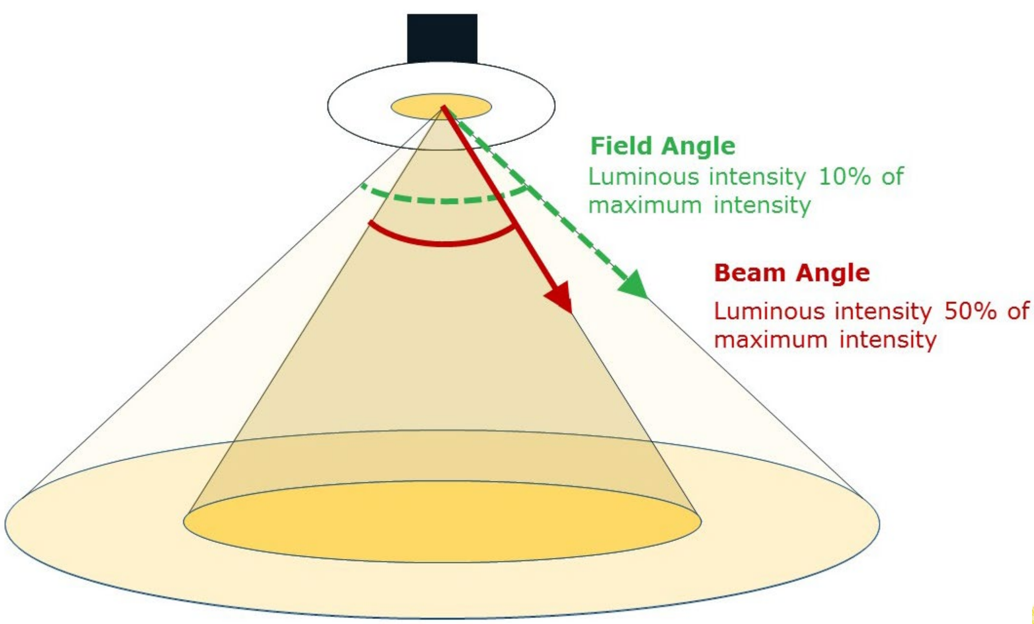


***Figure 7**: Illustration to clarify the above definitions of field and beam angle*

- **BUG rating (Backlight, Uplight and Glare (forward light))[24]:** The IES Luminaire Classification System (LCS) defines the distribution of light from a luminaire within three primary solid angles: forward light, backlight, and uplight. LCS Type V Roadway luminaires do not have a back side, so the B value does not correspond to back light for those products. These are further divided into ten secondary solid angles (represented in **Table 5** and graphically in **Figure 7** below).

***Table 5**: BUG rating (Backlight, Uplight and Glare (forward light)) Descriptions*

Primary Solid Angles	Secondary Solid Angles	Angle Zones	Lumen Distribution
Backlight	Low (BL)	0°- 30°	Vertical behind luminaire
	Mid (BM)	30°- 60°	
	High (BH)	60°- 80°	
	Very High (BVH)	80°- 90°	
Uplight	Low (UL)	90°- 100°	Vertical 360 degrees around luminaire
	High (UH)	100°- 180°	
Forward light	Low (FL)	0°- 30°	Vertical in front of luminaire
	Mid (FM)	30°- 60°	
	High (FH)	60°- 80°	
	Very High (FVH)	80°- 90°	

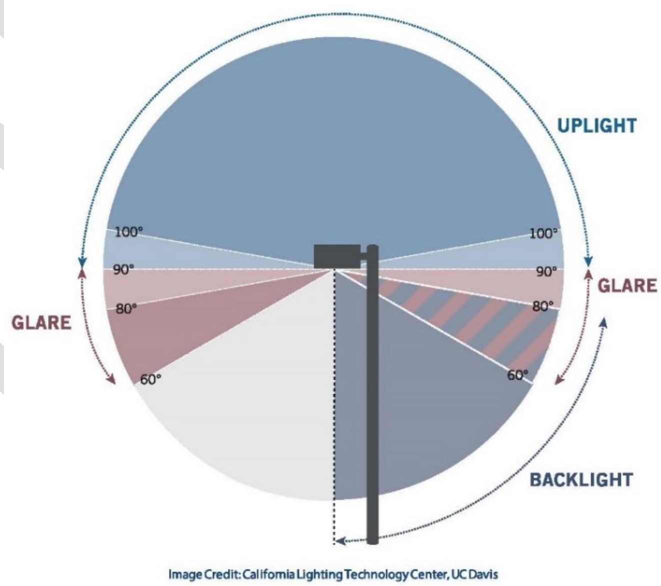


***Figure 8**: Backlight, Uplight and Glare angle zones in the BUG system, reprinted with permission from California Lighting Technology Center, UC Davis*

[24] IES TM-15-11 Luminaire Classification System for Outdoor Luminaires and Addendum A for IES TM-15-11: Backlight, Uplight, and Glare (BUG) Ratings

***Table 6**: Back and Uplight Rating Threshold Values from [IES 10th Edition Lighting Handbook](#)*, Reprinted with permission from *The IES Lighting Handbook, 10th Edition*. © 2010 The Illuminating Engineering Society.

Backlight Ratings For each rating (B0-B5), the maximum lumens are shown for each secondary solid angle involved

Secondary Solid Angle	B0	B1	B2	B3	B4	B5
BH	110	500	1000	2500	5000	>5000
BM	220	1000	2500	5000	8500	>8500
BL	110	500	1000	2500	5000	>5000

Uplight Ratings For each rating (U0-U5), the maximum lumens are shown for each secondary solid angle involved

Secondary Solid Angle	U0	U1	U2	U3	U4	U5
UH	0	10	100	500	1000	>1000
UM	0	10	100	500	1000	>1000
FVH	10	75	150	>150		
BVH	10	75	150	>150		

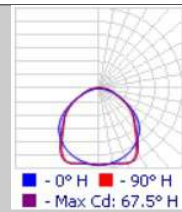
Draft Testing and Reporting Requirements

SSL products will report the following values, which will be generated using the submitted .ies files and photometric evaluation software:

Table 7: *Draft Testing and Reporting Requirements for Distribution*

Metric and/or Data set	Current V4.4 Requirement	V5.0 Draft Requirements		Method of Measurement	Applies to
		Threshold	Reported		
.ies file	.ies file for each optic variation	None	.ies files for each variation	IES LM-79-08[25], ANSI/IES LM-63-02(R2008) and/or ANSI/IES TM-33-18	All products
Back light, Uplight and Glare (BUG) Rating	No related requirement	None	Backlight and Uplight (Glare as part of Glare policy) values from 0 to 5 based on IES 10th Edition Lighting Handbook	IES TM-15-11 and Addendum A: Luminaire Classification System for Outdoor Luminaires	All QPL outdoor products, except Landscape/ Accent Flood and Spot Luminaires and Architectural Flood and Spot Luminaires
Beam Angle	No related requirement	None	Angle from 0 - 180°	Values produced by photometric analysis from .ies file	•Landscape/ Accent Flood and Spot Luminaires •Architectural Flood and Spot Luminaires •Track or Mono-Point Luminaires •Wall Wash Luminaires
Field Angle	No related requirement	None	Angle from 0 - 180°		
Zonal Lumen Distributions & Spacing Criteria	Specific Requirements for each PUD	Specific Requirements for each PUD, Identical to V4.4 reporting		Values produced by photometric analysis from .ies file	All PUDs

[25] IES LM-79-08: Electrical and Photometric Measurements of Solid-State Lighting Products, ANSI/IES LM-79-19 has yet to be published but is expected in 2019 and will replace the 2008 version.

Polar Plot of Distribution	No related requirement	None	 Polar plots for 0°, 90°, and Maximum Intensity angle	Plot produced by photometric analysis of .ies file	All PUDs

SSL products whose PUDs fall under the general category of outdoor luminaires and outdoor retrofit kits must report the 6-digit BUG rating. The representation of a BUG Rating is similar to the example: **B2 U0 G2**. The BUG rating shall be generated following IES TM-15-11*: Luminaire Classification System for Outdoor Luminaires* and the Addendum A for IES TM-15-11: Backlight, Uplight, and Glare (BUG) Ratings.

For outdoor luminaires and outdoor retrofit kits, the reported BUG rating will be listed on the QPL to provide information on the quantity of uplight and, for asymmetric luminaires, backlight.

Considerations

Research during development of this policy revealed that although overarching metrics that give numeric ranking for luminaire light distribution exist (i.e. Target Efficacy Rating, Fitted Target Efficacy), they are neither widely-known nor without flaws. Utilizing current horizontal task-plane efficacy metrics could bring the potential for unwanted and unwarranted effects on luminaire design. In the absence of adequate metrics, the DLC will monitor application efficacy and efficiency metrics as developments continue for possible implementation in the future. The proposed SSL V5.0 reported values are already in widespread use and aim to provide added information to the specifier community: BUG, beam and field angles, and polar distribution intensity plots.

Regarding the use of BUG information, DLC would like to note that some fixture designations, e.g., Type V Roadway and Area luminaires, are meant to distribute light onto the ground in all directions, therefore, a high B (backlight) value does not (necessarily) provide an indication of inferior performance.

The metrics in Table 6 can be generated using the photometric distribution in IES LM-63-02 and/or ANSI/IES TM-33-18 format. The DLC, therefore, considers simplifying the submission process by asking only for submission of the photometric data files; with the information values on the QPL being autogenerated according to the listed industry metrics and procedures. The DLC is seeking feedback from the industry regarding this approach: see Key Question number 4 below. Adding graphical components to the SSL QPL will support a more informative interface and its use as a design resource.

Key Questions: Distribution

1. The DLC has proposed reporting of the BUG rating according to IES TM-15 and Addendum. What are the major questions or complicating issues you have with this proposal to evaluate outdoor lighting distribution and light trespass, and what are your suggestions to address them?
2. The DLC has proposed reporting of the photometric distribution, beam and field angle. Is this information more useful as a visual diagram, or a set of numbers? What are your suggestions to make this information most useful?
3. The DLC has proposed to retain the V4.4 requirements for zonal lumen distribution according to Primary Use Designation. Are there any major questions or complicating issues you have with this proposal? For example, are there any specific PUD ZLD requirements that need to be revised, and what are your suggestions to address them?
4. The DLC has proposed to require reporting of the photometric distribution in IES LM-63-02 and/or ANSI/IES TM-33-18 format and additional separate reporting of the metrics specified in **Table 6** that are all derived from this information. As an alternative approach to simplify the submission and review process, these metrics could be autogenerated by the DLC using the submitted photometric distribution (.ies) file. Would you support this approach to generate QPL fixture information from manufacturer submitted .ies files? What are the major questions or complicating issues you have with this proposal, and what are your suggestions to address them?

Please provide your responses to these key questions in the Excel-based SSL V5.0 Comment Form, under the Distribution tab.

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Glare

Rationale

SSL technology has advanced dramatically in a short timeframe and has become significantly more efficacious and much less expensive. Although LEDs have enabled creative and sophisticated luminaire design, the high-power LED chips are inherently bright, small point sources. Absent appropriate optical control, LED products may be more likely to cause glare sensations compared to other light sources. Glare can impact:

- Task performance: hinder visibility and/or distract attention and focus from the task at hand
- Safety: hinder visibility for navigation and detecting relevant obstacles
- Wellbeing: create annoyance, eye strain, and discomfort

Therefore, provisions, specifically on discomfort glare, are included in this policy.

High efficacy in luminaires is more easily achieved by compromising on quality optics and glare control. With the proposed V5.0 Requirements, the DLC intends to implement a mechanism to differentiate quality products by enabling users of the QPL to identify products with a higher likelihood of causing glare because of (insufficient) optical control. The DLC QPL often serves as a basis for identifying products that are eligible for utility energy efficiency programs. The intent of including glare information on the QPL is to support lighting decision-makers in reducing the likelihood of selecting products with poor optical design and glare control (that have high-efficacy) for use in projects; which are then incentivized and deployed in the field. This will consequently help prevent user complaints, negative implications for performance, safety, and wellbeing, and accelerate market adoption and transformation.

Definitions

The DLC references the following terms as defined in the Illuminating Engineering Society (IES) ANSI/IES RP-16-17: Nomenclature and Definitions for Illuminating Engineering, and, when applicable, the International Commission on Illumination (CIE) CIE S 017/E:2011 ILV: International Lighting Vocabulary. The exact source of reference for each term is listed in the footnote.

- **Discomfort glare**[26] is glare that produces discomfort. It does not necessarily interfere with visual performance or visibility.

  Other definitions of discomfort glare include:
  - Discomfort glare is a sensation of annoyance or pain caused by high luminance in the field of view. Four factors are known to participate in the perception of discomfort glare: Luminance of the glare source, Size of the glare source, Position of the source in the field of view, Luminance of the background (10th edition of the IES Handbook, Chapter 4.10.1.)

[26] ANSI/IES RP-16-17 5.9.11.5.

- **Unified Glare Rating (UGR)** is a measure of the discomfort produced by a lighting system along a psychometric scale of discomfort.[27]
    - The Unified Glare Rating formula is a discomfort glare likelihood assessment method developed, published and recommended by the CIE. The UGR formula produces a glare rating which is a psychophysical parameter estimating the discomfort in response to glare in a visual environment containing light sources. The practical UGR range is from 10 to 30 with most lighting systems producing values in that range. A high value indicates [likelihood of] significant discomfort glare, while a low value indicates little likelihood of discomfort glare.[28]
- **Uncorrected UGR table**[29] refers to a set of UGR values of the luminaire tested based on pre-set room definitions and a luminous flux of 1000 lm. The data are provided for 19 standard room shapes with 5 different combinations of room surface reflectance. For application of the uncorrected UGR table, the values must be corrected to the actual luminous flux in the luminaire.
- **Corrected UGR table** refers to a set of UGR values presented in the same format as the uncorrected UGR table with the same pre-set room definitions but corrected using the actual luminous flux of the luminaire.
- **BUG Rating**[30] is the IES Luminaire Classification System (LCS) that defines the distribution of light from a luminaire within three primary solid angles: forward light, backlight and uplight. These are further divided into ten secondary solid angles as listed under the BUG rating definition in the Distribution section in this policy draft.

  The glare ratings in the BUG system are determined using **Table 8** according to a luminaire's lumen output within the following four solid angle zones as illustrated in **Figure 9**: forward high (FH), forward very high (FVH), back high (BH) and back very high (BVH).

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[27] ANSI/IES RP-16-17 Definitions and Nomenclature 5.9.11.5.8
[28] CIE 117-1995 Discomfort Glare in Interior Lighting
[29] CIE 190-2010 Calculation and Presentation of Unified Glare Rating Tables for Indoor Lighting Luminaires
[30] IES TM-15-11 Luminaire Classification System for Outdoor Luminaires

Figure 9: *Glare angle zones in the BUG system*

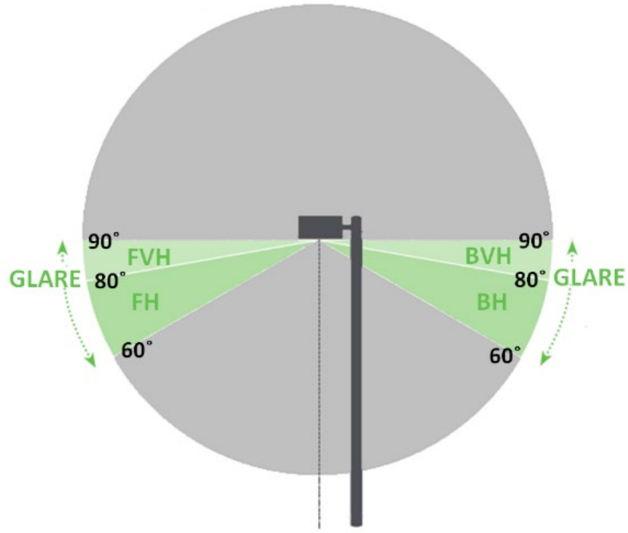

Table 8: *Glare ratings values in the BUG system from [IES 10th Edition Lighting Handbook](), Reprinted with permission from The IES Lighting Handbook, 10th Edition. © 2010 The Illuminating Engineering Society.*

Glare Ratings, Types I, II, III, and IV For each rating (G0-G5), the maximum lumens are shown for each secondary solid angle involved

Secondary Solid Angle	G0	G1	G2	G3	G4	G5
FVH	10	250	375	500	750	>750
BVH	10	250	375	500	750	>750
FH	660	1800	5000	7500	12000	>12000
BH	100	500	1000	2500	5000	>5000

Glare Ratings, Types V and Vs For each rating (G0-G5), the maximum lumens are shown for each secondary solid angle involved

Secondary Solid Angle	G0	G1	G2	G3	G4	G5
FVH	10	250	75	500	750	>750
BVH	10	250	375	500	750	>750
FH	660	1800	5000	7500	12000	>12000
BH	660	2800	5000	7500	12000	>12000

Draft Testing and Reporting Requirements

The proposed glare testing and reporting requirements are detailed in **Table 9**.

Table 9: *Draft Testing and Reporting Requirements for Glare*

Metric and/or Data Set	Current V4.4 Requirements	V5.0 Draft Requirements			Method of Evaluation
		Threshold	Reported	Listing	
.ies file	.ies file for each optic variation	None	.ies files for each variation	N/A	IES LM-79-08[31], ANSI/IES LM-63-02(R2008) and/or ANSI/IES TM-33-18
Unified Glare Rating (UGR) *Applicable to indoor luminaires and indoor retrofit kits only*	No related requirement	None	Uncorrected UGR Table and Corrected UGR Table	Designation of glare potential: • Low * • Medium • High (to be defined in a later draft)	Uncorrected UGR and corrected UGR tables generated using luminaire photometric data, per CIE 117-1995 and CIE 190-2010
Backlight, Uplight, and Glare (BUG) *Applicable to outdoor luminaires and outdoor retrofit kits only*	No related requirement	None	BUG Rating	G rating (BU listed as part of Distribution policy)	BUG rating generated per IES TM-15-11 and Addendum A for IES TM-15-11 using luminaire photometric data

** Efficacy allowances may be developed for low-glare fixtures (details TBD).*

SSL products whose Primary Use Designation (PUD) fall under the general category of indoor luminaires or indoor retrofit kits must report both the uncorrected UGR table and the corrected UGR table. The UGR table shall be produced using the product's photometric data, namely the IES file, and conform to the format of Table A2 in CIE 117-1995: Discomfort Glare in Interior Lighting or Table 1 of CIE 190-2010: Calculation and Presentation of Unified Glare Rating Tables for Indoor Lighting Luminaires. A sample UGR table is provided in **Table 10**.

[31] IES LM-79-08: Electrical and Photometric Measurements of Solid-State Lighting Products, ANSI/IES LM-79-19 has yet to be published but is expected in 2019 and will replace the 2008 version.

Table 10: *A sample UGR table*

Reflectances:											
Ceiling (cavity)		0.7	0.7	0.5	0.5	0.5	0.7	0.7	0.5	0.5	0.5
Wall		0.5	0.3	0.5	0.3	0.3	0.5	0.3	0.5	0.3	0.3
Reference plane		0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Room Dimensions		Viewed crosswise					Viewed endwise				
X=2H	Y=2H	8.9	10.5	9.3	10.8	11.1	10.7	12.2	11.0	12.5	12.9
	3H	10.5	11.9	10.8	12.2	12.6	12.4	13.8	12.8	14.2	14.5
	4H	11.0	12.3	11.4	12.6	13.0	13.1	14.5	13.5	14.8	15.2
	6H	11.5	12.7	11.9	13.1	13.5	13.6	14.8	14.0	15.2	15.6
	8H	11.7	12.9	12.2	13.3	13.7	13.8	14.9	14.2	15.3	15.7
	12H	12.0	13.2	12.5	13.5	14.0	13.8	15.0	14.3	15.3	15.8
4H	2H	9.6	11.0	10.0	11.3	11.7	11.0	12.4	11.4	12.7	13.1
	3H	11.4	12.5	11.8	12.9	13.3	13.0	14.1	13.4	14.5	14.9
	4H	12.0	13.0	12.4	13.4	13.9	13.9	14.9	14.3	15.3	15.7
	6H	12.7	13.5	13.1	14.0	14.4	14.5	15.4	15.0	15.8	16.3
	8H	13.0	13.8	13.5	14.2	14.7	14.7	15.5	15.2	16.0	16.4
	12H	13.4	14.1	13.8	14.6	15.0	14.8	15.6	15.3	16.0	16.5
8H	4H	12.4	13.2	12.8	13.6	14.1	14.0	14.8	14.5	15.3	15.8
	6H	13.2	13.8	13.7	14.3	14.8	14.8	15.4	15.3	15.9	16.4
	8H	13.6	14.2	14.1	14.7	15.2	15.0	15.6	15.5	16.1	16.6
	12H	14.1	14.7	14.6	15.1	15.7	15.2	15.7	15.7	16.2	16.8
12H	4H	12.4	13.1	12.9	13.6	14.1	14.0	14.8	14.5	15.2	15.7
	6H	13.2	13.8	13.8	14.3	14.8	14.8	15.4	15.3	15.9	16.4
	8H	13.7	14.3	14.3	14.8	15.3	15.1	15.6	15.6	16.1	16.7

SSL products whose PUD falls under the general category of outdoor luminaires and outdoor retrofit kits must report the 6-digit BUG values. The representation of a BUG Rating is similar to the example: **B2 U0 G2**. The BUG rating shall be generated following IES TM-15-11 Luminaire Classification System for Outdoor Luminaires and the Addendum A for IES TM-15-11: Backlight, Uplight, and Glare (BUG) Ratings.

For product listing simplicity, the DLC is considering adopting a simplified glare assessment on the QPL for indoor luminaires and indoor retrofit kits; for example, a new field on the QPL with designations of “low glare potential”, “medium glare potential” and “high glare potential” to indicate the likelihood of a product resulting in discomfort glare in actual indoor installations. The delineation of the different levels has not been defined in this conceptual specification and will be formalized in the subsequent V5.0 requirements for each PUD based on the reported UGR tables. The DLC will evaluate the feasibility of implementing efficacy allowances for products that qualify for the category “low glare potential”.

The actual impact of glare in an application – regardless of the identified glare potential of the product – should be evaluated at the project level. A luminaire with medium or high glare potential might still be appropriate and best practice for an application as determined and laid out by a lighting design professional.

For outdoor luminaires and outdoor retrofit kits, the reported BUG rating will be listed on the QPL to provide indication on luminaire optical performance related to high angle glare control.

Considerations

This policy was developed with consideration of the lack of standardized metrics for characterizing glare in the U.S. lighting market. In contrast, UGR as an indoor glare metric is well established and widely used in the European market. It is referenced in European Union lighting standards (e.g. CEN EN 12464-1) and reported commonly by manufacturers on luminaire specification sheets. In addition, it is referenced by the WELL™ rating system in section Light 55: Electric Light Glare Control. The DLC's outreach shows consensus that, while glare metrics have shortcomings, and glare evaluation methods are still being developed, the benefits would outweigh those shortcomings as complaints about high-glare luminaires have been increasing since LED technologies entered the lighting industry.

Glare sensitivity varies by individual, and the sensation of glare depends greatly on the geometry and layout on site. Therefore, a luminaire-based glare metric is a rough estimation at best; it condenses application-specific glare evaluation using reference conditions to provide guidance on the probability of glare. With this limitation in mind, however, the draft policy aims to provide an informed first indication regarding the level of consideration needed when selecting a luminaire for an application where low glare is a key design criterion. A luminaire with a low glare rating does not automatically eliminate all glare possibilities; conversely, a luminaire with a high glare rating may still be well-suited and appropriate for certain applications in a deliberated design. The same consideration should be given to the glare assessment system the DLC is considering for product listing. A product designated as "high glare potential" does not necessarily translate to inferior quality with subpar glare control. Rather, it signals to the practitioners that attention in design and site integration is needed when selecting the product for meeting low-glare design needs.

The glare metrics, particularly UGR, adopted in this policy predate the SSL technologies, even though peer-reviewed research papers have shown that the metrics are still good predictors of glare sensation under SSL light sources in most cases[32]. There is a growing recognition in the lighting industry that the distribution of luminance across a luminaire affects the glare response. An array of intensely bright LEDs, for example, producing the same light output and distribution as a luminaire with a diffuser, may be perceived as far more glaring. The DLC is mindful of these potential limitations and is in close touch with organizations that work on glare evaluation and standards revisions in order to monitor the latest activities and to implement updated evaluation methods when available.

The DLC is aware of the limitations of the glare policy in regard to adjustable products, such as aimable luminaires as well as those governed by the Field-Adjustable Light Distribution policy. In these cases, the testing and reporting requirements in this policy only represent the glare rating at a single adjustment instance, and the final glare conditions can only be meaningfully assessed at the luminaire's actual setting and/or aiming in the field.

It should also be noted that the Glare Ratings in the BUG system relate most closely to vehicle driver glare response, rather than pedestrian glare response. Drivers almost always have the roof of the

[32] Y. Yang, M.R. Luo, S-N Ma and X-Y Liu, "Assessing glare. Part 1: Comparing uniform and non-uniform LED luminaires," 49:2, Lighting Res. Technol., 2015, pp. 195-210.

vehicle to block light from luminaire angles of 60° from nadir and below. Pedestrians do not, and it is frequently the angles from 0 to 60° that cause discomfort and distraction.

BUG and UGR tables can be generated using the photometric distribution in IES LM-63-02 and/or TM-33-18 format. The DLC, therefore, considers simplifying the submission process by asking only for submission of the photometric data files; with the information on the QPL being autogenerated according to the listed industry metrics and procedures. The DLC is seeking feedback from the industry regarding this approach.

Key Questions: Glare

1. The DLC has proposed reporting of the UGR tables for indoor luminaires in the format conforming to CIE 190-2010 calculated using the luminaire IES file. What are the major questions or complicating issues you have with this proposal and what are your suggestions to address them?
2. The DLC has proposed the development of a 3-level system with the designations of "low glare potential", "medium glare potential" and "high glare potential" for product listing simplicity. Does this level of delineation provide a meaningful balance between being respectful of design freedom, being concise and providing indicative information? What are your suggestions to develop or improve the proposed delineation?
3. The DLC realizes that calculation details of the glare metrics could sometimes be subject to interpretation. What supporting documents should the DLC provide to ensure the glare metrics are generated in a consistent manner across all eligible products? Is any vetting required, such as use of a certified, accredited test lab, to prevent potential gaming possibilities?
4. The DLC has proposed reporting of the BUG rating according to TM-15 and Addendum. In consideration of your specific role in the industry, what are the major questions or complicating issues you have with this proposal to evaluate outdoor lighting glare and what are your suggestions to address them?
5. The DLC is considering efficacy allowances for low-glare products. In consideration of your specific role in the industry, what are your suggestions to help determine allowances? What are the major questions or complicating issues you have with this proposal and what are your suggestions to address them?
6. The DLC has proposed the reporting of the photometric distribution in IES LM-63-02 and/or ANSI/IES TM-33-18 format as part of the requirements in addition to separate reporting of the metrics specified in **Table 8** that are all derived from this information. As an alternative, to simplify the submission process, the DLC could autogenerate these metrics using the submitted photometric distribution file (IES file). Would you support this approach to generate QPL fixture information from submitted IES files? What are the major questions or complicating issues you have with this proposal, and what are your suggestions to address them?

Please provide your responses to these key questions in the Excel-based SSL V5.0 Comment Form, under the Glare tab.

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Flicker

Rationale

Whether perceptible or not, most conventional light sources modulate luminous flux and intensity, commonly known as flicker. Fluorescent luminaires with magnetic ballasts are commonly cited as flicker offenders, but SSL sources flicker too, primarily as a function of the driver, as its job is to regulate current to the LEDs. Humans perceive flicker in different ways depending on a number of factors, such as frequency of the flicker, amount of light modulation, duration of exposure, brightness, contrast, motion of the light and/or observer, and more.

Flicker control is relevant for:

- Task performance (distraction, reduction in reading and comprehension rates)
- Safety (objects appear to be moving at different rates/speeds than they truly are due to the stroboscopic effect)
- Wellbeing (annoyance, eyestrain, headaches, migraine, seizures)

Luminaires that exhibit flicker can have a range of impacts on occupants, from eyestrain and discomfort leading to losses in productivity, or more serious health impacts such as migraines and seizures. Flicker can interfere with other aspects of buildings as well, such as video cameras, imaging equipment, and barcode scanners. High frequency stroboscopic flicker can be dangerous when working with machinery, as flickering light can create an optical illusion of slowing or stopping rotating parts. These reasons and more indicate a need for standardization and consideration in the DLC's policy requirements to mitigate the occurrence of flicker in DLC qualified products.

Definition

The DLC uses "flicker" as a generic term to describe three categories of Temporal Light Artifacts (TLA) that all result from the variation in light output from a light source over time. TLA is an undesired change in visual perception induced by a light stimulus (Temporal Light Modulation, TLM) whose luminance or spectral distribution fluctuates with time. TLA includes the following categories:

- Flicker (< 80Hz): Perception of visual unsteadiness for a static observer in a static environment.
- Stroboscopic Effect (80Hz – 2,000Hz): Change of motion perception for a static observer in a non-static environment
- Phantom Array Effect (also known as the Ghost effect) (80Hz – 2,500Hz): Change in perceived shape or spatial layout of objects for a non-static observer in an otherwise static environment

Draft Testing and Reporting Requirements

SSL products must meet the thresholds using the referenced Methods of Evaluation outlined in **Table 11**. Because dimmers can introduce flicker to SSL products if not carefully engineered for combined operation, it is critical to report flicker performance at multiple levels of dimming, as well as at full output. A sample reporting table is shown in **Table 12**.

__Table 11:__ Draft Flicker Testing and Reporting Requirements

<table>
<tr><th rowspan="3">Metric</th><th rowspan="3">Current V4.4 Require-ments</th><th colspan="3">V5.0 Draft Requirements</th><th rowspan="3">Method of Evaluation</th></tr>
<tr><th colspan="2">Threshold</th><th rowspan="2">Reported</th></tr>
<tr><th>Tier 1</th><th>Tier 2</th></tr>
<tr><td>Short Term Flicker (P_{st})</td><td>n/a</td><td colspan="2">≤1.0 at 100% and 20% light output</td><td>P_{st} at 100%, 20%, and minimum fraction of light output</td><td rowspan="4">ANSI/IES LM-xx-19 Approved Method: Measuring Optical Waveforms for use in Temporal Light Artifact (TLA) Calculations [33]</td></tr>
<tr><td>Stroboscopic Visibility Measure (SVM)</td><td>n/a</td><td>≤0.4 at 100% and 20% light output</td><td>≤0.9 at 100% and 20% light output</td><td>SVM at 100%, 20%, and minimum fraction of light output</td></tr>
<tr><td>Percent Flicker</td><td>n/a</td><td colspan="2" rowspan="2">No required threshold</td><td rowspan="2">Report values at 100%, 20%, and minimum fraction of light output for frequencies under 40, 90, 200, 400, and 1,000 Hertz</td></tr>
<tr><td>Flicker Index</td><td>n/a</td></tr>
</table>

__Table 12:__ Sample Reporting Table: Flicker

Metric	Value at 100% Light Output	Value at 20% Light Output	Value at Minimum Light Output
Short Term Flicker (P_{st})			
Stroboscopic Visibility Measure (SVM)			
Percent amplitude modulation; 1,000 Hz cut-off			
Percent amplitude modulation; 400 Hz cut-off			
Percent amplitude modulation; 200 Hz cut-off			
Percent amplitude modulation; 90 Hz cut-off			
Percent amplitude modulation; 40 Hz cut-off			
Flicker Index; 1,000 Hz cut-off			
Flicker Index; 400 Hz cut-off			
Flicker Index; 200 Hz cut-off			
Flicker Index; 90 Hz cut-off			
Flicker Index; 40 Hz cut-off			

[33] ANSI/IES LM-xx-19 Approved Method: Measuring Optical Waveforms for use in Temporal Light Artifact (TLA) Calculations has yet to be published but is expected in 2019.

Considerations

This policy was developed based on research of existing literature and outreach to experts within the field. From this research and outreach, the DLC observed a lack of standardization around flicker and revealed little alignment around the proper metrics and appropriate thresholds.

The DLC does not currently have flicker-related QPL reporting requirements. A main concern of QPL users is that as manufacturers look to cut costs, there is a potential decrease in quality with a resulting increase of light flicker. In response to this concern from stakeholders, the DLC set out to identify appropriate metrics that best represent flicker performance across products and applications. This included identifying the metrics that will allow DLC stakeholders to clearly understand how a product performs and how it compares to similar products, while minimizing the testing burden on manufacturers. It also included researching acceptable levels of flicker and stroboscopic effects that could serve as a minimum requirement for listing on the QPL, alongside other SSL Technical Requirements.

At this point in time, there are generally two dominant perspectives on appropriate sets of metrics:

- IEEE PAR 1789-2015 - Recommended Practices for Modulating Current in High-Brightness LEDs for Mitigating Health Risks to Viewers
    - Uses amplitude modulation (percent flicker) and frequency to plot product performance on a Low Risk / No Effect chart that allows users to easily compare products against one another.
    - California's Building Energy Efficiency Standards, known as Title 24, contains flicker requirements using a percent flicker and frequency threshold.
- NEMA 77-2017 - Temporal Light Artifacts: Test Methods and Guidance for Acceptance Criteria,
    - Uses Short Term Flicker (P_{st}) and Stroboscopic Visibility Measure (SVM), which are more sophisticated metrics displayed in an easy to understand single-digit value, to measure flicker performance.
    - NEMA 77 includes recommendations for both P_{st} and SVM thresholds

Because of the QPL design and intent, the DLC wants users to understand the minimum requirements and be able to compare performance between products. As such, the draft V5.0 requirements include requirements from both dominant perspectives: P_{st} and SVM as described in NEMA 77, and percent flicker and frequency as described in IEEE PAR 1789. Additionally, the draft requirements include reporting on Flicker Index, which accounts for average peak-to-peak amplitude, wave-form shape, and duty cycle of the flicker. Requiring these four metrics will provide DLC stakeholders with all of the information they need to decide if a product has the right flicker performance for their application.

Finally, it should be noted that while the NEMA 77 recommended value of $P_{st} = 1.0$ is proposed within the V5.0 Technical Requirements, the DLC is proposing a two-tier approach to SVM which are both lower than the recommended limit of SVM = 1.6 in NEMA 77. As described in a recently released interim study by Jennifer Veitch and Christophe Martinsons on detection of the stroboscopic effect[34], an SVM of 0.9 means 25% of the population will see the flicker 63% of the time and an SVM of 0.4 means that just 10%

[34] Visual Perception under Energy-Efficient Light Sources - Detection of the Stroboscopic Effect Under Low Levels of SVM. 2018

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of people will detect stroboscopic flicker. The DLC found these levels appropriate and proposed them as Tier 2 and Tier 1 levels, respectively.

Key Questions: Flicker

1. What are the major questions or complicating issues you have with the metrics proposed and methods of evaluation? What are your suggestions to address them?
2. To help ensure DLC qualified lighting does not produce negative health or safety implications, the DLC has referenced the latest research in recommending SVM threshold values of 0.4 for Tier 1 and 0.9 for Tier 2. What specifically would be the impact of these levels on existing products in the market? What impact would the levels have on product design and the cost of products?
3. Flicker performance will vary depending on the dimmer installed in the application, which may be different from the dimmer the product was tested with for qualification. How best can the DLC address this?

Please provide your responses to these key questions in the Excel-based SSL V5.0 Comment Form, under the Flicker tab.

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Draft Technical Requirements: Controllability

Controllability

Rationale

The long service life that can be expected from modern SSL products is a great benefit. However, if a product is installed in an un- or under-controlled state, this same long service life can ensure that it will remain as such for five to ten years. When considering the extra savings possible from controls – both networked lighting controls (NLC) and non-networked controls – installations with no or minimal controls represent a large opportunity cost. **Figure 10** shows the savings potential from NLC systems when aggressively supported by electric utilities.[35]

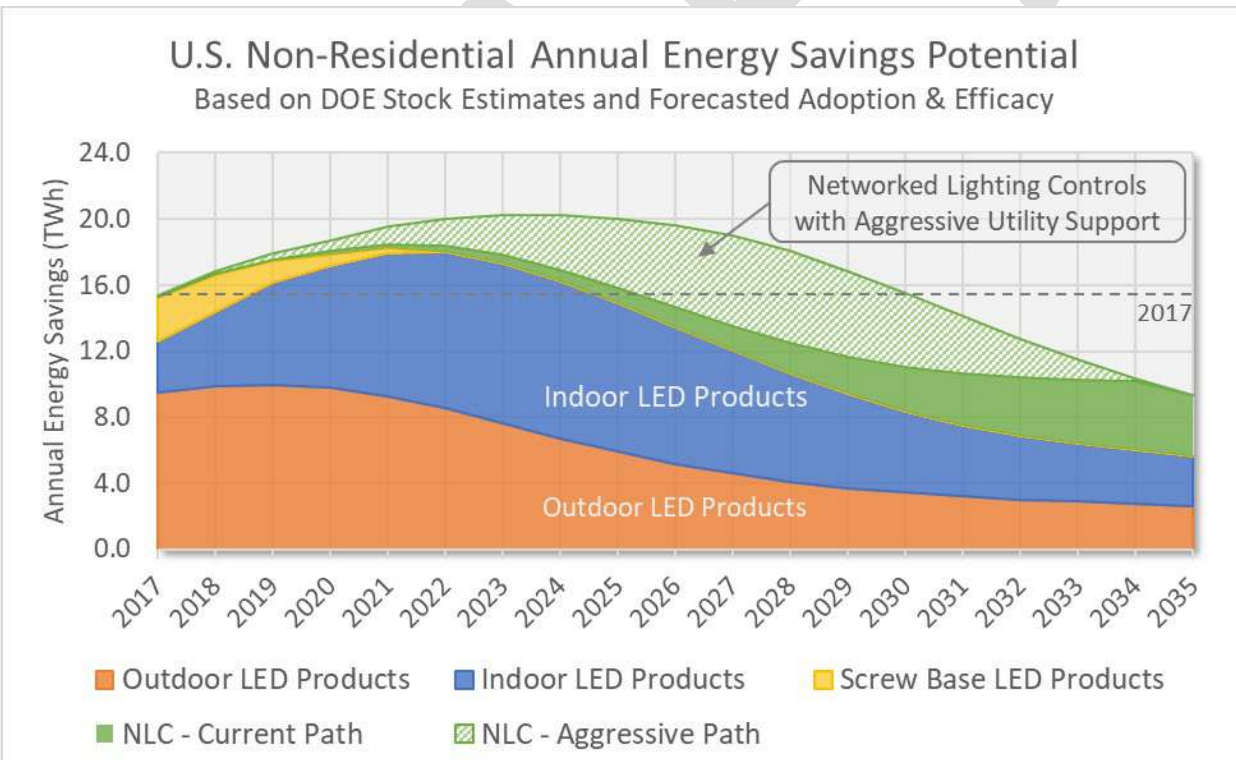

***Figure 10**: U.S. non-residential (C&I) savings potential by REEO, without NLC (left) and with NLC (right)*

[35] Figure and data from: https://www.designlights.org/resources/energy-savings-potential-of-dlc-commercial-lighting-and-networked-lighting-controls/

By ensuring that listed products meet certain controllability standards and enhancing the QPL's information relating to a product's ability to be controlled, the DLC aims to support lighting decision makers in identifying and promoting products that can be more easily controlled, thereby increasing adoption of controls.

The DLC's research found that understanding which controls are compatible for a project's products remains complicated, with frequent reference to technical documentation in inconsistent formats and availabilities. By centralizing a uniform description of basic elements of controllability, the DLC's updated reporting will reduce confusion and make it easier to find the most energy-saving and effective solution possible.

Definitions

This policy will reference three areas: dimming, integral controls, and controls compatibility.

- **Dimming**: Per NEMA LSD-64, Continuous Dimming is defined as a lighting control strategy that varies the light output of a lighting system over a continuous range from full light output to a minimum light output without flickering in imperceptible steps. Stepped Dimming is defined as a lighting control strategy that varies the output of lamps in one or more predetermined steps of greater than one percent of full output. The changes between levels are generally perceptible.
- **Integral Controls**: The DLC defines Integral Controls as the capability to have sensing and control of output light state based on this sensing, installed for each product, and directly integrated or embedded into the product form factor during the manufacturing process.
- **Controls Compatibility**: The capability to receive and implement commanded changes to the dimmed state, color setting, timing, etc.

Draft Testing and Reporting Requirements

Table 13: *Controllability Testing and Reporting Requirements*

Metric	Current V4.4 Requirements	Draft Requirement	Method of Evaluation
Dimming	Reporting of dimming capability required for all products	Dimming capability required for all products, with category exceptions. Continuous dimming required for indoor, stepped dimming for outdoor.	Product documentation

Integral Controls	Reporting optional, with Yes/No answers of whether product has integral controls (Reporting required for Premium).	Required to report, with additional information provided	Product documentation
Controls compatibility	None	Required to report method of inducing dimming in the product.	Product documentation

Dimming Requirements

- Dimming is proposed to be a **required** capability for luminaires, retrofit kits, and lamps.
- Categories exempted from this requirement are: case lighting, landscape accent/flood, specialty hazardous, and specialty sports flood. These exemptions are due to the unique nature of these applications making them unsuitable or unlikely for general controls application. For example, hazardous location products have safety considerations beyond saving energy that they must primarily consider, and specialty sports flood products are often connected to more sophisticated theatrical-style control systems.
- Dimming must be continuous for indoor categories. It must be at least stepped for outdoor categories.
- Dimming can be satisfied by either of two approaches:
    - Demonstrating via product documentation that the product can dim according to an external communications signal.
    - Demonstrating via product documentation that the product can dim in response to a generally used modulation of the power signal (i.e. phase-cut dimming).
    - This second proposed approach is an acknowledgement of the challenges in dimming lamps that have prescribed socket form factors, and that dimming commands for certain product classes may be non-addressable and sent from already-existing equipment that is impractical or expensive to replace.
- The DLC does *not* issue requirements around dimming control protocol (0-10V, DALI, etc.) for this requirement. The act of dimming itself is the focus of this requirement.

Integral Controls

- Reporting of “Yes/No” about integral controls for all products is **required**.
- If “Yes”, products must provide more detail on a set of yet-to-be-determined control and data collection modes (occupancy, daylight, temperature, energy measurement, etc.). These modes would not be evaluated against any standards and treated as simple assertions of capability, and validated with references in product documentation.

Controls Compatibility

- Reporting of the protocol (0-10V, DALI, on-board sensing, phase-cut, etc.) used for commanding dimmed states of SSL products is **required**. This could be used to perform a “self-service QPL linkage” when comparing NLC systems that offer the same protocol.
- The DLC may evaluate the potential, in limited cases, for a “soft” SSL-NLC linkage for SSL products with integrated controls available that report NLC capability. Equity and the balance between within-OEM and cross-OEM relationships would need to be fairly addressed before the DLC moves in this direction.

Considerations

A dimming requirement received strong support from nearly all stakeholders engaged through the DLC’s research, since dimming enhances product controllability while supporting quality aspects. The DLC’s analysis showed a high rate of dimmable products in both indoor and outdoor luminaire and retrofit kit categories on its existing QPL. A minimal cost impact is expected since commodity drivers are widely dimmable. The DLC found that lamps do have lower rates of dimming, but stakeholders were generally still supportive of requiring *some* form of dimming in these categories.

Enacting a dimming requirement for luminaires but not lamps *could* create a bias towards less expensive lamps, since the dimming-capable equipment would not need to be present in lamps, simplifying design and lowering cost. This would counter the DLC’s intent to emphasize sector-wide controllability and would compound the issue of installing LED products with no or limited controls. Overlaying the DLC’s proposed flicker reporting would also help ensure that the subjective quality of the dimmed products’ performance remains satisfactory as well.

The continuous dimming requirement for indoor lighting is recommended to enable task tuning and daylight dimming while ensuring occupant satisfaction. Stepped dimming for adaptive control and/or part-night dimming is a reasonable option for outdoor products since continuously-present observers are less of a concern and the strategy meets code requirements in most jurisdictions

A large majority of stakeholders indicated that the current integral controls reporting on the QPL is not sufficient. Nearly all responded that providing more detailed information would be helpful to specifiers, customers, and utilities. Respondents *were* concerned about any reporting requirement that would multiply the number of product variations. Therefore, the proposed solution maintains the “yes/no” reporting with an added field for more detail, similar to the approach used for dimming reporting.

Stakeholders appreciated the concept of a linkage between the SSL and NLC QPLs but shared universal concern about vetting and maintaining accurate information about each product’s compatibility with a listed NLC system.

As a first step to addressing compatibility, the DLC will collect and report information about the dimming protocol to aid specifiers and customers in identifying solutions that may work together. If “NLC” is a response option for the more detailed integral controls reporting, the DLC can evaluate the accuracy and effectiveness of this soft linkage to the NLC QPL using these products.

Key Questions: Controllability

1. Does the proposed dimming requirement conflict with other “quality” aspects of Version 5.0?
2. By not specifying explicit standards for dimming or control input, the DLC aims to make reporting simple and minimally burdensome, especially during this time of rapid evolution in the lighting industry. What risks do stakeholders face from this reduced rigidity?
3. Are there other aspects of controllability for lamps, luminaires, and retrofit kits that the DLC should consider within V5.0?
4. Are there other General Applications/Primary Usage Designations that should be exempted from a dimming requirement? If so, please provide data and rationale.
5. What capability information for integral controls should the DLC collect and report?

Please provide your responses to these key questions in the Excel-based SSL V5.0 Comment Form, under the Controllability tab.

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Other Topics Under Consideration

The DLC is considering a number of other topics to include in the next draft of V5.0 and requests comment from stakeholders on the following using the "Other Topics" tab in the Comment Form:

- From your individual industry perspective, rank Topics 1-6 in order of priority for the DLC to address.
- Do you support or not support the DLC addressing these topics as proposed?
- Identify any major issues or concerns you have with what is proposed with each topic and how they might be addressed.

Table 14: *Other topics under consideration for inclusion in Version 5.0*

Topic No.	Topic	Description
1	DLC Premium	The current DLC Premium designation is awarded to products that that achieve a higher level of efficacy (typically 15% higher than minimum DLC efficacy), demonstrate improved luminous flux maintenance performance ($L_{90} \geq 50{,}000$ hours), and pass an in-situ temperature measurement test of the driver. The DLC has received feedback that many products that achieve the Premium designation through higher efficacies have done so at the expense of lighting quality, for example by compromising the glare or optical control of the product which can be a trade-off with efficacy. The DLC is considering revising the Premium designation to incorporate additional quality metrics including glare, color quality, distribution, controllability, and other factors that would appropriately account for the potential trade-offs between efficacy and lighting quality, potentially using the tiers as proposed in this document. The DLC would seek to develop a system that would only award the Premium designation to products that demonstrate both high efficiency and quality of light performance.

Topic No.	Topic	Description
2	DLC Product Information Sheet	The DLC is considering a standardized .pdf "DLC Product Information Sheet" for each listing. This .pdf formatted sheet would combine both written and graphical product information and make it downloadable in a standardized format for QPL users. Designers, specifiers, and end-users could use these sheets to understand products and utilities could accept the sheets as evidence the product is listed. The sheet will include several plots or graphics made from QPL product data, enabling users to better understand the product data. This may include a manufacturer logo, manufacturer link, product photo, basic product information, as well as glare, distribution, flicker, color quality, and circadian performance information and charts. The sheet could either be customizable, where users can select what info they want on the spec sheet, or standardized, where the spec sheet and content is the same for every product. The sheet would reflect the date the product is qualified.
3	Non-Standard Form Factors	Manufacturers continue to leverage LED technology to create new form factors of luminaires that were not possible with traditional lighting technology. This innovation is exciting for the industry and can provide additional benefits; however, many of these products have been challenged in qualifying with the DLC because they do not align with the current DLC category and requirements structure that is based on traditional form factors. The DLC previously developed a system to allow manufacturers to specify a "Specialty" designation to allow some of these non-standard products to qualify under certain conditions; however, some products are still not able to align with this structure. The DLC is considering other approaches or mechanisms to enable new form factors of products that can demonstrate high quality and efficiency to be qualified. One concept under consideration is to create a broad new non-standard form factor or luminaire category for products that do not meet the current traditional form factor structure or any "Specialty" designations. While these products may not qualify for some utility program incentive or rebate offerings that are based on traditional product form factors and categories, they may qualify for other utility programs and provide value to other DLC stakeholders such as designers, specifiers, and end-users in ensuring the efficiency and quality performance of the products.
4	Platform Qualification	Similar to the non-standard form factors issue described above, some manufacturers have been challenged with qualifying certain types of products that are more modular in nature and built-to-order that do not match traditional form factors. The products that have been brought to the DLC's attention are typically linear products that can be built to any length, in some cases in increments of less than 1" and in total lengths that can exceed 100' or more. The number of unique configurations and SKUs of these products when

Topic No.	Topic	Description
		all of the length and other product options and variations are accounted for creates a scenario where many thousands of configurations would need to be individually qualified and listed with the DLC in order for a single modular product platform to be qualified. While these products may not qualify for some utility program incentive or rebate offerings that are based on traditional product form factors and categories, they may qualify for other utility programs and provide value to other DLC stakeholders such as designers, specifiers, and end-users in ensuring the efficiency and quality performance of the products.
5	Reference Housings	The DLC requires lamps and retrofit kits to be tested within traditional reference housings to demonstrate suitability of the product for the application in which it is meant to be used. Linear lamps are required to be tested as a bare lamp as well as in a troffer. This adds cost and complication to the testing and qualification process and creates challenges in obtaining the housings that are increasingly no longer sold. As the DLC has gained confidence in the performance of some of these products and has heard concerns of the variability in performance depending on which reference housing is used, it is under consideration to eliminate the reference housing requirement for linear lamps. The DLC is also investigating the necessity of reference housing testing for MogLEDs, CFLEDs, and retrofit kits. Additional concerns exist with MogLEDs, CFLEDs, and retrofit kits, which have less predictable performance, and both retrofit kits and MogLEDs are qualified for specific uses rather than general use like CFLEDs and TLEDs.
6	Dark-Sky Friendly Luminaires	The DLC is considering indicating glare-related light trespass and/or dark-sky rating compliance on the QPL, based on BUG Rating, for outdoor fixtures. These would give QPL users the ability to easily cross-reference the uplight and glare components of the BUG rating with the specification set by the International Dark-Sky Association or the Smart Outdoor Lighting Alliance.