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California Statewide Non-Residential LED Quality and Market Characterization Study

Part 2 – LED Market Characterization and Final Non-Residential LED Quality Criteria

Final Report

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EXECUTIVE SUMMARY

Navigant Consulting, Inc. (Navigant) was contracted by Pacific Gas and Electric Company (PG&E), on behalf of California's electric investor-owned utilities (IOUs), to conduct market research, including a market share study, in an effort to determine the size of the non-residential LED market and the relative market share of products on the DesignLights Consortium (DLC) Qualified Products List (QPL). This research also included the development of a proposed definition of "quality" for non-residential LED lighting. This Study was designed to include the following research objectives:

1. Within a set of DLC QPL priority product categories agreed upon by the California Investor-Owned Utilities (CA IOUs), how can the market for non-residential LED lighting be characterized?
    a. How will the non-residential LED lighting market evolve over the next 3-5 years?
    b. Which LED products require greater program assistance now and in the future?
    c. How will U.S. Department of Energy (DOE) energy efficiency lighting standards impact California's non-residential lighting baseline and energy efficiency code?
2. What is the market share of the DLC QPL and DLC "premium" for LED priority products?
3. What are the criteria and specification requirements that define non-residential LED products that exhibit top-half of lighting quality?
4. What proportion of the non-residential LED lighting market conforms to the lighting quality definition proposed in this study?

This report represents Part Two of the California Statewide Non-Residential LED Quality and Market Characterization Study and includes discussion of the methodologies and results of the LED market characterization, as well as revisions to the Preliminary California Non-Residential LED Lighting Quality Criteria (hereafter referred to as the "Criteria"), that are described in the Part One report.

ES 1. Methodology

In coordination with the lighting quality definition efforts in Part One, Navigant conducted a market characterization analysis on the non-residential LED market in California in this Part Two of the Study. The directive of the market evaluation is to identify which priority product categories capture the most significant shares of the California market, the shares of LED sales that are on the DLC QPL, and the range of product performance of these products sold.

The framework illustrated in Figure ES - 1 was used to develop the methodologies for Parts One and Two of the Study. The decision framework model for Part One, shown outside of the dotted boxed line, was used to help guide the lighting quality definition and Criteria development process. Part Two, which is the focus of this report, is shown within the dotted boxed line and outlines the methodology used for the market characterization and finalization of the Criteria based on public feedback from the Part One analysis.

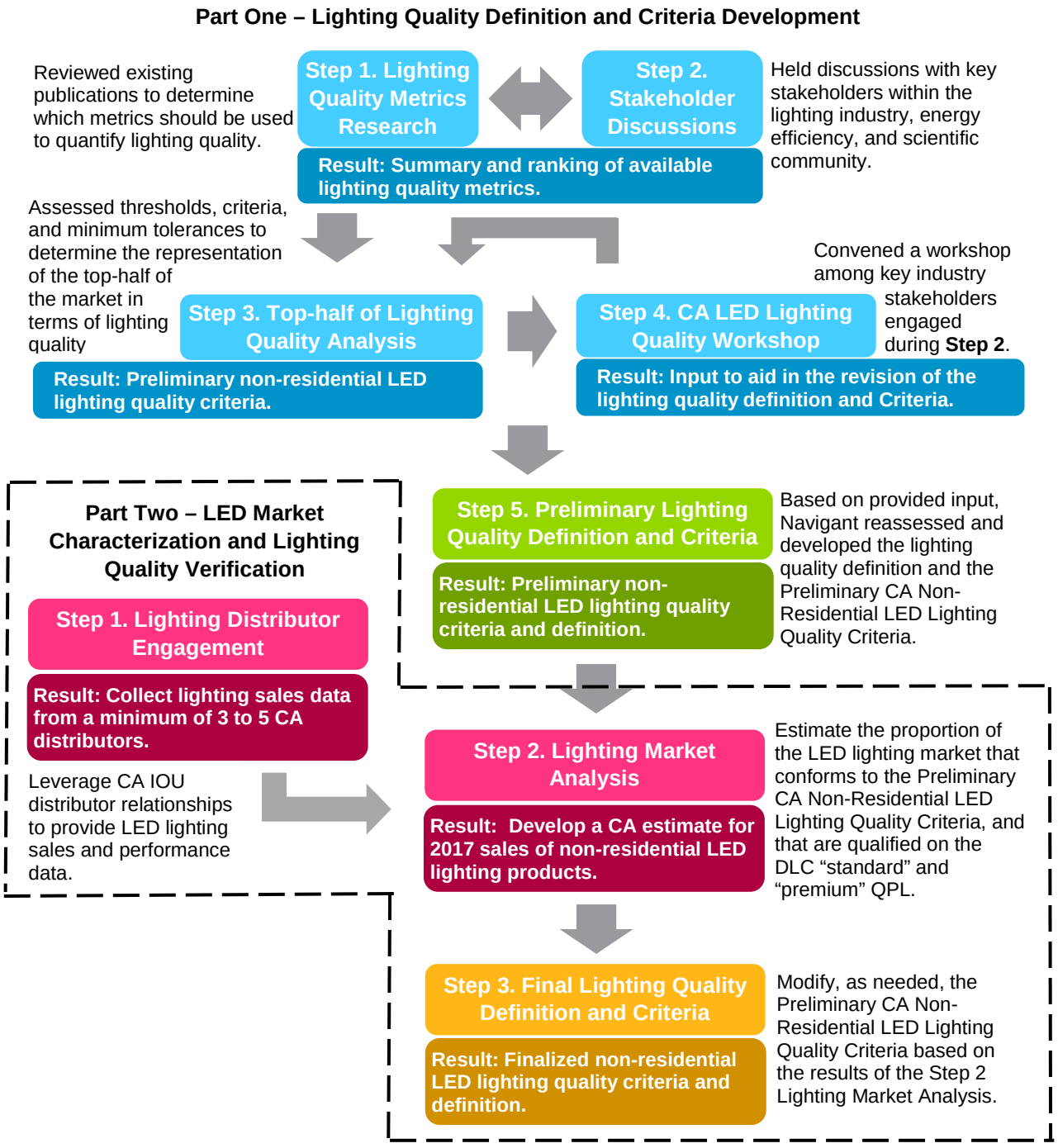

Figure ES - 1 Part One and Two of the Lighting Quality Definition and Criteria Framework Process

ES 2. California Non-Residential LED Market Characterization

As part of the California non-residential LED market characterization, Navigant analyzed the market size by product category, the market share of DLC qualified and ENERGY STAR certified products, and the market evaluation results compared to the finalized lighting quality definition. The market size and segmentation were estimated by using sales volume instead of SKUs available on the market.

As a data source for the market evaluation, Navigant engaged the top 20 lighting distributors (in terms of estimated 2017 sales) serving the California non-residential lighting market and was successful in receiving sales data from three primary distributors. These three distributors comprise approximately 20% of the California distributor market, which was estimated using the 2017 sales of the California branches for each major electrical distributor found in the Hoovers online company database.[1]

Overall, based on the distributor survey results combined with an analysis of available data, there were approximately 12 million non-residential LED products sold in California in 2017, and a majority of the overall sales were supplied to the indoor lighting market (84%). Of the indoor products, the most prominent product types are within the Ambient Commercial Lighting and Linear Replacement Lamps and Downlight categories. Pole/Arm-Mounted Area and Roadway luminaires comprise the most significant portion of the outdoor market.

Figure ES - 2 presents the estimated 2017 sales summarized by Criteria category, which align with the categories chosen for the LED lighting quality Criteria discussed in Section 4.2. In addition to the Ambient Commercial Lighting and Linear Replacement Lamps and Downlight categories, the Other category represents a large portion of the total 2017 sales. This category covers pin-base replacement LED lamps for CFLs and mogul-base replacement LED lamps for HID lamps, which are popular as convenient one-to-one replacements for many non-residential CFL and HID lamps.

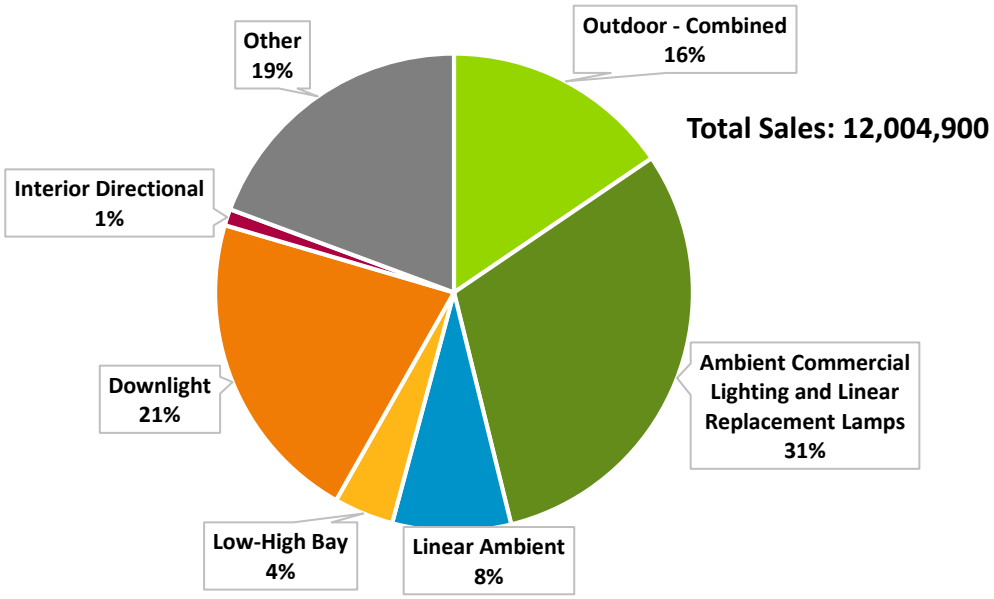

Figure ES - 2 Estimated 2017 Non-Residential LED Sales in CA by Criteria Category[2]

In terms of DLC and ENERGY STAR market penetration, approximately 41% of DLC-eligible products analyzed in the market evaluation were DLC Standard, and 14% of the products are listed as DLC Premium. Of indoor downlight products eligible under the ENERGY STAR specification, 80% were ENERGY STAR certified.

[1] http://www.hoovers.com/, last accessed December 21, 2018.

[2] These categories include luminaires, retrofit kits, and lamps, where applicable.

The analysis also determined the proportion of the non-residential LED lighting market that conforms to the lighting quality definition previously proposed in this Study. Of the indoor products analyzed with the distributor sales data, approximately 46% overall met the Criteria, while 43% of the outdoor products analyzed met the Criteria. Comparing these results with those discussed in Appendix B of Part One, Navigant concludes that the prescriptive minimum/maximum tolerances and the performance points for each point tier adequately represent products in the top-half of the market with regard to the proposed definition of lighting quality. However, it is recommended that the Criteria, if implemented, should be updated on a regular basis and would benefit from a full, comprehensive dataset that includes data for each metric within the Criteria. The analysis framework provided in this Study is a foundation for the Criteria to be optimized and enhanced over time.

ES 3. LED Lighting Quality

While lighting quality is dynamic, and its definition is ever-changing, the goal of Part One of this Study was to develop a procedure to evaluate an LED product's lighting quality relative to those available within California's non-residential lighting market. Therefore, Part One aimed to develop a lighting quality definition based on parameters and metrics that can be controlled at the product level, rather than at the application level or during installation. Based on this premise, and the input from the CA IOUs, California Energy Commission (CEC), and industry stakeholders, Navigant concluded that non-residential LED lighting quality can be defined based on its performance in the following parameter categories: Power Quality, Optical Performance, Reliability & Safety, Efficiency, Spectrum and Controllability. At this time, these six parameters best describe the categories of LED product performance which can be used to evaluate a product's lighting quality. It should be noted, however, that as the non-residential LED market continues to develop, these parameters could change or be enhanced based on R&D progress and the introduction of new product attributes.

Each of these parameters is described in the summary below, and the metrics considered within each quality parameter are described in detail in Section 3.2 of the Part One report. Table ES - 1 below illustrates how each of the evaluated lighting performance metrics maps to the lighting quality parameters identified for the Criteria. Metrics listed in bold font in Table ES - 1 were determined feasible to include in the Criteria.

Power Quality – Electricity-consuming products contribute to overall power quality in buildings and power grids. Building owners, utilities, and end users are affected by power quality, as electric power loads, transmission and distribution networks, circuitry in buildings, and visible flicker can be adversely impacted by poor management of power quality in lighting products.

Optical Performance – Lighting products are designed to meet a vast array of applications and task areas. In order to properly deliver light, in terms of light intensity and direction, manufacturers and lighting designers specify optical attributes that enable lighting products to meet customer and end-use application needs.

Reliability & Safety – A basic quality parameter for any lighting product is that it meets performance claims and operates safely for the duration of its use. In particular, LED products have very long anticipated lifetimes relative to much of the electrical equipment installed in non-residential buildings and outdoor spaces. Therefore, ensuring that products are reliable in meeting their rated light levels and spectral parameters for the duration of their rated lifetimes, while operating under safe conditions, is an important quality factor for LED products.

Efficiency – The ratio of the useful work performed by a product to the total energy expended is an important parameter throughout all electric appliance industries for rating quality. High efficiency products reduce electric load-burden and improve building performance. In the lighting industry, one of the most commonly analyzed product attributes is the ratio of light emitted over the power input required to produce it. Higher quality products are designed to optimize this ratio, while not overproducing light and causing unnecessary glare.

Spectrum – Human color perception is a vital aspect of lighting quality, as the spectral emission of the installed lighting products change the appearance of objects in a space. Lighting designers and specifiers use light spectrum parameters to select products for their intended applications. Quantifying and describing the product's light spectrum, in the most comprehensive manner, allows lighting designers and specifiers to appropriately design indoor and outdoor environments in which end users operate and perform tasks.

Controllability – A relatively new lighting parameter, controllability is a product's ability to be controlled during its useful life. Controls better enable a lighting product to provide the right amount and type of light where and when it is needed. The number and capabilities of controllable LED products continue to expand, as these products often lead to reduced consumption (i.e., dimmed light levels results in lower operating wattages), as well as increased human comfort and added services (e.g., health-centric lighting, asset tracking in retail settings, etc.). However, standardizing communication protocols and ensuring these systems offer interoperability between manufacturers, is key to customer and end user acceptance.

Table ES - 1 Lighting Quality Parameters and Metric Categorization

Power Quality	– **Total Harmonic Distortion (THD)** – Electrical Power Consumption – **Operating Frequency**	– **Power Factor** – Flicker Index – Percent Flicker	– Flicker (IEC P_{st}) – Stroboscopic Effect (SVM) – NEMA-77-2017
Optical Performance	– **Lumen Output** – **Zonal Lumen Density** – Perceived Luminance	– **Beam Angle Classification** – Upward Light Ratio – BUG Rating	– Visual Comfort Probability (VCP) – Unified Glare Rating (UGR)
Reliability & Safety	– **Lumen Maintenance** – **Color Maintenance** – **Driver ISTMT**	– **Warranty** – **IP Rating** – **Safety Certification**	
Efficiency	– **Luminous Efficacy** – Application Efficacy – Lighting Power Density	– Light Utilization – Power Supply Efficiency	
Spectrum	– **Color Rendering Index (CRI)** – **Correlated Color Temperature (CCT)** – Red Rendering (**R_9**)	– **Color Fidelity (Rf)** – **Color Gamut (Rg)** – Color Consistency	– **Color Angular Uniformity**
Controllability	– **Dimmability** – Networked Lighting Control Features – Communication Protocols (e.g., Bluetooth, Wi-Fi, Zigbee, etc.)	– Luminaire-Level Control Features	

Navigant identified that lighting quality can best be measured with a combination of prescriptive, performance, and reporting requirements. The prescriptive requirements raise the base level of quality to a minimum of, and in certain instances exceeding, the DLC or ENERGY STAR requirements, depending on the product category and lighting quality parameter. The performance requirements extend beyond

those outlined in the prescriptive requirements and incentivize manufacturers to improve the design of products based on tiered levels of lighting quality performance. Products that receive a performance score of greater than or equal to 50 meet the performance requirements. Lastly, Navigant recommended enhanced reporting requirements for metrics that are new to industry – yet vital to ensuring greater industry-wide transparency and accessibility to product information and data enabling consumers to make more informed decisions. Products that meet the requirements for each component – prescriptive, performance, and reporting – meet the California Non-Residential LED Lighting Quality Criteria. This blended approach best serves to comprehensively ensure that the Criteria successfully depicts the quality of LED lighting products entering the California market.

ES 4. Limitations and Challenges

Navigant identified several challenges that arose when developing the Criteria (in Part One) and conducting the non-residential LED market characterization (in Part Two). These limitations and challenges are focused on the following areas: data availability; lighting quality definition and available metrics and test methods; and product-level vs. application-level metrics.

- **Data Gaps**: Resources such as the DLC's QPL and DOE's LED Lighting Facts database were essential during the lighting quality analysis effort to understand the statistical distribution and variations in product performance for various metrics. However, these datasets have significant data gaps. For well-established metrics, such as L70 lumen maintenance, dimmability, and R9, lack of reported LED product data limits the ability of Part One of this Study to determine the representative distribution of performance. In addition, metrics such as IP Rating, operating frequency, color fidelity (Rf), and color gamut (Rg) are often not reported. Without knowing the distribution of performance for these important lighting quality metrics, the ability of this analysis to determine the products representing the top-half of lighting quality is limited.
- **Lack of Quantifiable Metrics**: Lighting quality is dependent on multiple factors – including visibility, comfort, function, color, and health. Many of these factors are still debated within the academic and research community, while others have no quantifiable metrics to enable quality assessment. The struggle is in the development and application of numeric metrics to provide an indication of top level lighting quality. For example, metrics for flicker, glare, color consistency, and communication protocols were all identified by industry stakeholders as important to lighting quality; however, none of the available metrics are currently feasible to include based on the lack of industry-accepted test methods or precedent through existing specifications. Part One of this Study aimed to define lighting quality for inclusion within the Criteria, though it is important to acknowledge that this Study is limited to the best available metrics.
- **Application-Based Quality**: One of the main challenges associated with defining lighting quality is that it is highly dependent on the end-use application. For example, a high bay LED luminaire that is installed in a warehouse will need to be optimized for drastically different operating conditions and lighting quality parameters compared to one installed in a gymnasium. Because the Criteria is limited to those metrics that can be controlled at the product-level, or point-of-sale, there are several metrics that are important to lighting quality that cannot feasibly be included. Metrics such as application efficacy, lighting power density, light utilization, and perceived luminance are not feasible to include because they must be measured when the LED is "in-installation." While the Criteria does enable the identification of products representing the top-half of lighting quality for the non-residential LED market, it is still critical to ensure the right quality product is installed for a given application.
- **Distributor Data Availability**: Although the data received in the distributor engagement process were substantial, the detailed product categories analyzed in this Study are inherently specific

and, in some cases, represent niche product applications servicing small segments of California's non-residential lighting market. Therefore, the product types analyzed in the market evaluation were limited to those provided in the distributor data. In some cases, where LED sales data were limited, the estimated CA sales of these categories were adjusted to more accurate market magnitudes as described in Step 3 in Section 2.2.2. However, for categories that were not represented in the distributor sales data received, they were not analyzed or represented in the results of the market evaluation portion of the Study. Further, Section 2.2.2 details other steps taken to make the market estimates relevant, which introduce additional uncertainty. Similarly, for the DLC penetration analysis, data availability presented a challenge with estimating the market shares of DLC qualified products at the detailed level of the priority product category. Product categories with smaller sample sizes have greater uncertainty and are subject to a higher level sensitivity in the market characterization.

ES 5. Recommendations

Navigant has identified the following recommendations for consideration by the CA IOUs and other stakeholders:

Program Emphasis on Key Product Categories

CA IOUs should provide program assistance to priority categories that have the most market leverage and potential energy savings impact. Navigant identified several product categories – low and high bay, ambient commercial lighting and linear replacement lamps, downlights, and outdoor products – that are well-positioned in the market currently, expected to grow significantly in the next 5-7 years, and have the greatest energy savings potential based on legacy technologies currently installed. To accelerate the adoption of LED technologies in these applications and achieve significant energy savings, the CA IOUs should continue to place program emphasis on these product categories.

Criteria Results and Implementation

Move forward with the blended prescriptive, reporting, and performance approach to the Criteria. The research and analysis showed that the representation of the top-half of the market in terms of lighting quality is best identified by a combination of prescriptive, reporting, and performance criteria. In particular, the performance criteria, which is implemented through the Lighting Quality Rating described in Section 4.2.3, rewards higher performance using a tiered point structure. In addition, several industry stakeholders were in favor of the performance approach since it incentivizes increased lighting quality performance while allowing for tradeoffs between the metrics included.

The Criteria has been vetted with key industry stakeholders to ensure LED products meeting the Criteria are of high lighting quality when compared to those qualified by the DLC and ENERGY STAR. Additionally, existing data from the DOE's LED Lighting Facts database and DLC's QPL were used to optimize the Lighting Quality Rating approach. The results of this optimization are discussed in Appendix B of Part One.

Utilize the LED Product Quality Evaluation Tool to analyze LED products meeting or not meeting the Criteria. This tool aids in determining the appropriate metrics and thresholds that represent the top-half of the market for LED non-residential products in terms of the proposed definition of lighting quality. The LED Product Quality Evaluation Tool should be updated annually, if the Criteria is implemented in practice, to evaluate future versions of each database, as well as additional metrics and revised performance tolerances as needed. This update process will help to ensure that LED products available

are able to meet any future revised Criteria and that any future revised Criteria continues to represent the top-half of the market in terms of the proposed definition of lighting quality.

Use the outcomes of this initial Criteria analysis, paired with those of the non-residential market characterization, as justification to defer to DLC and ENERGY STAR for program incentive requirements. The results of the Criteria analysis, the proposed definition of lighting quality, and the market characterization depict a market snapshot that confirms the most suitable approach for the CA IOUs is to reference DLC and ENERGY STAR for program incentive qualification instead of implementing the Criteria in practice. Section 3.2.2 details that the DLC market penetration of the 2017 sales was approximately 55%, which generally aligns with the top-half of lighting quality initiative in this Study. Additionally, manufacturers and other stakeholders noted during the stakeholder engagement process that the testing and verification considerations with this type of implementation would require program bandwidth and support staff that would be difficult for California to provide. As such, Navigant recommends the CA IOUs use the insights found in this evaluation as feedback to monitor DLC and ENERGY STAR developments and provide feedback where necessary to ensure lighting quality is continually emphasized by those organizations.

Trial Run of Data Reporting and Criteria Scoring Evaluation

Engage with stakeholders to encourage participation in a trial run of the Criteria. Stakeholder feedback received at various phases of the Study suggested there could be issues with a compliance system designed for the Criteria implementation and the current lack of available data for metrics considered in the Criteria. Should the Criteria be implemented by California, Navigant proposes to install a trial period (e.g., 6 months) of the Criteria prior to the CA IOUs putting it into effect. The threshold for incentives during this period could remain as currently structured, with the addition of manufacturers submitting the data needed for Criteria participation. After or during the trial run, the Criteria can be re-evaluated and optimized based on an accurate and up-to-date full dataset.

DLC and ENERGY STAR Requirements

Align with DLC Technical Requirements and ENERGY STAR Program Requirements. Stakeholder engagement and research showed that DLC and ENERGY STAR are the most established organizations for developing specification tolerances and thresholds that influence product design and lighting quality. As such, CA IOUs should continue to reference the most current versions of the DLC Technical Requirements (currently V4.4) and the ENERGY STAR Program Requirements Product Specification for Luminaires (Light Fixtures) Eligibility Criteria (currently V2.1) as first levels of qualification for the Criteria. In coming months, DLC Technical Requirements v5.0 will likely be finalized (per comments received by DLC representatives on Part One of this Study), which is set to include several additional metrics related to quality. The CA IOUs should review this document when published and update references within the Criteria to DLC v5.0 if applicable.

Maintain ongoing coordination with DLC and ENERGY STAR. CA IOUs should monitor and examine changes made within each new version of the DLC Technical Requirements and ENERGY STAR Program Requirements. Contact should be maintained between the CA IOUs, DLC, and ENERGY STAR representatives as new versions of each organization's specifications or criteria are being developed to align interests with industry and minimize conflicts with the California Non-Residential LED Lighting Quality Criteria.

Test and Verification Considerations

Work with the CPUC and CEC to determine the most suitable route forward for ensuring product compliance. Stakeholders suggested that fully developing the structure of a testing and verification system parallel to finalizing the Criteria is vital to ensuring high quality products are adopted by customers as a result of the Criteria's implementation. Therefore, should the Criteria be implemented in practice after conferring with the CPUC, the CA IOUs should work with the CPUC and CEC to determine the most viable route to ensure product compliance.

Consider three potential testing and verification pathways identified as a starting point for the CA IOUs, CPUC, and CEC. If implemented, these pathways for the Criteria's testing and verification are as follows: 1) allow manufacturers to self-report certification data, 2) CA implement its own testing and verification system, or 3) CA could leverage the DLC and ENERGY STAR reporting infrastructures.

Future Revisions

Utilize the outlined Criteria Future Revisions Plan for updating the Criteria, if implemented in practice. Several key industry stakeholders emphasized the need for the CA IOUs to remain vigilant as new metrics and test methods become available for defining and quantifying lighting quality for LED products. In addition, stakeholders commented that revisions should be continued for the Criteria, preferably on an annual basis. The LED industry is evolving rapidly, and industry standards and metrics are continually developed to assess the performance of products coming to market.

In order to maintain the relevancy of the Criteria if it is implemented, the CA IOUs should refer to Section 4.4 which describes the recommended process for updating the Criteria, This Criteria Future Revisions Plan indicates the CA IOUs should 1) review new and updated metrics, test methods and industry-accepted tolerances, 2) continually engage with key stakeholders, 3) regularly update the LED Product Quality Evaluation Tool with new products, and lastly 4) propose new metrics and tolerances for consideration with the CPUC.

1. INTRODUCTION

Lighting has been a major and important part of California's electric Investor-Owned Utilities ("IOUs") Energy Efficiency portfolio for more than a decade, and the lighting market is changing. There are changes in available technology, with an increasing number and variety of products, manufacturers and sales channels. The evolution of the lighting market, and particularly the emergence of light emitting-diode (LED) technology, has led to greater uncertainty and presents challenges to the CA IOUs' Statewide Program team and their goals to better serve their customers and improve energy savings' reporting to the California Public Utilities Commission ("CPUC"). It is important that the CA IOUs only offer incentives for quality lighting products that meet customer expectations and result in a favorable lighting experience.

This research includes a market share study, which is an effort to determine the size of the non-residential LED market in California and the relative market share of products on the DesignLights Consortium (DLC) Qualified Products List (QPL). This research also includes the development of a proposed definition of "quality" for non-residential LED lighting.

1.1 Research Objectives and Scope

This Study includes the following research objectives:

1. Within a set of DLC QPL priority product categories agreed upon by the CA IOUs, how can the market for non-residential LED lighting be characterized?
    a. How will the non-residential LED lighting market evolve over the next 3-5 years?
    b. Which LED products require greater program assistance now and in the future?
    c. How will U.S. Department of Energy (DOE) energy efficiency lighting standards impact California non-residential lighting baseline and energy efficiency code?
2. What is the market share of the DLC QPL and DLC "premium" for LED priority products?
3. What are the criteria and specification requirements that define non-residential LED products that exhibit top-half of lighting quality?
4. What proportion of the non-residential LED lighting market conforms to the lighting quality definition proposed in this study?

From the research objectives, Navigant has divided the Study into two major tasks, the first being the LED lighting quality definition and criteria development, and the second is an LED market characterization. This report represents Part Two of the California Statewide Non-Residential LED Quality and Market Characterization Study and includes discussion of the methodologies and results of the LED market characterization, as well as revisions to the Preliminary California Non-Residential LED Lighting Quality Criteria (hereafter referred to as the "Criteria"), that are described in the Part One report.[3] The directive of the market evaluation is to identify which priority product categories capture the most significant shares (in terms of sales) of the California market, the shares of LED sales that are on the DLC QPL, and the range of product performance of these products sold. The remainder of this report is organized as follows:

- **Section 2: Methodology** presents a discussion of the approach used to address research objectives for the LED market characterization and revision process for the non-residential LED lighting quality definition and criteria development.

[3]California Statewide Non-Residential LED Quality and Market Characterization Study, Part 1 – Preliminary Non-Residential LED Quality Criteria. Submitted for public comment in August 2018.

- **Section 3: LED Market Characterization** describes the results of the non-residential LED market characterization in California, including the proportion of the market that is DLC qualified, and how the market evaluation effort affects the final lighting quality definition and Criteria.
- **Section 4: LED Lighting Quality** describes revised criteria used to define non-residential LED lighting quality and highlights the changes from those presented in the Part One report.
- **Section 5: Recommendations** provides Navigant's recommendations to the CA IOUs based on the results and outcomes of Part Two – LED Market Characterization and Final Non-Residential LED Quality Criteria for the Study.

2. METHODOLOGY

This section details the selected approach for each research objective and discusses the LED product categories considered for Part Two of the Study – LED Market Characterization and Final Non-Residential LED Quality Criteria (hereafter referred to as "Part Two").

2.1 Approach Overview

Navigant considered several potential approaches to address the set of key research objectives relevant to Part Two. Given the resources available and the nature of the research objectives at hand, Navigant proposed the following high-level approach for this, Part Two of, the California Statewide Non-Residential LED Quality and Market Characterization Study:

Part Two – LED Market Characterization and Final Non-Residential LED Quality Criteria

1. Lighting distributor engagement – Corresponded with electrical distributors based in California to collect non-residential LED sales data.
2. LED lighting market analysis – Evaluated distributor sales data and the overall CA electrical distributor market to develop a scaled California statewide estimate that characterizes the California non-residential LED market, including what proportion of the non-residential LED market the DLC QPL represents.
3. Final lighting quality definition and criteria – Used results of market analysis and public comment feedback to inform updates to the lighting quality definition and California Non-Residential LED Lighting Quality Criteria.

The approaches for each major component of Part Two are discussed in greater detail in the following Section 2.2.

2.2 LED Market Characterization

In coordination with the lighting quality definition efforts in Part One, Navigant conducted a market characterization analysis on the non-residential LED market in California in this Part Two of the Study. As mentioned, the directive of the market evaluation is to identify which priority product categories capture the most significant shares (in terms of sales) of the California market, the shares of LED sales that are on the DLC QPL, and the range of product performance of these products sold.

The framework illustrated in Figure 2-1 was used to develop the methodologies for Parts One and Two of the Study. The decision framework model for Part One, shown outside of the dotted boxed line, was used to help guide the lighting quality definition and Criteria development process. Part Two, which is the focus of this report, is shown within the dotted boxed line and outlines the methodology used for the market characterization and finalization of the Criteria based on public feedback from the Part One analysis.

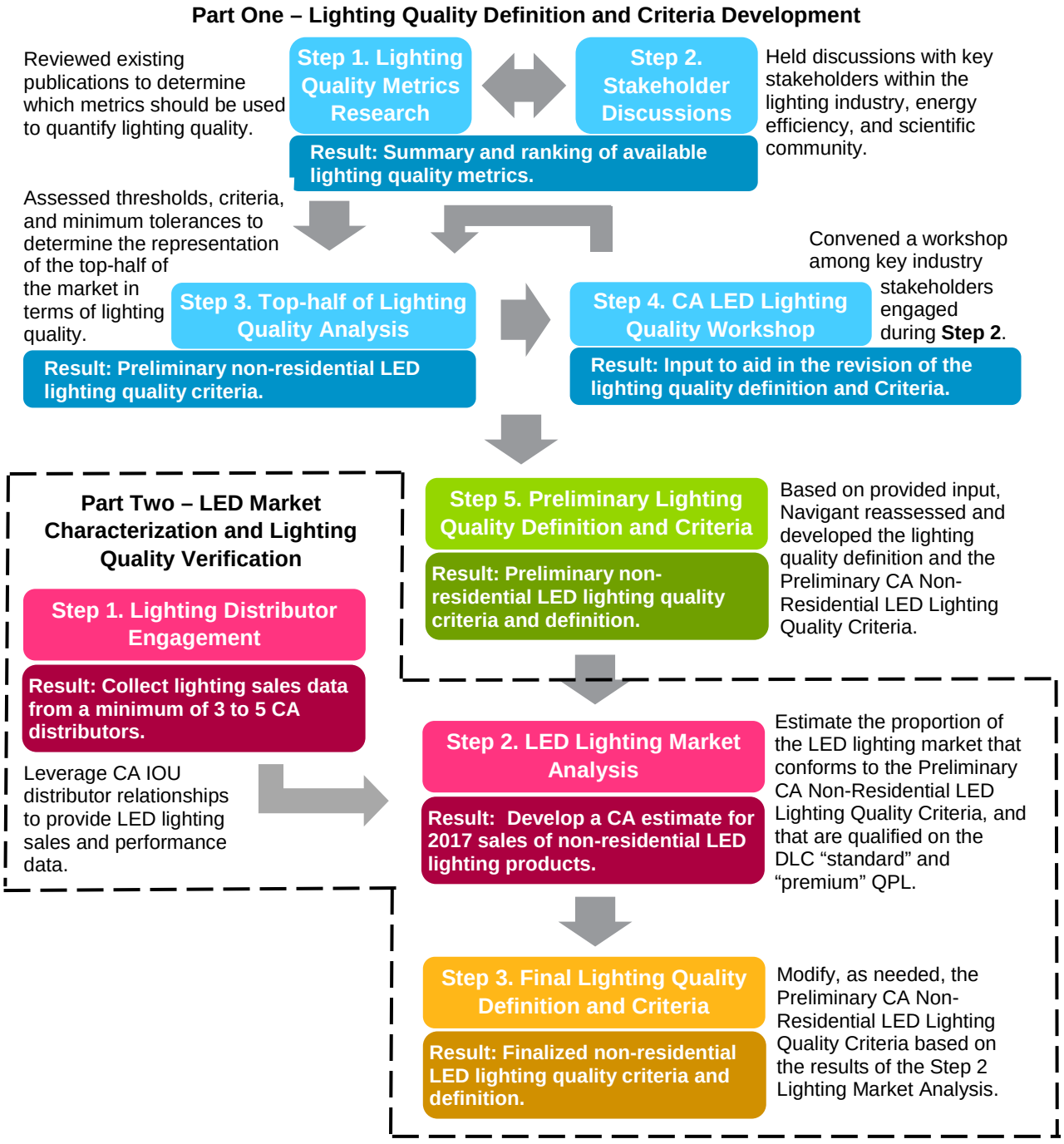

Figure 2-1. Parts One and Two of the Lighting Quality Definition and Criteria Framework Process

2.2.1 Lighting Distributor Engagement

Data quality and quantity are vital in any market evaluation effort. As such, Navigant identified that an ideal data source for the non-residential lighting market is through electrical distributors. Distributors have localized representation in California, and their lighting sales represent a majority of the non-residential

sales on the market.[4] Navigant, with support from the CA IOUs' lighting program staff, leveraged established relationships with California distributors to contact and incentivize distributors to confidentially share their California lighting sales data for this Study. The required objective of this effort was to collect detailed sales inventory data on non-residential LED products sold (indoor and outdoor) from a minimum of three distributors.

Navigant estimated the 2017 sales of the California branches for each major electrical distributor using the Hoovers online company database.[5] This process enabled the identification of California's largest and top-selling distributors. Out of nearly 200 electrical distributors with California branches, it was found that the top 20 cumulatively account for 90% of the California distributor market. Therefore, Navigant and the CA IOUs focused data collection efforts on the top 20 distributors, whose estimated 2017 California sales and cumulative market shares are shown in Table 2-1. The team was successful in receiving detailed sales inventory data from the distributors listed in **bold**, which represent approximately 20% of the California distributor market. Data sharing efforts were completed under confidentiality agreements, thus all provided data were aggregated together and distributor-specific information (such as in Table 2-1) is presented without the distributor names attached.

Table 2-1. Summary of California Distributor Market Shares (including all Electrical Products)

Distributor Rank	Total 2017 CA Sales ($ Millions)	Cumulative % of CA Distributor Market
1	**$592**	**14%**
2	$592	27%
3	$485	38%
4	$474	48%
5	$385	57%
6	$360	65%
7	$169	69%
8	**$167**	**73%**
9	$146	76%
10	$118	78%
11	$106	81%
12	**$97**	**83%**
13	$83	85%
14	$54	86%
15	$45	87%
16	$36	88%
17	$31	89%

[4] The "2015 Non-Residential Lighting Market Characterization" conducted for BPA assumed that 85% of total sales flow through wholesale distribution, based on interviews with manufacturers and distributors.
https://www.bpa.gov/EE/Utility/research-archive/Documents/Momentum-Savings-Resources/2015_Non-Res_Lighting_Market_Characterization.pdf

[5] http://www.hoovers.com/, last accessed December 21, 2018.

18	$30	89%
19	$30	90%
20	$14	90%

2.2.2 Non-Residential LED Lighting Market Analysis

The objective of the non-residential LED market analysis was to estimate the size and performance of the products entering the California market in 2017. Specifically, the evaluation was conducted to determine the product types with the most units sold, the DLC and ENERGY STAR market shares of each priority product category, and the product categories' performance with respect to the metrics proposed within the Criteria in Part One of this Study.

After data collection efforts were completed (discussed in Section 2.2.1), Navigant underwent a detailed data cleaning process to fill data gaps pertaining to the lighting performance metrics considered in the Criteria analysis. Navigant also standardized each product type sold to align with the priority product categories listed in Table 2-2 for comparison in the market evaluation. The market size and segmentation were then estimated by using sales volume instead of SKUs available on the market. This is due, in large part, to the vast number of SKUs on the market and the typical product cycling of SKUs by manufacturers.

Table 2-2. LED Products Covered by the CA Non-Residential LED Lighting Quality Criteria

#	Criteria Category[6]	Priority Luminaire, Retrofit, and Lamp Product Types[7]	Indoor/Outdoor	Type
1	Outdoor: Low, Mid, High, Very High Output	Outdoor Pole/Arm-Mounted Area and Roadway Luminaires	Outdoor	Luminaire
2		Retrofit Kits for Outdoor Pole/Arm-Mounted Area and Roadway Luminaires	Outdoor	Retrofit
3		Retrofit Kits for Large Outdoor Pole/Arm-Mounted Area and Roadway Luminaires	Outdoor	Luminaire
4		Outdoor Full-Cutoff Wall-Mounted Area Luminaires	Outdoor	Luminaire
5		Outdoor Non-Cutoff and Semi-cutoff Wall-Mounted Area Luminaires	Outdoor	Luminaire
6		Retrofit Kits for Outdoor Full-Cutoff Wall-Mounted Luminaires	Outdoor	Retrofit
7		Parking Garage Luminaires	Outdoor	Luminaire
8		Retrofit Kits for Parking Garage Luminaires	Outdoor	Retrofit
9		Fuel Pump Canopy Luminaires	Outdoor	Luminaire
10		Retrofit Kits for Fuel Pump Canopy Luminaires	Outdoor	Retrofit
11		Landscape/Accent Flood, Spot Luminaires and Wall-Wash Luminaires	Outdoor	Luminaire
12		Architectural Flood and Spot Luminaires	Outdoor	Luminaire
13		Stairwell/Passageway Luminaires	Outdoor	Luminaire
14	Ambient Commercial Lighting and Linear Replacement Lamps	1x4, 2x2, and 2x4 Luminaires for Ambient Lighting of Interior Commercial Spaces	Indoor	Luminaire
15		Integrated-Style Retrofit Kits for 1x4, 2x2, and 2x4 Luminaires for Ambient Lighting of Interior Commercial Spaces	Indoor	Retrofit
16		Linear-Style Retrofit Kits for 2x2, 1x4, and 2x4 Luminaires for Ambient Lighting of Interior Commercial Spaces	Indoor	Retrofit
17		T12/T8/T5/T5HO Linear Replacement Lamps	Indoor	Lamp
18	Linear Ambient	Linear Ambient Luminaires with Indirect Component	Indoor	Luminaire
19		Direct Linear Ambient Luminaires	Indoor	Luminaire
20		Retrofit Kits for Direct Linear Ambient Luminaires	Indoor	Retrofit
21	Low-High Bay	High-Bay Luminaires for Commercial and Industrial Buildings	Indoor	Luminaire
22		Low-Bay Luminaires for Commercial and Industrial Buildings	Indoor	Luminaire
23		High-Bay Aisle Luminaires for Commercial and Industrial Buildings	Indoor	Luminaire
24		Retrofit Kits for High-Bay Luminaires for Commercial and Industrial Buildings	Indoor	Retrofit
25		Retrofit Kits for Low-Bay Luminaires for Commercial and Industrial Buildings	Indoor	Retrofit
26	Downlight	Downlight Luminaires	Indoor	Luminaire
27		Downlight Retrofits	Indoor	Retrofit
28	Interior Directional	Track or Mono-Point Directional Luminaires	Indoor	Luminaire
29	N/A	Pin-Based Replacement LED Lamps for CFLs	Indoor	Lamp
30	N/A	Mogul Screw-Base (E39) Replacement LED Lamps for HID Lamps	Indoor/Outdoor	Lamp

To estimate the 2017 statewide sales, Navigant employed the following scaling methodologies and adjustments to the distributor sales inventory data.

[6] See Section 4.2 for the finalized Criteria. These Criteria categories were aggregated for coordination with DLC and ENERGY STAR product categories. Summarized results of the market evaluation and the Performance Criteria in Section 4.2 are presented at this aggregated level. Pin-Based Replacement LED Lamps for CFLs and Mogul Screw-Base (E39) Replacement LED Lamps for HID Lamps were included in the market characterization portion of the study, but stakeholder feedback in Part One suggested to omit these lamps from inclusion in the Criteria scope for performance-based reasons.

[7] Where data granularity and abundance allow, the results of the market characterization are presented at the priority product category level. In other cases, the results are presented at the Criteria product category level, which align with the DLC general applications and can be found here: https://www.designlights.org/default/assets/File/Workplan/DLC_Technical-Requirements-Table-V4-4.pdf.

- ***Step 1 –Distributor Scaling Factor and Weighting***: As shown in Section 2.2.1, the distributor engagement team was successful in receiving sales data from three prominent distributors that comprise approximately 20% of the California non-residential distributor market. To estimate the size of the California market, Navigant calculated a scaling factor using the annual sales of the remaining top 20 distributors serving the California lighting market. In an attempt to ascertain the product mix (i.e., the types of LED products sold vs conventional technologies) of the remaining top 20 distributors, Navigant compiled the counts of online product offerings for each distributor ("in-scope" LED products and conventional products) to compare to the offerings of the three distributors that provided data. This exercise yielded an adjustment to the initial scaling factor to better represent the market share of "in-scope" LED products that are within the priority product categories list (shown in Table 2-2).
- ***Step 2 – 2017 Baseline Adjustment***: One distributor provided sales data over a three-year period (2016 – 2018) without a "date sold" field tied to each product, so these data points were normalized to the 2017 analysis year. To do so, a second adjustment factor was calculated by using the historical and forecasted LED adoption rates[8] for each year to isolate the approximate total products sold in 2017 out of the three-year period.
- ***Step 3 – Comparison to U.S. DOE LED Adoption Sales Estimates***: Navigant leveraged the DOE Lighting Model to estimate the magnitude of California non-residential LED lighting sales by distributors as a comparison to the scaled sales data from Step 2. This lighting model includes estimated national sales inputs in various applications and submarkets (e.g., linear lamps in the commercial sector, low/high bay luminaires in the industrial sector, etc.), and to scale these values to the California statewide level (instead of national), California's portion of U.S. non-residential floorspace and road miles (for street/roadway products) were applied. The magnitude of the initial scaled sales data was approximately four times less than the estimated California sales from the U.S. DOE Lighting Model.
- ***Step 4 – California ACEEE[9] Adjustment Factor***: Since California represents a progressive region in terms of energy efficiency policy and technology adoption, Navigant applied a final adjustment to the magnitude of the estimated 2017 sales based on the CA IOUs' rankings in the ACEEE's "2017 Utility Energy Efficiency Scorecard." PG&E, SCE, and SDG&E are all in the top 10 of this scorecard, which serves as a quantifiable way to analyze the progressiveness of California's energy efficiency policies and initiatives. After developing the national scaling factor in Step 3 (which evaluated each state equally in terms of LED adoption progressiveness), this Step 4 methodology enabled Navigant to provide California with a greater LED sales weight relative to other states within the U.S.

Section 3 discusses the results of the analysis, highlighting the product categories that comprise significant shares of the market, their performance characteristics, and the penetration of DLC qualified and ENERGY STAR certified products in each eligible category. As shown in Section 3.1, detailed data were not provided for each product category. While the detailed results are not provided for these product categories, the analysis ensured that the total market size estimates are accurate through the use of the national scaling data in Step 3 above.

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[8] U.S. Department of Energy Solid-State Lighting Program, "Energy Savings Forecast of Solid-State Lighting in General Illumination Applications." September 2016. https://www.energy.gov/sites/prod/files/2016/10/f33/energysavingsforecast16_0.pdf

The model used for this report is annually updated with inputs from manufacturer interviews to estimate total annual sales for the U.S. in various lighting applications.

[9] American Council for an Energy Efficient Economy, "2017 Utility Energy Efficiency Scorecard." June 2017. https://aceee.org/sites/default/files/publications/researchreports/u1707.pdf

2.2.3 Final Lighting Quality Definition and Criteria

Based on the results of the non-residential LED market characterization and public comments received on Part One, Navigant reassessed and finalized the Criteria and lighting quality definition. Section 4 details updates made to the finalized Criteria.

As discussed in Part One, Navigant identified that lighting quality can best be measured with a combination of prescriptive, performance, and reporting requirements, where products that represent the top-half of the market can be identified by the proposed definition of lighting quality in Section 4.1. This approach was maintained after the Part Two analysis. The prescriptive requirements raise the base level of quality to a minimum of, and in certain instances exceeding, the DLC or ENERGY STAR requirements, depending on the product category and lighting quality parameter. The performance requirements extend beyond those outlined in the prescriptive requirements and incentivize manufacturers to improve the design of products based on tiered levels of lighting quality performance. Products that receive a performance score of greater than or equal to 50 meet the performance requirements. Lastly, Navigant has recommended enhanced reporting requirements for metrics that are new to industry – yet vital to ensuring greater industry-wide transparency and consumer accessibility to product information and data that enables more informed decision-making – such as the color rendition test methods incorporated by IES TM-30-18.

Products that meet the requirements for each component – prescriptive, performance, and reporting – meet the California Non-Residential LED Lighting Quality Criteria. This blended approach best serves to comprehensively ensure that the Criteria successfully depicts the quality of LED lighting products entering the California market.

2.3 Limitations and Challenges

In this Part Two report, Navigant encountered several challenges while evaluating the California non-residential LED market and finalizing the Criteria. While each of the limitations and challenges discussed in the Part One report remain relevant in Part Two, the most significant challenge to the Part Two analysis was regarding data availability.

Although the data received in the distributor engagement process were substantial, the detailed product categories analyzed in this Study are inherently specific and, in some cases, represent niche product applications servicing small segments of California's non-residential lighting market. Therefore, the product types analyzed in the market evaluation were limited to those provided in the distributor data. In some cases, where LED sales data were limited, the estimated CA sales of these categories were adjusted to more accurate market magnitudes as described in Step 3 in Section 2.2.2. However, for categories that were not represented in the distributor sales data received, they were not analyzed or represented in the results of the market evaluation portion of the Study. Further, Section 2.2.2 details other steps taken to make the market estimates relevant, such as the need to scale data representing 20% of the distributor market to the remaining portion of the market, which introduces additional uncertainty.

Similarly, for the DLC penetration analysis, data availability presented a challenge with projecting the market shares of DLC qualified products at the detailed level of the priority product category. Product categories with smaller sample sizes have greater uncertainty and are subject to a higher level of sensitivity in the market characterization.

3. CALIFORNIA NON-RESIDENTIAL LED MARKET CHARACTERIZATION

This section discusses the results of the California non-residential LED market evaluation, including details on the data sample received from the electrical distributors, the segmentation and size estimation of the non-residential LED market in California, and the comparison of the lighting distributor data to the Criteria developed in Part One of the Study.

3.1 Lighting Distributor Sampling

As discussed in Section 2.2.1, Navigant engaged the top 20 lighting distributors (in terms of estimated 2017 sales) serving the California non-residential lighting market and was successful in receiving sales data from three primary distributors. These three distributors comprise approximately 20% of the California distributor market, and this section discusses the data characteristics of the sample received from these distributors.

After the initial data cleaning effort was completed, Navigant found that there were 863 unique entries[10] of usable LED sale records to analyze, representing over 200,000 LED products sold. Some LED products included were out of the scope of the analysis (e.g., general purpose lamps, decorative lamps and fixtures, exit signs, etc.), so these products were filtered out of the market evaluation study. The resulting final sample size was 575 entries, and the sample size distribution among the priority product categories is shown in Table 3-1. In addition to standardizing the product types within the distributor data to the appropriate priority product categories, Navigant cross-referenced each in-scope product with the DLC QPL and ENERGY STAR certified products list. Lastly, data gaps pertaining to the performance Criteria metrics (e.g., wattage, lumen output, efficacy, lifetime, CRI, dimmability, power factor, THD, R9, etc.) were filled in using manufacturer catalog information, where applicable.

[10] The amount of unique entries in the distributor sales data gives an initial sense of the distribution of product types and performance within the dataset.

Table 3-1 Data Sample Distribution for Priority Product Categories

#	Criteria Category	Priority Luminaire, Retrofit, and Lamp Product Types	Indoor/ Outdoor	Type	Sample Quantity	Representation of Total Sample
1	Outdoor: Low, Mid, High, Very High Output	Outdoor Pole/Arm-Mounted Area and Roadway Luminaires	Outdoor	Luminaire	14	2%
2		Retrofit Kits for Outdoor Pole/Arm-Mounted Area and Roadway Luminaires	Outdoor	Retrofit	1	<1%
3		Retrofit Kits for Large Outdoor Pole/Arm-Mounted Area and Roadway Luminaires	Outdoor	Luminaire	0	0%
4		Outdoor Full-Cutoff Wall-Mounted Area Luminaires	Outdoor	Luminaire	34	6%
5		Outdoor Non-Cutoff and Semi-cutoff Wall-Mounted Area Luminaires	Outdoor	Luminaire	32	6%
6		Retrofit Kits for Outdoor Full-Cutoff Wall-Mounted Luminaires	Outdoor	Retrofit	1	<1%
7		Parking Garage Luminaires	Outdoor	Luminaire	6	1%
8		Retrofit Kits for Parking Garage Luminaires	Outdoor	Retrofit	0	0%
9		Fuel Pump Canopy Luminaires	Outdoor	Luminaire	6	
10		Retrofit Kits for Fuel Pump Canopy Luminaires	Outdoor	Retrofit	0	0%
11		Landscape/Accent Flood, Spot Luminaires and Wall-Wash Luminaires	Outdoor	Luminaire	0	0%
12		Architectural Flood and Spot Luminaires	Outdoor	Luminaire	35	6%
13		Stairwell and Passageway Luminaires	Outdoor	Luminaire	2	<1%
14	Ambient Commercial Lighting and Linear Replacement Lamps	1x4, 2x2, and 2x4 Luminaires for Ambient Lighting of Interior Commercial Spaces	Indoor	Luminaire	89	15%
15		Integrated-Style Retrofit Kits for 1x4, 2x2, and 2x4 Luminaires for Ambient Lighting of Interior Commercial Spaces	Indoor	Retrofit	6	1%
16		Linear-Style Retrofit Kits for 2x2, 1x4, and 2x4 Luminaires for Ambient Lighting of Interior Commercial Spaces	Indoor	Retrofit	6	1%
17		T12/T8/T5/T5HO Linear Replacement Lamps	Indoor	Lamp	66	11%
18	Linear Ambient	Linear Ambient Luminaires with Indirect Component	Indoor	Luminaire	1	<1%
19		Direct Linear Ambient Luminaires	Indoor	Luminaire	77	13%
20		Retrofit Kits for Direct Linear Ambient Luminaires	Indoor	Retrofit	4	1%
21	Low-High Bay	High-Bay Luminaires for Commercial and Industrial Buildings	Indoor	Luminaire	27	5%
22		Low-Bay Luminaires for Commercial and Industrial Buildings	Indoor	Luminaire	6	1%
23		High-Bay Aisle Luminaires for Commercial and Industrial Buildings	Indoor	Luminaire	0	0%
24		Retrofit Kits for High-Bay Luminaires for Commercial and Industrial Buildings	Indoor	Retrofit	0	0%
25		Retrofit Kits for Low-Bay Luminaires for Commercial and Industrial Buildings	Indoor	Retrofit	2	<1%
26	Downlight	Downlight Luminaires	Indoor	Luminaire	67	12%
27		Downlight Retrofits	Indoor	Retrofit	40	7%
28	Interior Directional	Track or Mono-Point Directional Luminaires	Indoor	Luminaire	11	2%
29	Other	Pin-Based Replacement LED Lamps for CFLs	Indoor	Lamp	23	4%
30		Mogul Screw-Base (E39) Replacement LED Lamps for HID Lamps	Indoor/ Outdoor	Lamp	19	3%
				Total	**575**	

As shown in the table and discussed in Section 2.3, several product categories had no reported sales or had limited entries from the distributors that provided data for this Study. While Navigant understands these products are sold in the market, the products without reported sales were not included in this analysis.

3.2 Non-Residential LED Market Size and Segmentation

The following three sections examine the results of the non-residential LED market characterization. Specifically, details are shared on the estimated market size by product category, the market share of DLC qualified and ENERGY STAR certified products, and the comparison of the market evaluation results to the lighting quality definition finalized in Section 4.

3.2.1 Estimated Market Size

The estimated sales for each analyzed product category are presented in Table 3-2 below. Overall, based on the distributor survey results combined with an analysis of available data, there were approximately 12 million non-residential LED products sold in California in 2017, and a majority of the overall sales were supplied to the indoor lighting market (84%). Of the indoor products, the most prominent product types are within the Ambient Commercial Lighting and Linear Replacement Lamps and Downlight categories. Pole/Arm-Mounted Area and Roadway luminaires comprise the most significant portion of the outdoor market.

Figure 3-1 presents the estimated 2017 sales summarized by Criteria category, which align with the categories chosen for the LED lighting quality Criteria discussed in Section 4.2. In addition to the Ambient Commercial Lighting and Linear Replacement Lamps and Downlight categories, the Other category represents a large portion of the total 2017 sales. This category covers pin-base replacement LED lamps for CFLs and mogul base replacement LED lamps for HID lamps, which are popular as convenient one-to-one replacements for many non-residential CFL and HID lamps.

The ratio of indoor (84%) to outdoor (16%) products sold similarly aligns with DOE's 2015 Lighting Market Characterization (LMC).[11] The 2015 LMC estimated that 90% of the non-residential lighting inventory are indoor products and 10% are outdoor products. This potentially suggests that in California, outdoor LED products could be replacing outdoor conventional technologies at a quicker rate than indoor LED products replacing indoor conventional technologies. Alternatively, this trend could be due a larger presence of outdoor lighting, in general, in California compared to other states, as it is one of the larger states by land area.

[11] U.S. Department of Energy, "2015 U.S. Lighting Market Characterization." November 2017. https://www.energy.gov/sites/prod/files/2017/12/f46/lmc2015_nov17.pdf

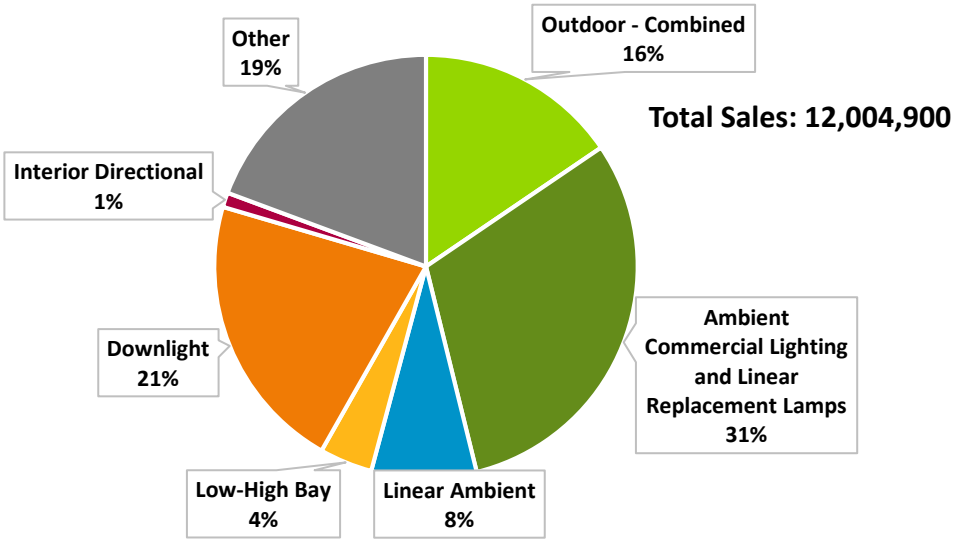


Figure 3-1 Estimated 2017 Non-Residential LED Sales in CA by Criteria Category

Table 3-2 California 2017 Non-Residential LED Market Characterization Key Results

#	Criteria Category	Priority Luminaire, Retrofit, and Lamp Product Types[12]	Indoor/Outdoor	Type	Estimated 2017 Unit Sales
1	Outdoor: Low, Mid, High, Very High Output	Outdoor Pole/Arm-Mounted Area and Roadway Luminaires	Outdoor	Luminaire	734,400
2		Retrofit Kits for Outdoor Pole/Arm-Mounted Area and Roadway Luminaires	Outdoor	Retrofit	11,700
4		Outdoor Full-Cutoff Wall-Mounted Area Luminaires	Outdoor	Luminaire	25,700
5		Outdoor Non-Cutoff and Semi-cutoff Wall-Mounted Area Luminaires	Outdoor	Luminaire	268,300
6		Retrofit Kits for Outdoor Full-Cutoff Wall-Mounted Luminaires	Outdoor	Retrofit	15,800
7		Parking Garage Luminaires	Outdoor	Luminaire	88,300
9		Fuel Pump Canopy Luminaires	Outdoor	Luminaire	312,100
12		Architectural Flood and Spot Luminaires	Outdoor	Luminaire	404,400
13		Stairwell and Passageway Luminaires	Outdoor	Luminaire	500
				Total	*1,861,200*
14	Ambient Commercial Lighting and Linear Replacement Lamps	1x4, 2x2, and 2x4 Luminaires for Ambient Lighting of Interior Commercial Spaces	Indoor	Luminaire	1,299,500
15		Integrated-Style Retrofit Kits for 1x4, 2x2, and 2x4 Luminaires for Ambient Lighting of Interior Commercial Spaces	Indoor	Retrofit	110,100
16		Linear-Style Retrofit Kits for 2x2, 1x4, and 2x4 Luminaires for Ambient Lighting of Interior Commercial Spaces	Indoor	Retrofit	138,200
17		T12/T8/T5/T5HO Linear Replacement Lamps	Indoor	Lamp	2,130,900
				Total	*3,678,700*
18	Linear Ambient	Linear Ambient Luminaires with Indirect Component	Indoor	Luminaire	1,200
19		Direct Linear Ambient Luminaires	Indoor	Luminaire	885,900
20		Retrofit Kits for Direct Linear Ambient Luminaires	Indoor	Retrofit	76,100
				Total	*963,200*
21	Low-High Bay	High-Bay Luminaires for Commercial and Industrial Buildings	Indoor	Luminaire	457,000
22		Low-Bay Luminaires for Commercial and Industrial Buildings	Indoor	Luminaire	21,100
25		Retrofit Kits for Low-Bay Luminaires for Commercial and Industrial Buildings	Indoor	Retrofit	7,300
				Total	*485,400*
26	Downlight	Downlight Luminaires	Indoor	Luminaire	1,924,400
27		Downlight Retrofits	Indoor	Retrofit	636,600
				Total	*2,561,000*
28	Interior Directional	Track or Mono-Point Directional Luminaires	Indoor	Luminaire	134,000
29	Other	Pin-Based Replacement LED Lamps for CFLs	Indoor	Lamp	1,392,100
30		Mogul Screw-Base (E39) Replacement LED Lamps for HID Lamps	Indoor/Outdoor	Lamp	929,300
				Overall Total	***12,004,900***

3.2.2 DLC and ENERGY STAR Market Share

The second objective of the California non-residential LED market characterization was to determine the current market share of DLC Standard and DLC Premium products in the California market. Figure 3-2 summarizes the overall DLC and ENERGY STAR market penetration, where applicable. Approximately 41% of DLC-eligible products analyzed in the market evaluation were listed as DLC Standard, and 14% of

[12] Luminaires, retrofit kits, and lamps were weighted the same on an individual unit basis.

the products are listed as DLC Premium. Of the indoor downlight products that are eligible for ENERGY STAR certification, an estimated 80% of the indoor downlight market is ENERGY STAR certified.[13]

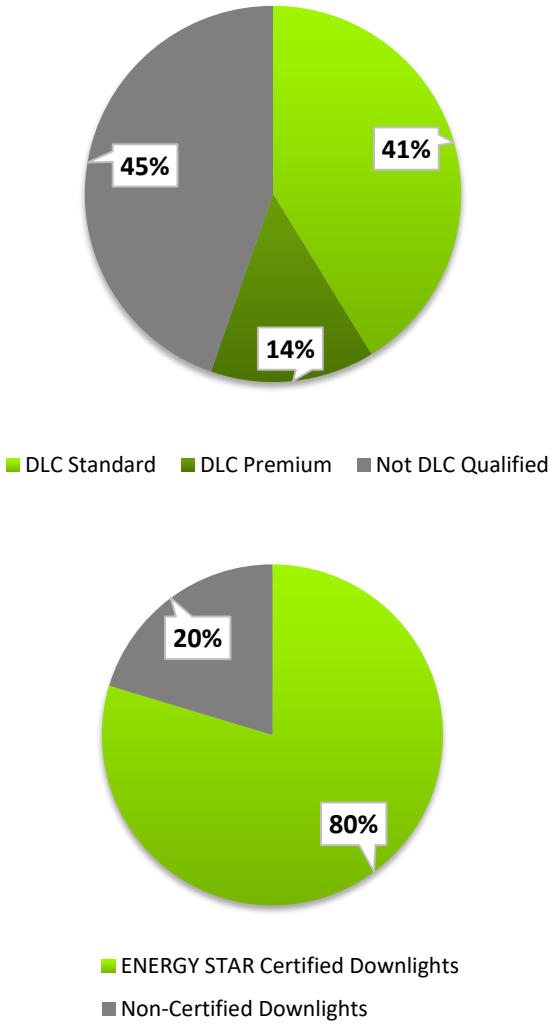


Figure 3-2 DLC and ENERGY STAR Overall Market Share for Eligible Products[14]

Figure 3-3 summarizes the DLC indoor and outdoor market penetration for non-residential LED products sold in California in 2017. DLC products in the indoor sector reached a higher overall market share of 56%, compared to DLC products in the outdoor sector, which reached 53% market share. However, the outdoor sector was slightly more represented by DLC Premium products at 21% of the overall outdoor sector, compared to the indoor sector's 12% DLC Premium market penetration.

[13] Outdoor downlights are excluded from the scope of this market analysis and the Criteria finalized in Section 4.2.

[14] Downlights are not eligible for DLC qualification, thus they were excluded from the DLC market share analysis and were the only products included in the ENERGY STAR market share analysis.

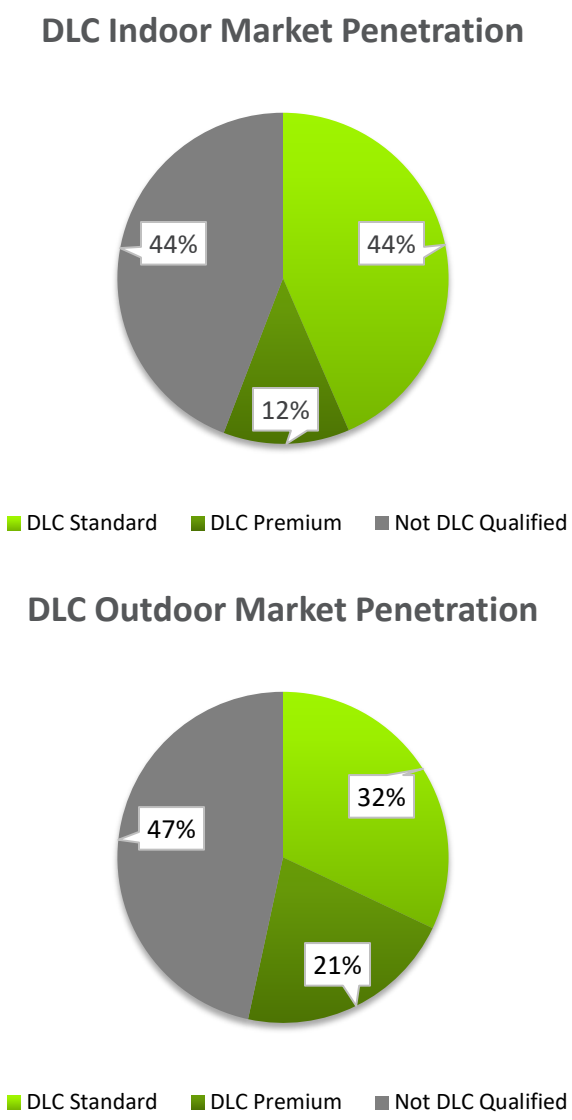


Figure 3-3 DLC 2017 Non-Residential Market Penetration by Indoor and Outdoor Product Types

Figure 3-4 summarizes the DLC penetration by Criteria product category. Two Criteria categories were excluded: 1) Downlights are not eligible for DLC Qualification and 2) the Interior Directional data were limited and did not include any DLC qualified products. The Interior Directional category is one of the smaller product categories (in terms of product offerings) on the DLC QPL, so sales data associated with these products are likely scarcer. The four Criteria categories included in the DLC analysis are Ambient Commercial Lighting and Linear Replacement Lamps, Linear Ambient, Low-High Bay, and all Outdoor. Three out of four Criteria categories had DLC market shares of greater than 60%. Low-High Bay products reached the highest overall market share (89%), while also registering the highest percentage of DLC Premium products (65%). However, compared to the other Criteria product categories, the Low-High Bay products registered lower overall sales. The other three categories were primarily represented by DLC Standard products.

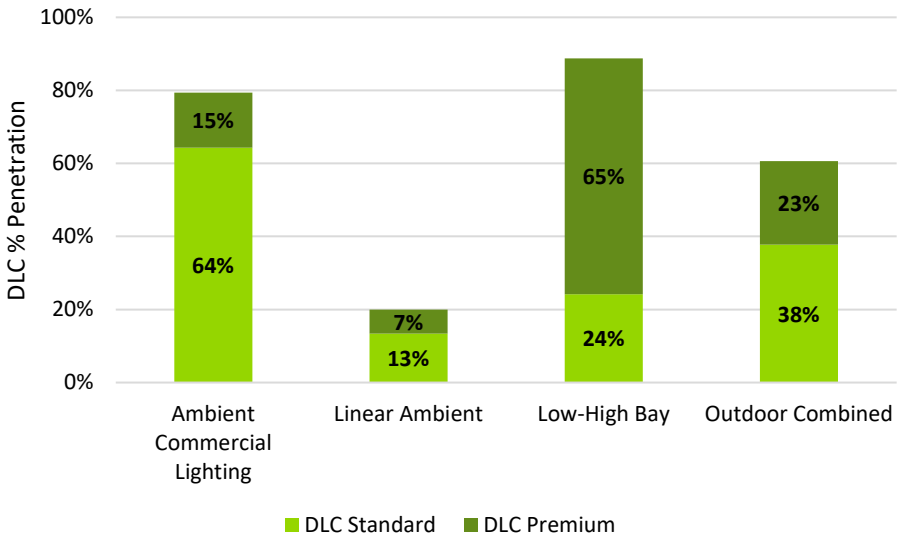


Figure 3-4 2017 DLC Market Penetration by Criteria Product Category

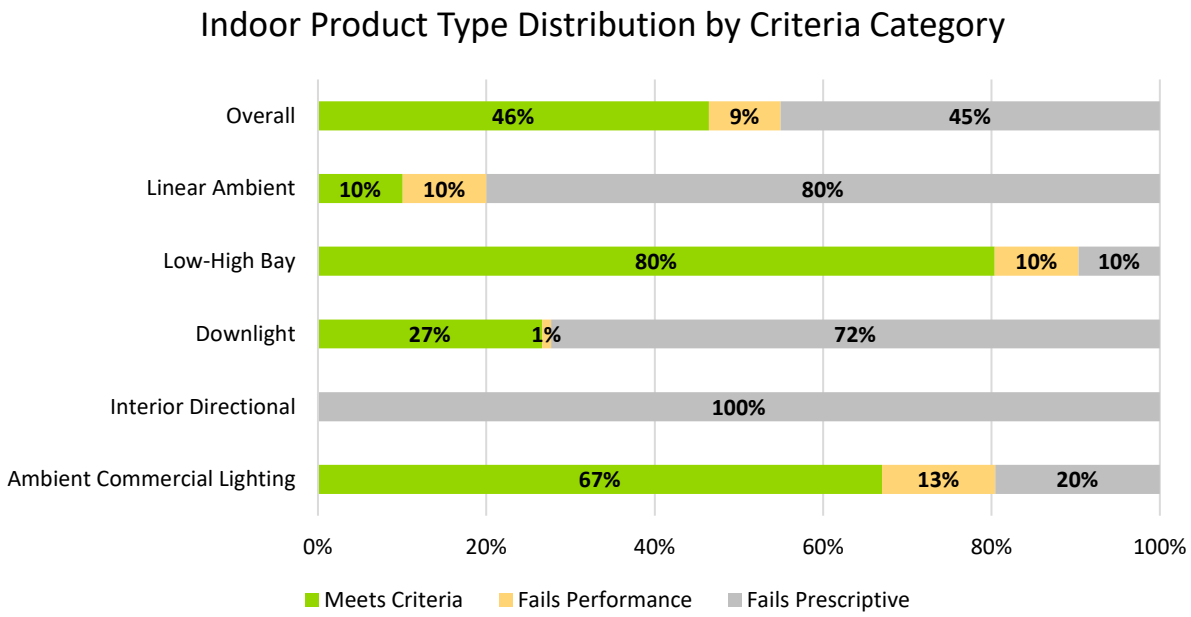
3.2.3 Lighting Quality Evaluation of LED Sales

The final research objective of the market characterization was to determine the proportion of the non-residential LED lighting market that conforms to the lighting quality definition previously proposed in this Study. This section compares the scoring results of the distributor data in the finalized non-residential LED lighting quality Criteria detailed in Section 4.2.

Figure 3-5 shows that of the indoor products analyzed with the distributor sales data, approximately 46% overall met the Criteria, while 43% of the outdoor products analyzed met the Criteria. The results vary by Criteria category, but the overall goal of the lighting quality portion of the Study was to define a set of criteria such that products meeting the requirements represent the top-half of the market. The overall results of 46% and 43% meeting the Criteria for indoor and outdoor products, respectively, supports the proposed stringency of the Criteria. The distribution of products meeting the Criteria requirements generally align with the distribution of products that are DLC qualified, as this is a prescriptive requirement for passing the Criteria. The primary reason for products not meeting the Criteria is their failure of the prescriptive requirements, which mostly leverage the DLC and ENERGY STAR requirements for initial qualification into the Criteria. As mentioned in Section 3.2.2, the provided Interior Directional data were scarcer than other categories and did not feature any DLC qualified products. Therefore, the results show that the products sales analyzed in the Interior Directional category do not meet the Criteria due to the prescriptive requirements. Navigant does not believe this to be reflective of the Interior Directional product category as a whole, as the results discussed in Appendix B of Part One indicate there are products listed in the LED Lighting Facts database and the DLC QPL that meet the Interior Directional Criteria requirements.

Overall, in Appendix B of Part One, Navigant identified that 39% of the indoor products passed the Criteria, and 52% of the outdoor products passed the Criteria. The vast majority of the DLC Premium products passed (98% and 97% for indoor and outdoor products, respectively), while a more limited amount of DLC Standard products passed the Criteria (15% and 38% for indoor and outdoor products, respectively).

Using the overall results from the distributor sales analysis (i.e., 46% of Indoor products and 43% of Outdoor products passing the Criteria) combined with the analysis of the LED Lighting Facts database and DLC QPL in Appendix B of Part One, Navigant concludes that the prescriptive minimum/maximum tolerances and the performance points for each point tier adequately represent products in the top-half of the market with regard to the proposed definition of lighting quality. As suggested in Navigant's recommendations to the CA IOUs (Section 5), the Criteria, if implemented in practice, should be updated on a regular basis and would benefit from a full, comprehensive dataset that includes data for each metric within the Criteria. The analysis framework provided in this Study is a foundation for the Criteria to be optimized and enhanced over time.



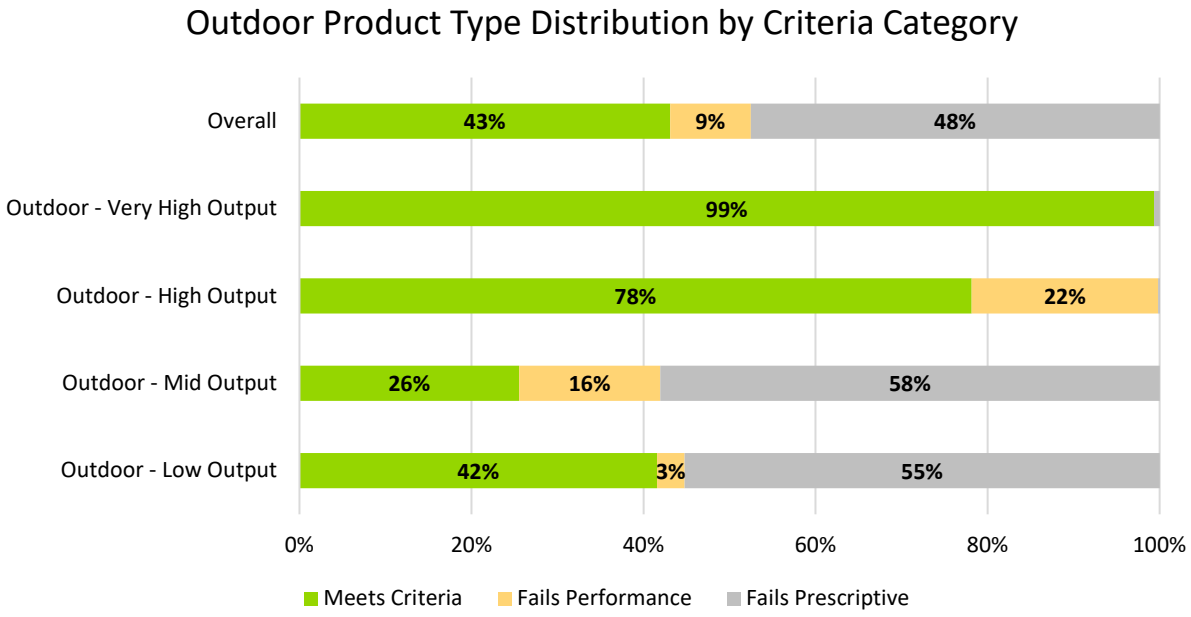
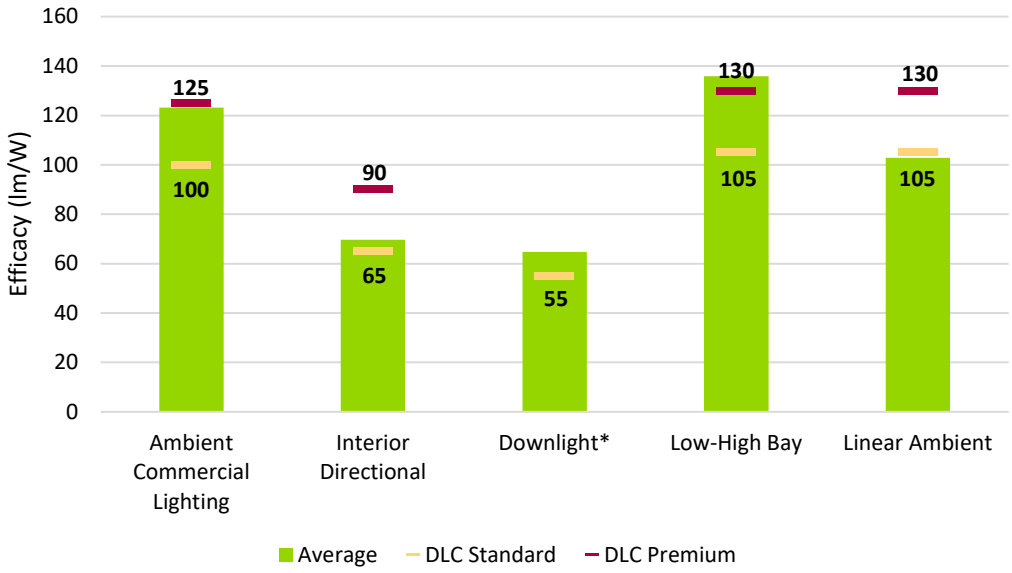


Figure 3-5 Comparison of Estimated Sales to Lighting Quality Definition by Criteria Category

Navigant also compiled performance data associated with each distributor sales item, and Figure 3-6 details the sales-weighted efficacy in each Criteria category with the efficacy thresholds for products to qualify as DLC Standard or DLC Premium also noted on the figure. The average efficacies (of the analyzed sales) for each Criteria category generally track with the DLC efficacy requirements for each category. The Indoor – Linear Ambient category and Outdoor – Mid Output category have average efficacies lower than the DLC Standard requirement, which gives insight on the reason these categories have lower Criteria passing rates in Figure 3-5. The samples received for these categories could be representing the generally lower end of quality. Appendix B in Part One demonstrated that these categories have passing rates similar to the other Criteria categories when using the LED Lighting Facts database and DLC QPL.



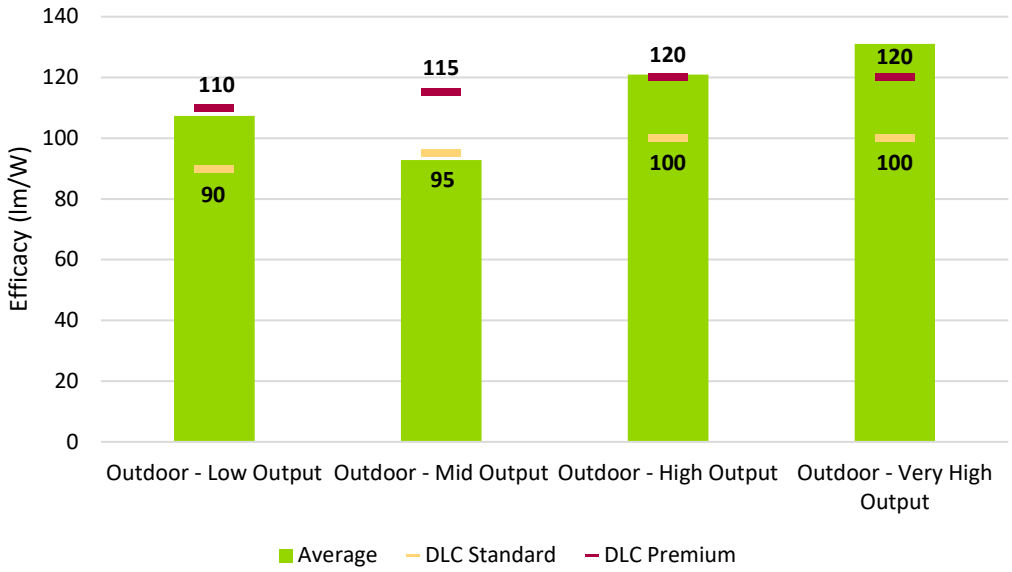


Figure 3-6 Sales-Weighted Average Efficacy of Non-Residential LED Products Sold in California Compared to DLC Efficacy Levels

3.3 Market Trends and Program Emphasis

This section discusses secondary research on expected market trends and pairs these trends with the priority product categories that have the most market influence (as shown in Table 3-2). Figure 3-1 details that there are three primary categories that had the highest estimated 2017 sales: Ambient Commercial Lighting and Linear Replacement Lamps, Downlights, and all Outdoor products. Although these categories had the highest estimated sales, their sales should be considered with respect to the sizes of the conventional markets they are competing against, as these markets have some of the higher quantities of installed stock. These product categories are expected to continue to grow in coming years (and continue to penetrate the conventional technology markets) and could benefit from program assistance to maintain these levels of market penetration.

The DOE 2016 SSL Forecast Report[15] predicts that the overall LED installed stock penetration could reach 59% by 2025 (compared to 6% in 2015). Of the non-residential submarkets examined in the report, LED products are anticipated to grow most rapidly in the area and roadway, low and high bay, directional/downlight, and linear fixture applications.

LED luminaires tend to offer benefits over LED lamps, such as higher efficacies and capacity for integrated controls, so Navigant also recommends the CA IOUs focus on priority product categories that compete with LED lamp installations as well. Downlight applications often are served with LED replacements for pin base CFLs, and low/high bay applications can be served with screw base LED replacements for HID lamps. To continue the adoption of downlight and low/high bay luminaires and retrofit kits, Navigant recommends the CA IOUs to emphasize these product types when developing program assistance structures in coming years, especially considering low/high bay luminaires and retrofit kits comprised a smaller portion of the estimated sales in Table 3-2. The low/high bay sales relative to the other categories could be explained, in part, by the smaller size of the high/low bay market compared to other lighting markets in the commercial and industrial sectors. The 2015 LMC estimated that HID lamps (which typically serve in these applications) in the industrial sector made up approximately 6% of the total lamps in that sector and 1% of the total lamps in the commercial sector.

Outdoor LED products are also anticipated to grow into a vast majority of the market share by 2025, with area and roadway lighting expected to reach 91% of the installed stock in the market by that time. Although the quantity of lighting installations is much lower in the outdoor sector (compared to the commercial and industrial sectors), the 2015 LMC[16] concluded that the outdoor sector's energy use estimates (202 TWh) are relatively close to the commercial and industrial sectors (290 TWh, combined). This is due to the remaining presence of high wattage HID lamps in the outdoor sector. Although LED products have certainly cut into the HID market share since 2015, the per unit energy savings impact (when compared to the typical outdoor sector HID baseline) of continued focus of LED adoption in

[15] U.S. Department of Energy Solid-State Lighting Program, "Energy Savings Forecast of Solid-State Lighting in General Illumination Applications." September 2016. https://www.energy.gov/sites/prod/files/2016/10/f33/energysavingsforecast16_0.pdf

The DOE Lighting Forecast model accounts for lighting standards that are effective (i.e., drafted or pending legislation is not included), and it predicts the shift to more efficient technologies, including modifying anticipated efficacy improvements and resulting price increases.

[16] U.S. Department of Energy, "2015 U.S. Lighting Market Characterization." November 2017. https://www.energy.gov/sites/prod/files/2017/12/f46/lmc2015_nov17.pdf

outdoor applications is immense. As such, Navigant recommends the CA IOUs to provide program assistance to the outdoor product categories analyzed in this Study.

LED linear fixtures (e.g., troffers) are estimated to grow to 47% of the market by 2025 in the SSL Forecast Report, and in the non-residential sector, these product types make up a significant portion of the market. The 2015 LMC estimated that over 75% of the lamps installed in the commercial and industrial sectors are linear fluorescent lamps. Therefore, continuing to convert these conventional product types (i.e., linear fluorescent fixtures) to LED luminaires and retrofit kits can garner some of the most energy savings available in the non-residential sector by way of the larger volume of potential savings (when compared to the typical fluorescent lamp baseline). Navigant recommends the CA IOUs to provide program assistance to these product categories as well, which predominantly fall within the Ambient Commercial Lighting and Linear Replacement Lamps Criteria category and have significant market leverage and energy savings impact.

4. LED LIGHTING QUALITY

This section discusses the updated Criteria, including the parameters included in the Criteria, the detailed technical requirements of the Criteria, the proposed plan for updating the Criteria in future revisions, and a basic framework for implementing the Criteria through testing and verification.

As previously indicated, the main body of this report documents the detailed findings of Part Two for the California Statewide Non-Residential LED Quality and Market Characterization Study. Part One is attached to this report, and additional details on the methodologies used to develop the Criteria can be found in Part One.

4.1 Lighting Quality Definition

While lighting quality is dynamic, and its definition is ever-changing, Part One of this Study developed a procedure to evaluate an LED product's lighting quality relative to those available within California's non-residential lighting market. Therefore, Part One aimed to develop a lighting quality definition based on parameters and metrics that can be controlled at the product-level, rather than at the application-level or during installation. Based on this premise, and the input from the CA IOUs, CEC, and industry stakeholders, Navigant proposed that non-residential LED lighting quality be defined based on its performance in the following parameter categories: Power Quality, Optical Performance, Reliability & Safety, Efficiency, Spectrum and Controllability. At this time, these six parameters best describe the categories of LED product performance which can be used to evaluate a product's lighting quality. It should be noted, however, that as the non-residential LED market continues to develop, these parameters could change or be enhanced based on R&D progress and the introduction of new product attributes.

Each of these parameters is described in the summary below, and the metrics considered within each quality parameter are described in detail in Section 3.2 of the Part One report. Table 4-1 below illustrates how each of the evaluated lighting performance metrics maps to the lighting quality parameters identified for the Criteria. Metrics listed in bold font in Table 4-1 were determined feasible to include in the Criteria.

Power Quality – Electricity-consuming products contribute to overall power quality in buildings and power grids. Building owners, utilities, and end users are affected by power quality, as electric power loads, transmission and distribution networks, circuitry in buildings, and visible flicker can be adversely impacted by poor management of power quality in lighting products.

Optical Performance – Lighting products are designed to meet a vast array of applications and task areas. In order to properly deliver light, in terms of light intensity and direction, manufacturers and lighting designers specify optical attributes that enable lighting products to meet customer and end-use application needs.

Reliability & Safety – A basic quality parameter for any lighting product is that it meets performance claims and operates safely for the duration of its use. In particular, LED products have very long anticipated lifetimes relative to much of the electrical equipment installed in non-residential buildings and outdoor spaces. Therefore, ensuring that products are reliable in meeting their rated light levels and spectral parameters for the duration of their rated lifetimes, while operating under safe conditions, is an important quality factor for LED products.

Efficiency – The ratio of the useful work performed by a product to the total energy expended is an important parameter throughout all electric appliance industries for rating quality. High efficiency products

reduce electric load-burden and improve building performance. In the lighting industry, one of the most commonly analyzed product attributes is the ratio of light emitted over the power input required to produce it. Higher quality products are designed to optimize this ratio, while not overproducing light and causing unnecessary glare.

Spectrum – Human color perception is a vital aspect of lighting quality, as the spectral emission of the installed lighting products change the appearance of objects in a space. Lighting designers and specifiers use light spectrum parameters to select products for their intended applications. Quantifying and describing the product's light spectrum, in the most comprehensive manner, allows lighting designers and specifiers to appropriately design indoor and outdoor environments in which end users operate and perform tasks.

Controllability – A relatively new lighting parameter, controllability is a product's ability to be controlled during its useful life. Controls better enable a lighting product to provide the right amount and type of light where and when it is needed. The number and capabilities of controllable LED products continues to expand, as these products often lead to reduced consumption (i.e., dimmed light levels results in lower operating wattages), as well as increased human comfort and added services (e.g., health-centric lighting, asset tracking in retail settings, etc.). However, standardizing communication protocols and ensuring these systems offer interoperability between manufacturers is key to customer and end user acceptance.

Table 4-1. Lighting Quality Parameters and Metric Categorization

Power Quality	− **Total Harmonic Distortion (THD)** − Electrical Power Consumption − **Operating Frequency**	− **Power Factor** − Flicker Index − Percent Flicker	− Flicker (IEC P_{st}) − Stroboscopic Effect (SVM) − NEMA-77-2017
Optical Performance	− **Lumen Output** − **Zonal Lumen Density** − Perceived Luminance	− **Beam Angle Classification** − Upward Light Ratio − BUG Rating	− Visual Comfort Probability (VCP) − Unified Glare Rating (UGR)
Reliability & Safety	− **Lumen Maintenance** − **Color Maintenance** − **Driver ISTMT**	− **Warranty** − **IP Rating** − **Safety Certification**	
Efficiency	− **Luminous Efficacy** − Application Efficacy − Lighting Power Density	− Light Utilization − Power Supply Efficiency	
Spectrum	− **Color Rendering Index (CRI)** − **Correlated Color Temperature (CCT)** − Red Rendering (**R_9**)	− **Color Fidelity (Rf)** − **Color Gamut (Rg)** − Color Consistency	− **Color Angular Uniformity**
Controllability	− **Dimmability** − Networked Lighting Control Features − Communication Protocols (e.g., Bluetooth, Wi-Fi, Zigbee, etc.)	− Luminaire-Level Control Features	

4.2 Final Non-Residential LED Lighting Quality Criteria

The analyses discussed in the Methodology Section 2 of the Part One report indicate Navigant has identified that products representing the top-half of the market can best be measured with a combination of prescriptive, performance, and reporting requirements. As such, the finalized Criteria detailed in this

section includes a technical description and pathway to qualification based on the combination of these three implementation methods. Based on these Criteria, non-residential LED products that fail any one, or combination, of the three implemented approaches are not eligible, and fail the overall Criteria. Products must comply with each Criteria category in order to be eligible. These pathways are detailed further in Table 4-2. It should be noted that these "final" Criteria are only a final proposal to the CA IOUs as a snapshot of the current market. The Criteria requirements detailed in this report are not legally effective from a CPUC or CEC standpoint, nor has there been a timeline mapped out for implementation or the intent from California to implement the Criteria in practice.

Table 4-2. Product Pathway for Criteria Eligibility

Criteria Categories	Description
Prescriptive	Product must meet the minimum/maximum metric thresholds detailed in the prescriptive portion of the Criteria as described in Section 4.2.2.
Reporting	Product must meet the reporting requirements detailed in the prescriptive portion of the Criteria as described in Section 4.2.2.
Performance	Product must receive a quality rating score of greater than or equal to 50 points as detailed in the performance portion of the Criteria as described in Section 4.2.3.

The following Sections 4.2.1, 4.2.2, and 4.2.3 detail the specific requirements within the Criteria, and Appendix B in Part One discusses the distribution of Criteria performance for products found in the DLC QPL and DOE LED Lighting Facts Database. Changes made to the Criteria since Part One of this Study are shown with ~~strikethroughs~~ for text removed and red text for information added.

4.2.1 Covered Products Categories

Products covered in the Criteria are the LED product categories (i.e., luminaires, retrofit kits, and lamps) as defined by DLC, excluding Mogul (E39) Screw-Base Replacement Lamps, Four Pin-Base Replacement Lamps, Bollard Luminaires, Decorative Luminaires, and Case Lighting Luminaires.

In addition to the DLC's LED product categories, commercial downlights, as defined in the ENERGY STAR Program Requirements Product Specification for Luminaires (Light Fixtures) Eligibility Criteria Version 2.1, are covered in the Criteria. The following Table 4-3 summarizes the LED product categories subject to the California Non-Residential LED Lighting Quality Criteria.

Table 4-3. LED Products Covered by the CA Non-Residential LED Lighting Quality Criteria

#	Criteria Category	Priority Luminaire, Retrofit, and Lamp Product Types	Indoor/Outdoor	Type
1	Outdoor: Low, Mid, High, Very High Output	Outdoor Pole/Arm-Mounted Area and Roadway Luminaires	Outdoor	Luminaire
2		Retrofit Kits for Outdoor Pole/Arm-Mounted Area and Roadway Luminaires	Outdoor	Retrofit
3		Retrofit Kits for Large Outdoor Pole/Arm-Mounted Area and Roadway Luminaires	Outdoor	Luminaire
4		Outdoor Full-Cutoff Wall-Mounted Area Luminaires	Outdoor	Luminaire
5		Outdoor Non-Cutoff and Semi-cutoff Wall-Mounted Area Luminaires	Outdoor	Luminaire
6		Retrofit Kits for Outdoor Full-Cutoff Wall-Mounted Luminaires	Outdoor	Retrofit
7		Parking Garage Luminaires	Outdoor	Luminaire
8		Retrofit Kits for Parking Garage Luminaires	Outdoor	Retrofit
9		Fuel Pump Canopy Luminaires	Outdoor	Luminaire
10		Retrofit Kits for Fuel Pump Canopy Luminaires	Outdoor	Retrofit
11		Landscape/Accent Flood, Spot Luminaires and Wall-Wash Luminaires	Outdoor	Luminaire
12		Architectural Flood and Spot Luminaires	Outdoor	Luminaire
13		Stairwell and Passageway Luminaires	Outdoor	Luminaire
14	Ambient Commercial Lighting and Linear Replacement Lamps	1x4, 2x2, and 2x4 Luminaires for Ambient Lighting of Interior Commercial Spaces	Indoor	Luminaire
15		Integrated-Style Retrofit Kits for 1x4, 2x2, and 2x4 Luminaires for Ambient Lighting of Interior Commercial Spaces	Indoor	Retrofit
16		Linear-Style Retrofit Kits for 2x2, 1x4, and 2x4 Luminaires for Ambient Lighting of Interior Commercial Spaces	Indoor	Retrofit
17		T12/T8/T5/T5HO Linear Replacement Lamps	Indoor	Lamp
18	Linear Ambient	Linear Ambient Luminaires with Indirect Component	Indoor	Luminaire
19		Direct Linear Ambient Luminaires	Indoor	Luminaire
20		Retrofit Kits for Direct Linear Ambient Luminaires	Indoor	Retrofit
21	Low-High Bay	High-Bay Luminaires for Commercial and Industrial Buildings	Indoor	Luminaire
22		Low-Bay Luminaires for Commercial and Industrial Buildings	Indoor	Luminaire
23		High-Bay Aisle Luminaires for Commercial and Industrial Buildings	Indoor	Luminaire
24		Retrofit Kits for High-Bay Luminaires for Commercial and Industrial Buildings	Indoor	Retrofit
25		Retrofit Kits for Low-Bay Luminaires for Commercial and Industrial Buildings	Indoor	Retrofit
26	Downlight	Downlight Luminaires	Indoor	Luminaire
27		Downlight Retrofits	Indoor	Retrofit
28	Interior Directional	Track or Mono-Point Directional Luminaires	Indoor	Luminaire

4.2.2 Prescriptive and Reporting Criteria

To be eligible for the Criteria, LED products must be listed as "qualified" on the DLC QPL as either "Standard" or "Premium," or for commercial downlights, these must be listed as ENERGY STAR certified.[17] This is an initial prescriptive requirement for the Criteria, however, DLC or ENERGY STAR certification does not guarantee that a product will meet the prescriptive and reporting requirements described in this section.

Sections 4.2.2.1 through 4.2.2.6 describe the Criteria's prescriptive and reporting requirements for each of the six lighting quality parameters. These requirements include those described in the DLC Technical

[17] This general requirement has been set based on research indicating that LED products that meet these specifications represent over 50% of non-residential lighting sales in the State of California.

Requirements V4.4 (Effective October 18, 2018),[18] or the ENERGY STAR Program Requirements Product Specification for Luminaires (Light Fixtures) Eligibility Criteria Version 2.1 (Final March 15, 2018),[19] in addition to new requirements not currently adopted by either existing specification.

4.2.2.1 Power Quality

Power Factor

Downlights must comply with the power factor test methods in the ENERGY STAR Program Requirements Product Specification for Luminaires (Light Fixtures) Eligibility Criteria Version 2.1. Instead of following the ENERGY STAR requirements – which stipulate that downlights with rated input power less than or equal to 5 watts must have a power factor of greater than or equal to 0.5 and for downlights with rated input power greater than 5 watts, the power factor must be greater than or equal to 0.7 – downlight products must have a minimum power factor of 0.9. The same measurement and reporting tolerances as specified by ENERGY STAR apply to this adjusted requirement. Refer to Appendix C for additional details regarding the ENERGY STAR testing requirements for power factor.

For all other LED products covered by the Criteria (see Table 4-3), products must comply with the DLC Technical Requirements V4.4, which require all DLC-eligible products to have a minimum power factor of 0.9.

Total Harmonic Distortion

LED products covered by the Criteria (see Table 4-3), with the exclusion of downlights, must comply with the THD requirements in the DLC Technical Requirements V4.4, which stipulates a maximum THD of 20%. Refer to Appendix C for additional details regarding the DLC requirements for THD.

Operating Frequency ~~(Downlight Products Only)~~

All ~~downlight products~~ LED products covered by the Criteria, as specified in Table 4-3, must comply with the operating frequency requirements detailed in Section 11.6 of the ENERGY STAR Program Requirements Product Specification for Luminaires (Light Fixtures) Eligibility Criteria Version 2.1. Products must maintain an operating frequency of greater than or equal to 120 Hz, and this requirement is to be met at all light output levels for dimmable products. Refer to Appendix C for additional details regarding the ENERGY STAR requirements for operating frequency.

4.2.2.2 Optical Performance

Lumen Output, Zonal Lumen Density, and Beam Classification

Downlights must comply with the ENERGY STAR Program Requirements Product Specification for Luminaires (Light Fixtures) Eligibility Criteria Version 2.1, which stipulates lumen output and zonal lumen density requirements for downlight products. Section 9.2 specifies a 345 lumen output minimum for downlight apertures less than or equal to 4.5 inches, and a 575 lumen output minimum for downlight

[18] DLC, "Technical Requirements Version 4.4," Released October 18, 2018.
https://www.designlights.org/default/assets/File/Workplan/DLC_Technical-Requirements-Table-V4-4.pdf

[19] ENERGY STAR, "ENERGY STAR Program Requirements Product Specification for Luminaires (Light Fixtures) Eligibility Criteria Version 2.1," Released March 15, 2018.
https://www.energystar.gov/sites/default/files/Luminaires%20V2.1%20Spec%20Final%20with%20Partner%20Commitments.pdf

apertures greater than 4.5 inches. Zonal lumen density requirements are also provided and states that downlights shall deliver a minimum of 75% of total lumens within the 0-60° zone (axially symmetric about the nadir). Refer to Appendix C for additional details regarding the ENERGY STAR requirements for lumen output and zonal lumen density.

For all other LED products covered by the Criteria (see Table 4-3), products must comply with the lumen output, zonal lumen density, and beam classification requirements in DLC Technical Requirements V4.4. Refer to Appendix C for details regarding the DLC requirements for lumen output, zonal lumen density, and beam classification.

Color Angular Uniformity (Downlight Products Only)

Downlight products must comply with the ENERGY STAR Program Requirements Product Specification for Luminaires (Light Fixtures) Eligibility Criteria Version 2.1. Section 9.5 specifies that throughout the beam angle, the variation of chromaticity shall be within a total linear distance of 0.006 from the weighted average point on the CIE 1976 (u',v') diagram. Refer to Appendix C for additional details regarding the ENERGY STAR requirements for color angular uniformity.

4.2.2.3 Reliability and Safety

Lumen Maintenance

Downlight products must comply with the ENERGY STAR Program Requirements Product Specification for Luminaires (Light Fixtures) Eligibility Criteria Version 2.1. Section 10.1 specifies the lumen maintenance requirements for indoor, outdoor and inseparable luminaires. However, it is proposed that all downlight products (luminaire or retrofit kit), shall comply with the minimum L70 lumen maintenance requirements for inseparable luminaires, of greater than or equal to 50,000 hours. Products can be tested according to Option 1 or Option 2. Refer to Appendix C for additional details regarding the ENERGY STAR requirements for lumen maintenance.

All other LED products covered by the Criteria (see Table 4-3), must comply with the lumen maintenance requirements in the DLC Technical Requirements V4.4. Refer to Appendix C for details regarding the DLC requirements for lumen output, zonal lumen density, and beam classification. Products can be tested according to Option 1 or Option 2.

For all product categories, product families must certify the "worst case" product with the lowest rated lifetime to qualify all products in that family.

Warranty

Downlight products must comply with the ENERGY STAR Program Requirements Product Specification for Luminaires (Light Fixtures) Eligibility Criteria Version 2.1. Section 17 specifies that downlight luminaires incorporating replaceable drivers, a written warranty shall be included with luminaire packaging at the time of shipment which covers repair or replacement of defective parts of the luminaire housing, mounting hardware, optics, driver and trim for a minimum of 3 years from the date of purchase. Downlight retrofit kits shipped with the luminaire shall carry a minimum 3 year warranty. For downlight luminaires incorporating non-replaceable drivers, the warranty requirement is extended to 5 years. Refer to Appendix C for additional details regarding the ENERGY STAR requirements for warranty.

All other LED products covered by the Criteria (see Table 4-3) must comply with the warranty requirements in the DLC Technical Requirements V4.4. The minimum warranty for all DLC-eligible products is 5 years. Refer to Appendix C for additional details regarding the DLC requirements for warranty.

Driver ISTMT

Downlight products must comply with the ENERGY STAR Program Requirements Product Specification for Luminaires (Light Fixtures) Eligibility Criteria Version 2.1. Section 13 describes thermal performance requirements, indicating that downlight luminaires and retrofits must have a measured driver case temperature at thermal equilibrium that does not exceed the driver manufacturer's maximum recommended temperature during in situ (installed in the luminaire) operation. This measurement shall be made at point for the hottest location on the driver case (TMP_C as detailed by the driver manufacturer). Refer to Appendix C for additional details regarding the ENERGY STAR requirements for thermal performance.

All other LED products covered by the Criteria (see Table 4-3), must comply with the driver in-situ temperature measurement testing requirements in the DLC Technical Requirements V4.4. Refer to Appendix C for details regarding the DLC requirements for driver ISTMT.

Color Maintenance (Downlight Products Only)

Downlight products must comply with the ENERGY STAR Program Requirements Product Specification for Luminaires (Light Fixtures) Eligibility Criteria Version 2.1. Section 10.3 states that change in chromaticity coordinates from 0-hour measurement, at any measurement point during operation, shall be less than or equal to a total linear distance of 0.007 on the CIE 1976 u'v' diagram. Refer to Appendix C for additional details regarding the ENERGY STAR requirements for color maintenance.

Safety Certification

Downlight products must comply with the ENERGY STAR Program Requirements Product Specification for Luminaires (Light Fixtures) Eligibility Criteria Version 2.1. Section 14 indicates that downlight luminaires must comply with ANSI/UL 1574-2004, ANSI/UL 1598-2008, ANSI/UL 1598C-2014, ANSI/UL 2108-2004 or 2015, and ANSI/UL 8750-2009 or 2015, as applicable. While downlight retrofit kits must comply with ANSI/UL 8750-2009 or 2015 – LED Component and ANSI/UL 1598C-2014 – LED Retrofit. Refer to Appendix C for additional details regarding the ENERGY STAR requirements for safety certification.

All other LED products covered by the Criteria (see Table 4-3), must comply with the safety certification requirements in the DLC Technical Requirements V4.4. Refer to Appendix C for details regarding the DLC requirements for safety certification.

4.2.2.4 Efficiency

Efficacy

Downlight products must comply with the ENERGY STAR Program Requirements Product Specification for Luminaires (Light Fixtures) Eligibility Criteria Version 2.1. Section 9.2 specifies that downlight luminaires must have initial rated efficacies of 55 lm/W or higher, while downlight retrofit kits must have

initial rated efficacies of 60 lm/W or higher. Refer to Appendix C for additional details regarding the ENERGY STAR requirements for efficacy.

All other LED products covered by the Criteria (see Table 4-3), must comply with the efficacy requirements displayed in Table 1, Table 2, and Table 3 within the DLC Technical Requirements V4.4. Refer to Appendix C for details regarding the DLC requirements for efficacy.

4.2.2.5 Spectrum

Color Rendering Index

Downlight products must comply with the ENERGY STAR Program Requirements Product Specification for Luminaires (Light Fixtures) Eligibility Criteria Version 2.1. Section 9.4 states that all downlight products shall be capable of meeting or exceeding a CRI of 80. Refer to Appendix C for additional details regarding the ENERGY STAR requirements for CRI.

All other LED products covered by the Criteria (see Table 4-3), must comply with the CRI requirements displayed in Table 1, Table 2, and Table 3 within the DLC Technical Requirements V4.4. Refer to Appendix C for additional details regarding the DLC requirements for CRI.

R_9 (Indoor Products Only)

Downlight products must comply with the ENERGY STAR Program Requirements Product Specification for Luminaires (Light Fixtures) Eligibility Criteria Version 2.1. Section 9.4 states that all downlight products shall be capable of exceeding a R_9 of 0. Refer to Appendix C for additional details regarding the ENERGY STAR requirements for R_9.

All indoor LED products, as specified in Table 4-3, must conduct R_9 testing as specified in Section 9.4 of the ENERGY STAR Program Requirements Product Specification for Luminaires (Light Fixtures) Eligibility Criteria Version 2.1, and report R_9 tested results.

Correlated Color Temperature

Downlight products must comply with the ENERGY STAR Program Requirements Product Specification for Luminaires (Light Fixtures) Eligibility Criteria Version 2.1. Section 9.3 states that downlight products shall be capable of providing at least one of the following nominal correlated color temperatures: 2700 K, 3000 K, 3500 K, 4000 K, or 5000 K. In addition, products shall also have a chromaticity that falls within the corresponding 7- step chromaticity quadrangles as defined in ANSI C78.377-2015 or C78.377-2017. Refer to Appendix C for additional details regarding the ENERGY STAR requirements for correlated color temperature.

All other LED products covered by the Criteria (see Table 4-3), must comply with the correlated color temperature requirements displayed in Table 1, Table 2, and Table 3 within the DLC Technical Requirements V4.4. Refer to Appendix C for additional details regarding the DLC requirements for correlated color temperature.

~~*Color Gamut and Fidelity*~~ *TM-30 Data Reporting*

All LED products covered by the Criteria, including downlights (see Table 4-3), must comply with the ~~optional color fidelity (Rf) and color gamut (Rg)~~ IES TM-30 reporting procedures provided in the DLC

Technical Requirements V4.4. IES TM-30-18 is the current version, and all products covered by the Criteria are required to test and report TM-30 data. Refer to Appendix C for additional details regarding the DLC requirements for reporting TM-30 data.

4.2.2.6 Controllability

Dimming

Downlight products listed as dimmable must comply with the ENERGY STAR Program Requirements Product Specification for Luminaires (Light Fixtures) Eligibility Criteria Version 2.1. Section 15.1 states downlight products shall provide continuous dimming from 100% to 20% of light output, and that at the minimum light output, the product shall not emit noise above 24 dBA when measured within one meter of the luminaire. Refer to Appendix C for additional details regarding the ENERGY STAR requirements for dimming.

All other products listed as dimmable and covered by the Criteria (see Table 4-3) must comply with the reporting requirements outlined in the DLC Technical Requirements V4.4. Refer to Appendix C for additional details regarding the DLC requirements for dimming.

4.2.3 Performance Criteria

In addition to the prescriptive criteria detailed in Section 4.2.2, Navigant recommends the Criteria evaluate lighting quality based on a performance approach for the most relevant lighting quality parameters. Points are allocated to an LED product based on the level of performance within the tiered metric tables detailed in the following sections. Separate scoring parameters, metrics, and tiering values are provided for indoor and outdoor LED products (see Table 4-3 for complete listing of indoor and outdoor products covered by the Criteria). For both indoor and outdoor classifications, products that receive a total score of less than 50 points do not qualify and subsequently fail the Criteria. As stated in Section 4.2.2, products that do not meet the DLC Technical Requirements or ENERGY STAR Specification requirements also do not qualify and fail the Criteria. Where applicable, the prescriptive minimum requirements are listed in the quality rating tables throughout this section for reference.

As discussed in Section 2.2 of Part One, the DLC QPL and DOE's LED Lighting Facts database were used to calibrate and optimize the Lighting Quality Rating, including the number of point tiers and point values for each of the lighting quality parameters included (i.e., Power Quality, Optical Performance, Reliability and Safety, Efficiency, Spectrum, and Controllability).

Section 4.2.3.1 describes the performance, or Lighting Quality Rating, for *indoor* non-residential LED products, while Section 4.2.3.6 describes the Lighting Quality Rating for *outdoor* non-residential LED products prescriptive requirements for each of the six lighting quality parameters.

4.2.3.1 Lighting Quality Rating: Indoor

Table 4-4 illustrates the quality parameters and associated metrics to be included in the indoor Lighting Quality Rating portion of the Criteria. For indoor, four of the six lighting quality parameters are included.

Table 4-4. Indoor Quality Rating Criteria Structure

Quality Parameter	Metrics Included	Total Points Possible
Reliability and Safety	Lumen Maintenance	25
Efficiency	Efficacy	40
Spectrum	CRI and R9	35
Controllability	Dimming	10
	Total Points Possible =	**110**

Optical Performance and Power Quality have been omitted due to feedback from stakeholders, as well as Navigant analysis, which indicated that there is not significant product variation at the higher performance values beyond the prescriptive thresholds. Therefore, given the available metrics, it is currently not feasible to develop a performance approach for the above stated two lighting quality parameters.

4.2.3.2 Reliability and Safety

Table 4-5 provides the Indoor Quality Rating tiers for the Reliability and Safety parameter, which rates products based on their lumen maintenance performance. In Section 4.2.2, Navigant proposed a prescriptive minimum lumen maintenance requirement for products to have an L70 rating of at least 50,000 hours for all eligible LED products. Tier 1 corresponds to the L70 and L90 requirements associated with the Premium level of performance in the DLC Technical Requirements V4.4. The performance structure contains two additional lumen maintenance tiers that incentivize increasingly higher lumen maintenance projections and incorporates thresholds for L70 and L90 ratings.

Table 4-5. Indoor Lumen Maintenance Criteria

Tiers	Qualification Thresholds (hours)	Points Accrued
Minimum	L70 ≥ 50,000	0
Tier 1	L90 ≥ 36,000 and L70 ≥ 50,000	15
Tier 2	L90 ≥ 50,000 and L70 ≥ 75,000	20
Tier 3	L90 ≥ 75,000 and L70 ≥ 100,000	25

4.2.3.3 Efficiency

The indoor Lighting Quality Rating tiers for the Efficiency parameter rates products based on their efficacy performance. Due to the varying nature of product category efficacies, different efficacy requirements are set for five indoor product groupings. Each product category has a prescriptive minimum efficacy (as discussed in Section 4.2.2) and five additional tiers of increasing efficacy ranges. Products included within each grouping are summarized in Table 4-3 above.

Table 4-6 provides efficacy performance tiers for interior directional products; Table 4-7 provides the efficacy performance tiers for downlight products; Table 4-8 provides the efficacy performance tiers for low-high bay products; Table 4-9 provides the efficacy performance tiers for linear ambient products; and Table 4-10 provides the efficacy performance tiers for ambient commercial lighting (troffers) and linear replacement lamp products.

Table 4-6. Efficacy Criteria for Interior Directional Products

Tiers	Qualification Thresholds (lm/W)	Points Accrued
Minimum	65 ≤ Efficacy < 85	0
Tier 1	85 ≤ Efficacy < 95	18
Tier 2	95 ≤ Efficacy < 105	22
Tier 3	105 ≤ Efficacy < 110	29
Tier 4	110 ≤ Efficacy < 125	34
Tier 5	Efficacy ≥ 125	40

Table 4-7. Efficacy Criteria for Downlight Products

Tiers	Qualification Thresholds (lm/W)	Points Accrued
Minimum	60 ≤ Efficacy < 65	0
Tier 1	65 ≤ Efficacy < 70	18
Tier 2	70 ≤ Efficacy < 75	22
Tier 3	75 ≤ Efficacy < 80	29
Tier 4	80 ≤ Efficacy < 90	34
Tier 5	Efficacy ≥ 90	40

Table 4-8. Efficacy Criteria for Low-High Bay Products

Tiers	Qualification Thresholds (lm/W)	Points Accrued
Minimum	105 ≤ Efficacy < 125	0
Tier 1	125 ≤ Efficacy < 130	18
Tier 2	130 ≤ Efficacy < 135	22
Tier 3	135 ≤ Efficacy < 140	29
Tier 4	140 ≤ Efficacy < 145	34
Tier 5	Efficacy ≥ 145	40

Table 4-9. Efficacy Criteria for Linear Ambient Products

Tiers	Qualification Thresholds (lm/W)	Points Accrued
Minimum	105 ≤ Efficacy < 115	0
Tier 1	115 ≤ Efficacy < 120	18
Tier 2	120 ≤ Efficacy < 125	22
Tier 3	125 ≤ Efficacy < 130	29
Tier 4	130 ≤ Efficacy < 140	34
Tier 5	Efficacy ≥ 140	40

Table 4-10. Efficacy Criteria for Ambient Commercial Lighting and Linear Replacement Lamp* Products

Tiers	Qualification Thresholds (lm/W)	Points Accrued
Minimum	100 ≤ Efficacy < 115	0
Tier 1	110 ≤ Efficacy < 115	18
Tier 2	115 ≤ Efficacy < 125	22
Tier 3	125 ≤ Efficacy < 130	29
Tier 4	130 ≤ Efficacy < 135	34
Tier 5	Efficacy ≥ 135	40

*Requirements for linear replacement lamps are to be based on “in-luminaire” measurements.

4.2.3.4 Spectrum

The indoor Lighting Quality Rating tiers for the Spectrum parameter rates products based on their CRI and R9 performance. As discussed in Section 3.2.5 of Part One, Navigant identified CRI and R9 as the most appropriate metrics to quantify spectral-related lighting quality in the Criteria.

For indoor lighting, stakeholders noted that CRI is not as valuable to industrial lighting products (i.e., the low-high bay product grouping, as shown in Table 4-3). Most industrial products are installed in end-use applications, such as warehouses and manufacturing facilities where spectral quality is less of a concern. Therefore, for the low-high bay product grouping, separate CRI requirement tiers are provided, and no Spectrum requirements are provided for R_9.

Table 4-11 and Table 4-12 provide the CRI requirements for low/high bay products and all other indoor products, respectively.

Table 4-11. CRI Criteria for Low/High Bay Products

Tiers	Qualification Thresholds	Points Accrued
Minimum	70 ≤ CRI < 80	1
Tier 2	80 ≤ CRI < 85	9
Tier 3	CRI ≥ 85	20

Table 4-12. CRI Criteria for All Other Indoor Products

Tiers	Qualification Thresholds	Points Accrued
Minimum	80 ≤ CRI < 85	5
Tier 2	85 ≤ CRI < 90	12
Tier 3	CRI ≥ 90	20

For all indoor product groupings, with the exclusion of low-high bay, an additional metric for the Spectrum parameter is required. As shown in Table 4-13, the Criteria provides three tiers of points awarded based on R_9 values. No minimum requirements for R_9 are specified since the Criteria currently has no prescriptive requirements. Products only fail if they do not report the R_9 performance as indicated in Section 4.2.2.5. The point tiers shown in Table 4-13 represent an effort to encourage manufacturers to

increase R_9, if applicable. If the product is not awarded any points for R_9, it is still eligible to meet the Criteria based on its performance in the other quality parameters.

Table 4-13. R_9 Criteria for All Other Indoor Products

Tiers	Qualification Thresholds	Points Accrued
Tier 1	$0 \leq R_9 < 12.5$	5
Tier 2	$12.5 \leq R_9 < 50$	10
Tier 3	$R_9 \geq 50$	15

4.2.3.5 Controllability

Controllability is an increasingly integral part of quality lighting in the non-residential lighting market, and Navigant identified dimmability as the most suitable metric available for evaluating the quality of product controllability at this time.

Table 4-14 contains the dimming Lighting Quality Rating tiers for indoor products that are marketed as dimmable. Dimmability is an optional design feature, and as such, there is no prescriptive minimum requirement for dimmability; therefore, products without dimmable features are not disqualified based on this metric. Additionally, if a manufacturer markets a product as "dimmable," but it does not meet Tier 1 (or better) in Table 4-14, the product does not fail the Criteria. No minimum requirements for dimmability are specified since the Criteria currently has no prescriptive requirements. Products only fail if they do not comply with the dimmability reporting requirements as indicated in Section 4.2.2.6. The point tiers shown in Table 4-14 represent an effort to encourage manufacturers to increase dimmability performance, if applicable. If the product is not awarded any points for dimmability, it is still eligible to meet the Criteria based on its performance in the other quality parameters.

Table 4-14. Dimming Criteria for Products Marketed as Dimmable

Tiers	Qualification Thresholds (Minimum Dimming %)	Points Accrued
Tier 1	$10\% \geq Dim > 1\%$	3
Tier 2	$1\% \geq Dim > 0.1\%$	6
Tier 3	$Dim \leq 0.1\%$	10

4.2.3.6 Lighting Quality Rating: Outdoor

Table 4-15 illustrates the lighting quality parameters and associated metrics to be included in the outdoor Lighting Quality Rating portion of the Criteria.

Table 4-15. Outdoor Quality Rating Criteria Structure

Quality Parameter	Metrics Included	Total Points Possible
Reliability and Safety	Lumen Maintenance and IP Rating	55
Efficiency	Efficacy	45
	Total Points Possible =	**100**

For outdoor, two of the six lighting quality parameters are included. Power Quality, Optical Performance, Spectrum, and Controllability have been omitted due to feedback from stakeholders, as well as Navigant analysis, which indicated that there is not significant product variation at the higher performance values beyond the prescriptive thresholds. In addition, many of the applicable lighting quality metrics for outdoor products are not fully developed, and therefore, are not viable for inclusion in the Criteria at this time. Given the available metrics, it is currently not feasible to develop a performance approach for the above stated four lighting quality parameters.

4.2.3.7 Reliability and Safety

For outdoor products, two metrics within the Reliability and Safety lighting quality parameter were identified for the Lighting Quality Rating portion of the Criteria: lumen maintenance and IP rating.

The outdoor lumen maintenance tiers, displayed in Table 4-16, are the same as for indoor products. Similar to indoor products, the Lighting Quality Rating has a prescriptive minimum lumen maintenance requirement for products to have an L70 rating of at least 50,000 hours. If products do not meet this minimum they fail the Criteria.

To incentivize increased lumen maintenance performance, Tier 1 corresponds to the L70 and L90 requirements associated with the Premium level of performance in the DLC Technical Requirements V4.4. The performance structure contains two additional lumen maintenance tiers that incentivize increasingly higher lumen maintenance projections and incorporates thresholds for L70 and L90 ratings.

Table 4-16. Outdoor Lumen Maintenance Requirements

Tiers	Qualification Thresholds (hours)	Points Accrued
Minimum	L70 ≥ 50,000	0
Tier 1	L90 ≥ 36,000 and L70 ≥ 50,000	15
Tier 2	L90 ≥ 50,000 and L70 ≥ 75,000	25
Tier 3	L90 ≥ 75,000 and L70 ≥ 100,000	35

Within the Reliability and Safety lighting quality parameter, outdoor products are also scored based on their IP rating. IP Rating is an optional design feature, and as such, there is no prescriptive minimum requirement for IP Rating. Products only fail if they do not comply with the IP Rating reporting requirements as indicated in Section 4.2.2.3. The point tiers shown in Table 4-17 represent an effort to encourage manufacturers to increase IP Rating performance, if applicable. If the product is not awarded any points for IP Rating, it is still eligible to meet the Criteria based on its performance in the other quality parameters.

Table 4-17 provides two performance tiers of IP Ratings, with points being rewarded on the basis of either the first or second digit, corresponding to the level of protection against solids (e.g., dust and other particles) and liquids intrusion, respectively.

Table 4-17. IP Rating Requirements

Tiers	Qualification Thresholds (IP Rating)	Points Accrued
Tier 1	1 ≤ First Digit < 4, OR 1 ≤ Second Digit < 5	10
Tier 2	First Digit ≥ 4, OR Second Digit ≥ 5	20

4.2.3.8 Efficiency

The outdoor Lighting Quality Rating tiers for the Efficiency parameter rate products based on their efficacy performance. Due to the varying nature of product category efficacies as lumen output increases, different efficacy requirements are set for each of the four outdoor product categories covered in the Criteria. The structure of the outdoor product categories is based on rated lumen output of the product, rather than by end-use application, corresponding to the DLC's low output (250-4,999 lumens), mid output (5,000-9,999 lumens), high output (10,000-29,999 lumens), and very high output (greater than 30,000 lumens) outdoor product categories as described in the DLC Technical Requirements V4.4. Each product category has a prescriptive minimum efficacy and five additional tiers of increasing efficacy ranges. If products do not meet these minimums, they fail the Criteria.

To incentivize increased efficacy performance, Table 4-18 provides efficacy performance tiers for low output products; Table 4-19 provides the efficacy performance tiers for mid output products; Table 4-20 provides the efficacy performance tiers for high output products; and Table 4-21 provides the efficacy performance tiers for very high output products.

Table 4-18. Efficacy Criteria for Low Output Outdoor Products (250-4,999 Lumens)*

Tiers	Qualification Thresholds (lm/W)	Points Accrued
Minimum	90 ≤ Efficacy < 100	0
Tier 1	100 ≤ Efficacy < 105	20
Tier 2	105 ≤ Efficacy < 110	25
Tier 3	110 ≤ Efficacy < 115	33
Tier 4	115 ≤ Efficacy < 125	38
Tier 5	Efficacy ≥ 125	45

*As described by the DLC Product Eligibility: https://www.designlights.org/solid-state-lighting/qualification-requirements/product-eligibility/.

Table 4-19. Efficacy Criteria for Mid Output Outdoor Products (5,000-9,999 Lumens)*

Tiers	Qualification Thresholds (lm/W)	Points Accrued
Minimum	95 ≤ Efficacy < 105	0
Tier 1	105 ≤ Efficacy < 110	20
Tier 2	110 ≤ Efficacy < 115	25
Tier 3	115 ≤ Efficacy < 120	33
Tier 4	120 ≤ Efficacy < 130	38
Tier 5	Efficacy ≥ 130	45

*As described by the DLC Product Eligibility: https://www.designlights.org/solid-state-lighting/qualification-requirements/product-eligibility/.

Table 4-20. Efficacy Criteria for High Output Outdoor Products (10,000-29,999 Lumens)*

Tiers	Qualification Thresholds (lm/W)	Points Accrued
Minimum	100 ≤ Efficacy < 115	0
Tier 1	115 ≤ Efficacy < 120	20
Tier 2	120 ≤ Efficacy < 125	25
Tier 3	125 ≤ Efficacy < 130	33
Tier 4	130 ≤ Efficacy < 135	38
Tier 5	Efficacy ≥ 135	45

*As described by the DLC Product Eligibility: https://www.designlights.org/solid-state-lighting/qualification-requirements/product-eligibility/.

Table 4-21. Efficacy Criteria for Very High Output Outdoor Products (≥ 30,000 Lumens)*

Tiers	Qualification Thresholds (lm/W)	Points Accrued
Minimum	100 ≤ Efficacy < 115	0
Tier 1	115 ≤ Efficacy < 120	20
Tier 2	120 ≤ Efficacy < 125	25
Tier 3	125 ≤ Efficacy < 130	33
Tier 4	130 ≤ Efficacy < 135	38
Tier 5	Efficacy ≥ 135	45

*As described by the DLC Product Eligibility: https://www.designlights.org/solid-state-lighting/qualification-requirements/product-eligibility/.

4.3 Test and Verification Considerations

Stakeholders indicated at each engagement point that the CA IOUs' considerations for the certification process, manufacturer burden, and testing and verification plans are critical for the implementation of the Criteria.

Navigant identified three initial testing and verification pathways for the CA IOUs to consider with regard to this stage of the Criteria, if implemented in practice.

1) **Allow Manufacturers to Self-Report Certification Data**. Similar to the early stages of the CEC's Voluntary California Quality LED Lamp Specification, this option would allow

manufacturers to self-report certification data according to the requirements listed in the Criteria. This option would require the development of a standardized test form for manufacturers to fill out and submit to the State of California, as well as a California-managed database or collection process of manufacturer data.

2) **CA Implement Testing and Verification System**. Similar to California's Appliance Efficiency Regulations (Title 20) which includes a publicly available database of certified products entitled the Modernized Appliance Efficiency Database System (MAEDBS),[20] this option would require the CA IOUs to develop a certification system where manufacturers submit test data. This option would require an ongoing enforcement role implemented by the State of California to ensure products are in compliance with the Criteria. Currently, the MAEDBS for California's Appliance Efficiency Regulations is operated by the CEC.

3) **CA Leverage DLC Reporting Infrastructure**. Navigant conducted an informal interview with DLC representatives to determine the feasibility of this option, and DLC expressed a willingness to offer integration of their database and online application programming interface (API) platform with the Criteria. This would involve leveraging DLC infrastructure to add a "CA Criteria Eligible" field to the DLC QPL. The benefit of this approach is that it minimizes the time commitment burden for the State of California for testing and verification. While Navigant has not conducted an analysis to verify the cost effectiveness of this option, it could potentially represent the most economically-efficient option given the reach and complexity of the non-residential LED lighting market.

4) **Considerations for Downlight Luminaires and Retrofits.** Currently, the DLC does not include downlight luminaire and retrofit products as eligible for the DLC QPL. These products are eligible for ENERGY STAR certification, so the State of California can attempt to leverage the ENERGY STAR dataset to verify compliance with the Criteria, similar to the DLC reporting option above.

4.4 Criteria Future Revisions Plan

During the stakeholder engagement activities for Part One of this Study, Navigant received feedback and recommendation that the Criteria undergo annual revisions to keep-up with the rapidly changing LED industry. If implemented in practice, and within the means of the CA IOUs and CPUC, Navigant recommends the CA IOUs to undergo an annual review of the Criteria that is composed of the following Steps shown below in Figure 4-1.

[20] The MAEDBS database can be accessed through the following link: https://cacertappliances.energy.ca.gov/Login.aspx

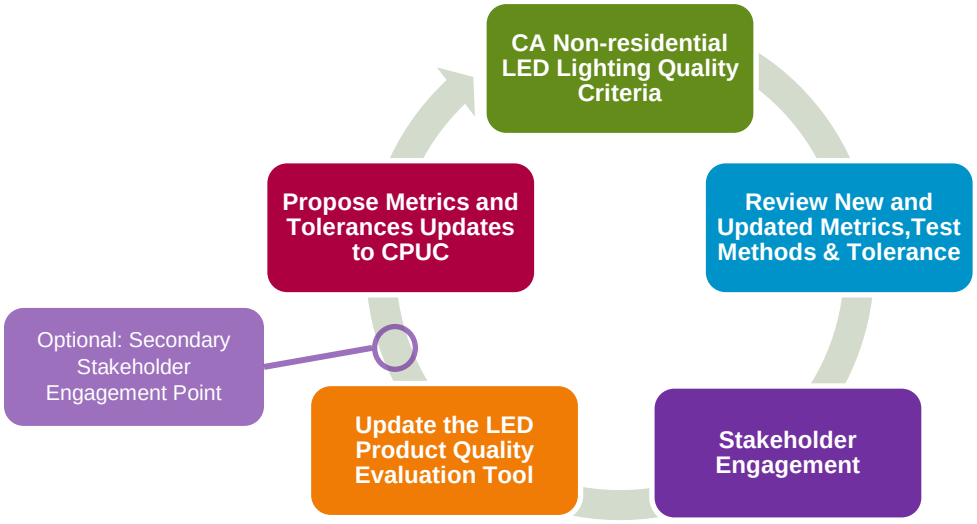


Figure 4-1. Annual Criteria Future Revisions Plan Cycle

1) **Review New and Updated Metrics, Test Methods, and Tolerances**. Navigant proposes that each year the CA IOUs conduct research to investigate new test methods, procedures and specifications that have been published and/or adopted. The goal of this step is to determine whether metrics identified as important to defining lighting quality could now potentially be considered feasible to include in the Criteria (see Section 3.2 of Part One for more detail on metrics omitted from this initial version). In addition, updates to existing metrics and tolerances based on LED technology development should also be considered. In particular, Navigant recommends the CA IOUs monitor the status of the following metrics, as they are currently being investigated by industry organizations to improve lighting quality: glare, flicker, color consistency, TM-30, BUG rating, communication protocols, and networked lighting control features.

2) **Stakeholder Engagement**. Following the review process, Navigant recommends that the CA IOUs engage key stakeholders with the goal of garnering consensus and industry perspective on recent trends for LED lighting quality metrics, test methods and performance. Key stakeholder groups to engage include the CEC, CLTC, DLC, IES, DOE, LRC at Rensselaer Polytechnic Institute, PNNL, IALD, as well as non-residential LED lighting manufacturers. Optionally, stakeholders could again be engaged prior to the proposal of metric and tolerance updates for the Criteria. This could serve as a final review prior to providing the CPUC with recommended updates.

3) **Update the LED Product Quality Evaluation Tool**. Part of Navigant's deliverables for Part One of this Study was to provide the CA IOUs with a spreadsheet that analyzes the DLC QPL and DOE's LED Lighting Facts database products which meet the proposed Criteria. This LED Product Quality Evaluation Tool[21] aids in determining the appropriate metrics and thresholds that represent the top-half of the market for LED non-residential products in terms of the proposed definition of lighting quality. This Tool can be updated to evaluate future versions of each database, as well as additional metrics and revised performance tolerances as needed. Navigant recommends this step in the revision plan to ensure 1) that products available are able to meet

[21] The LED Product Quality Evaluation Tool was provided to the CA IOUs along with this report on May 2, 2018, and the results of its contained analysis are discussed in Appendix B of Part One.

the revised Criteria and 2) that the revised Criteria continues to represent products in the top-half of the market as related to the proposed definition of lighting quality.

4) **Propose Metric and Tolerance Updates to CPUC**. Once Steps 1-3 have been completed, Navigant recommends that the CA IOUs then propose the necessary metric and tolerance updates to the CPUC. These updates can be provided using the technical Criteria outlined in Section 4.2.

5. RECOMMENDATIONS

Navigant has identified the following key findings and recommendations for consideration by the CA IOUs and other stakeholders.

5.1 Program Emphasis on Key Product Categories

CA IOUs should provide program assistance to priority categories that have the most market leverage and potential energy savings impact. Navigant identified several product categories – low and high bay, ambient commercial lighting and linear replacement lamps, downlights, and outdoor products – that are well-positioned in the market currently, expected to grow significantly in the next 5-7 years, and have the greatest energy savings potential based on legacy technologies currently installed. To accelerate the adoption of LED technologies in these applications and achieve significant energy savings, the CA IOUs should continue to place program emphasis on these product categories.

5.2 Criteria Results and Implementation

Move forward with the blended prescriptive, reporting, and performance approach to the Criteria. The research and analysis showed that the representation of the top-half of the market in terms of lighting quality is best identified by a combination of prescriptive, reporting, and performance criteria. In particular, the performance criteria, which is implemented through the Lighting Quality Rating described in Section 4.2.3, rewards higher performance using a tiered point structure. In addition, several industry stakeholders were in favor of the performance approach since it incentivizes increased lighting quality performance while allowing for tradeoffs between the metrics included.

The Criteria has been vetted with key industry stakeholders to ensure LED products meeting the Criteria are of high lighting quality when compared to those qualified by the DLC and ENERGY STAR. Additionally, existing data from the DOE's LED Lighting Facts database and DLC's QPL were used to optimize the Lighting Quality Rating approach. The results of this optimization are discussed in Appendix B of Part One.

Utilize the LED Product Quality Evaluation Tool to analyze LED products meeting or not meeting the Criteria. The LED Product Quality Evaluation Tool should be updated annually, if the Criteria is implemented in practice, to evaluate future versions of each database, as well as additional metrics and revised performance tolerances as needed. This update process will help to ensure that LED products available are able to meet any future revised Criteria and that any future revised Criteria continues to represent the top-half of the market in terms of the proposed definition of lighting quality.

Use the outcomes of this initial Criteria analysis, paired with those of the non-residential market characterization, as justification to defer to DLC and ENERGY STAR for program incentive requirements. The results of the Criteria analysis, the proposed definition of lighting quality, and the market characterization depict a market snapshot that confirms the most suitable approach for the CA IOUs is to reference DLC and ENERGY STAR for program incentive qualification instead of implementing the Criteria in practice. Section 3.2.2 details that the DLC market penetration of the 2017 sales was approximately 55%, which generally aligns with the top-half of lighting quality initiative in this Study. Additionally, manufacturers and other stakeholders noted during the stakeholder engagement process that the testing and verification considerations with this type of implementation would require program bandwidth and support staff that would be difficult for California to provide. As such, Navigant recommends the CA IOUs use the insights found in this evaluation as feedback to monitor DLC and

ENERGY STAR developments and provide feedback where necessary to ensure lighting quality is continually emphasized by those organizations.

5.3 Trial Run of Data Reporting and Criteria Scoring Evaluation

Engage with stakeholders to encourage participation in a trial run of the Criteria. Stakeholder feedback received at various phases of the Study suggested there could be issues with a compliance system designed for the Criteria implementation and the current lack of available data for metrics considered in the Criteria. Should the Criteria be implemented by California, Navigant proposes to install a trial period (e.g., 6 months) of the Criteria prior to the CA IOUs putting it into effect. The threshold for incentives during this period could remain as currently structured, with the addition of manufacturers submitting the data needed for Criteria participation. After or during the trial run, the Criteria can be re-evaluated and optimized based on an accurate and up-to-date full dataset.

5.4 DLC and ENERGY STAR Requirements

Align with DLC Technical Requirements and ENERGY STAR Program Requirements. Stakeholder engagement and research showed that DLC and ENERGY STAR are the most established organizations for developing specification tolerances and thresholds that influence product design and lighting quality. As such, CA IOUs should continue to reference the most current versions of the DLC Technical Requirements (currently V4.4) and the ENERGY STAR Program Requirements Product Specification for Luminaires (Light Fixtures) Eligibility Criteria (currently V2.1) as first levels of qualification for the Criteria. In coming months, DLC Technical Requirements v5.0 will likely be finalized (per comments received by DLC representatives on Part One of this Study), which is set to include several additional metrics related to quality. The CA IOUs should review this document when published and update references within the Criteria to DLC v5.0 if applicable.

Maintain ongoing coordination with DLC and ENERGY STAR. CA IOUs should monitor and examine changes made within each new version of the DLC Technical Requirements and ENERGY STAR Program Requirements. Contact should be maintained between the CA IOUs, DLC, and ENERGY STAR representatives as new versions of each organization's specifications or criteria are being developed to align interests with industry and minimize conflicts with the California Non-Residential LED Lighting Quality Criteria.

5.5 Test and Verification Considerations

Work with the CPUC and CEC to determine the most suitable route forward for ensuring product compliance. Stakeholders suggested that fully developing the structure of a testing and verification system parallel to finalizing the Criteria is vital to ensuring high quality products are adopted by customers as a result of the Criteria's implementation. Therefore, should the Criteria be implemented in practice after conferring with the CPUC, the CA IOUs should work with the CPUC and CEC to determine the most viable route to ensure product compliance.

Consider three potential testing and verification pathways identified as a starting point for the CA IOUs, CPUC, and CEC. If implemented, these pathways for the Criteria's testing and verification are as follows: 1) allow manufacturers to self-report certification data, 2) CA implement its own testing and verification system, or 3) CA could leverage the DLC and ENERGY STAR reporting infrastructures.

5.6 Future Revisions

Utilize the outlined Criteria Future Revisions Plan for updating the Criteria, if implemented in practice. Several key industry stakeholders emphasized the need for the CA IOUs to remain vigilant as new metrics and test methods become available for defining and quantifying lighting quality for LED products. In addition, stakeholders commented that revisions should be continued for the Criteria, preferably on an annual basis. The LED industry is evolving rapidly, and industry standards and metrics are continually developed to assess the performance of products coming to market.

In order to maintain the relevancy of the Criteria if it is implemented, the CA IOUs should refer to Section 4.4 which described the recommended process for updating the Criteria, This Criteria Future Revisions Plan indicates the CA IOUs should 1) review new and updated metrics, test methods and industry-accepted tolerances, 2) continually engage with key stakeholders, 3) regularly update the LED Product Quality Evaluation Tool with new products, and lastly 4) propose new metrics and tolerances for consideration with the CPUC.

Appendix A. PART ONE PUBLIC COMMENTS AND RESPONSES

Comment #	Topic	Organization	Comment[22]	Response
1	Study Background and Context	General Public	The stated goal of Part One of this Study is to develop a procedure to evaluate an LED product's lighting quality relative to those available within California's non-residential lighting market. It is not clear why a quality evaluation procedure is needed. What is the demonstrated need for a new quality standard, above and beyond the current DLC and Energy Star qualification standards? Is there evidence of widespread quality issues with LED products that have received incentives? If specific quality issues for LED lighting have been identified, I would suggest it would be more effective and efficient to work with the existing DLC and Energy Star programs to address these issues.	In response to the CPUC's 2015 LED Troffer work paper disposition, it was determined that additional clarification was needed on qualifying LED technologies for the CA IOUs. Specifically, a quantification of "products that are in the top-half of quality on the market" was suggested to avoid offering incentives for lighting products that do not meet consumer expectations and result in a poor lighting experience, discouraging customers from investing in energy efficient lighting in the future. While DLC and ENERGY STAR provide minimum performance requirements, these requirements do not provide insight on their relative performance to the rest of the LED market. Therefore, the goal of this study was to develop a set of criteria that quantifies the top-half of quality on the market and evaluates the criteria with respect to the market-weighted performance of products sold in California.
2	CA IOUs – DLC Cooperation	DLC	Thank you for the opportunity to comment on this proposal. The DLC is prepared and excited to work with the California utilities to address this important topic of lighting quality. We have many additional questions and comments, both technical and logistical, that we look forward to further discussing.	The CA IOUs appreciate the DLC's participation, inputs, and comments on this Study and will look forward to engaging with the DLC as the effort to identify lighting quality progresses.
3	Stakeholder Engagement and Representation	Acuity	Table 2-2 outlines the make-up of the stakeholders engaged in lighting quality discussions. The ratio of 2:1 of other stakeholders (24 participants) versus manufacturers (12 participants) is concerning since manufacturers are most impacted by and most essential (product offering) to the success of the program. It also underscores the misplaced notion that lighting manufacturers don't care about lighting quality. Manufacturers invest heavily in developing innovative, quality products that meet and exceed	In addition to the manufacturers listed, Navigant reached out to others that were not available for comment or did not respond. Manufacturers were engaged at multiple stages of the lighting quality Criteria development, and their participation and feedback were instrumental to the analysis. The CA IOUs understand that continued cooperation

[22] The public comments in this Appendix are to the California Statewide Non-Residential LED Quality and Market Characterization Study, Part 1 – Preliminary Non-Residential LED Quality Criteria report, which was posted for public review in August 2018. The comments (and Navigant's responses to those comments) are organized with other stakeholder comments of similar topics, but the original comments are unedited. General comments that were informative or introductory and did not require a response were excluded from this table.

			customer expectations. We take on all the burden only to be undercut by non-ethical competitors providing fraudulent data.	with manufacturers during this process is vital to the success of the finalized Criteria.
4		NEMA	1. Table 2-2: This table outlines the make-up of the stakeholders engaged in lighting quality discussions. The ratio of 2:1 of other stakeholders (24 participants) versus manufacturers (12 participants) is concerning since manufacturers are most impacted by and most essential (through product offerings) to the success of the program. It also underscores the misplaced notion that lighting manufacturers don't care about lighting quality. Manufacturers invest heavily in developing innovative, quality products that meet and exceed customer expectations and must bear the brunt of customer dissatisfaction through impacts to sales.	
5	Title 24 – Lighting Quality	Signify	The last sentence at the bottom of page 9 states: "While the Criteria does enable the identification of the "top-half of lighting quality" for non-residential LED products on the market, it does not replace codes and standards, such as California's Title 24, which are still critical for ensuring the right quality product is installed for a given application." We wish to point out that Title 24 is California's state building code and as such, is not responsible for nor does it set requirements for "right quality products" to be installed in a given application.	Navigant agrees with this clarification and removed the wording in the Executive Summary of Part Two. Although it was not feasible to implement an application-based quality criteria in this Study, Navigant understands this as a significant gap in lighting standards within the industry and looks forward to hopeful progress made in coming years.
6		NEMA	2. Section ES 3: Pages 9 and 10 The last sentence at the bottom of page 9 states: "While the Criteria does enable the identification of the "top-half of lighting quality" for non-residential LED products on the market, it does not replace codes and standards, such as California's Title 24, which are still critical for ensuring the right quality product is installed for a given application." CA Title 24 is the State's building code and as such, is not responsible for nor does it set requirements for "right quality products" to be installed in a given application. "The purpose of building codes is to provide minimum standards for safety, health, and general welfare including structural integrity, mechanical integrity (including sanitation, water supply, light, and ventilation), means of egress, fire prevention and control, and energy conservation." With respect to quality, it is incumbent on design professionals to ensure product quality as part of the design and construction process. The scope of Title 24 Part 6 (10-101(b)) clearly states the following: "Nothing in this article lessens any necessary qualifications or responsibilities of licensed or registered building	

			professionals or other designers or builders, or the duties of enforcement agencies that exist under state or local law."	
7	Lighting Quality Definition	Signify	The report appears to confound the following three topics: — Lighting quality — Quality of a lighting product — Lighting product attributes. From our perspective, lighting quality is related to how lighting is perceived in a space; the second topic relates to safety and whether a product is durable, i.e., will it last; the third includes items like efficacy, and IP rating, neither of which have to do with quality. It is not clear which of these three topics represents 'LED Quality'. The report should be reworked to separate these topics.	The metrics included in this initial version of the Criteria were recommended by stakeholders as important aspects of lighting quality, and the definition proposed in Section 4.1 attempt to cover each of these elements. One of the recommendations in this Study is to implement a trial period of reporting data associated with the Criteria requirements. The Criteria can then be revised and optimized based on a comprehensive dataset.
8		NEMA	7. The proposal as written is clearly an attempt at blending lighting quality, the quality of a lighting product, and lighting product attributes. The first item, lighting quality, is related to how lighting is perceived in a space; the second is related to safety and whether a product is durable, i.e. will it last; the third item of lighting quality includes factors like efficacy, or Ingress Protection (IP) rating, which may have more to do with the quality of the experience or application. The existing proposed requirements mix is unclear in how these three are prioritized overall. We suggest a further examination in Phase 2 of this mix and an analysis as to whether all three focuses benefit from inclusion. Providing examples of the representative products that score highly in one versus the other would go far in better demonstrating if there is a benefit. If no clear benefit of inclusion is unveiled, then those categories may want to be considered for removal.	
9	Data Source Quality and Comprehensiveness	Acuity	Navigant utilized the DOE Lighting Facts database and the DLC QPL to determine the "top-half of lighting quality." We find this problematic since the DOE Lighting Facts database was self-reporting with unreliable data. The Energy Star program data is uploaded by a 3rd party certification body and would be considered significantly more reliable.	Navigant agrees that there is no comprehensive dataset that contains information of all products available on the market, and this data limitation is noted in Section 2.3 of Part One. The initial framework developed in this Study is intended to be revised over time as data are submitted for the various quality metrics included in the Criteria. Further, the ENERGY STAR database (and the DLC QPL) do not represent the full spectrum of products available on the market, so analysis was based on the LED Lighting Facts database (the most comprehensive database at the time). However, the ENERGY STAR database and the DLC QPL were used to make adjustments and QC the final criteria.
10		General Public	The proposed quality evaluation process aims to identify the "top-half" of products. In order to do this, a comprehensive data set of 100% of available LED products would be needed. However, such a data set is not available. The study relied on the DLC QPL and the LED Lighting Facts databases. The DLC QPL is a self-selected database that includes only products that meet DLC specifications. The LED Lighting Facts database is a larger and broader product performance database, however, since it is voluntary, it still does not represent 100% of available LED lighting products and there is no assurance that products representative of the larger market will	

			be listed. Without a comprehensive database, the goal of identifying the “top-half” is impossible.	
11	General Misstatements and Unsupported Opinions	Acuity	There were a number of misstatements and unsupported opinions in the document that should be re-evaluated: a. Data transparency ensures lighting quality b. Standardizing communication protocols and ensuring systems offer interoperability between manufacturers is the key to customer and end-user acceptance c. R9 is often over-looked by manufacturers	Navigant agrees that these statements can be reworded and clarified. While the metrics discussion in Part One (where these comments were located) was not included or revised in this Part Two report, the language in these statements can be reworded. 1) Rather than “ensuring” lighting quality, data transparency better enables lighting designers and consumers to make more informed decisions on the quality of the products from which they are choosing. 2) Standardizing communication protocols and ensuring systems offer interoperability between manufacturers would benefit (rather than is “the key to”) customer and end-user acceptance 3) R9 is not necessarily over-looked by manufacturers; instead it is not reported as often in product information data.
12		NEMA	12. Unsupported Opinions: There are a number of misstatements and unsupported opinions in the document that should be re-evaluated and proven or redacted. NEMA proposes the following concepts or statements be redacted: • Data transparency ensures lighting quality • Standardizing communication protocols and ensuring systems offer interoperability between manufacturers is the key to customer and end-user acceptance • R9 is often over-looked by manufacturers	
13	Scope: Linear Replacement Lamps	NEMA	4. Section 3.3, Table 3-10 In Table 3-10, what is the difference between item # 29 (T8/T5/T5HO Four-Foot Replacement Lamps) and items #30 through 33? Where are T12 LED replacement lamps in this mix?	T12 LED replacement lamps are included within the scope of the Criteria, and the linear replacement lamp categories were consolidated into one category. See Table 4-3 for the full list of products covered by the Criteria.
14		Signify	Section 3.3.1 – Covered Product Categories: Table 3-10 Please clarify the difference between item # 29 (T8/T5/T5HO Four-Foot Replacement Lamps) and items #30 through 33? Other than the UL type, they appear to be the same. Where are T12 LED replacement lamps in this mix?	
15	Scope: Downlight Retrofit Kits	NEMA	11. It is not clear if downlight retrofit kits are addressed by this document. They need to be explicitly excluded as they are regulated by CA Title 20.	Downlight retrofit kits are included in the scope of the Criteria, as they were determined to have a significant market share and there are quality elements of the Criteria (e.g., TM-30 data reporting) that are not included in CA Title 20. ENERGY STAR certification is a prescriptive requirement for downlight luminaires and downlight retrofit kits, so products qualifying for the Criteria are inherently still eligible for incentives under ENERGY STAR.
16		Signify	Downlight retrofit kits are within the scope of Energy Star but are also subject to the minimum requirements in Title 20 to be sold in California. It is not clear how the CPUC intends to handle these, but the products should be excluded from the scope of this report without disrupting their ability to be eligible for incentives under Energy Star.	
17	Scope: Tunable Lighting	NEMA	10. White tunable and color tunable product are currently in the market. How does the Navigant plan to include these in the specification?	Although tunable products are a growing market segment, these products are a recent development and still a small market share at this

18		Signify	One current development in the market is tunable lighting. Has this been considered and how will it be included in the report?	time. The scope of the Criteria does not exclude or create separate requirements for tunable lighting, so if these products fall within an existing product category, they can be eligible for the Criteria provide they meet the prescriptive, performance, and reporting requirements.
19	Lack of Quality Metrics	General Public	In section 2.3.2, the study identifies a significant, fundamental flaw to the validity of the proposed quality evaluation process – lack of key quality metrics. The report states “metrics for flicker, glare, color consistency, and communication protocols were all identified by industry stakeholders as important to lighting quality; however, none of the available metrics are currently feasible to include based on the lack of industry accepted test methods or precedent through existing specifications.” As a result, products could meet the CA LED Lighting Quality Criteria, yet fail in an important quality aspect, such as terrible glare or flicker. Given that several key quality metrics are not part of the criteria, the validity of the criteria as a measure of "quality" LED lighting products would be suspect.	The framework developed in this Study for analyzing the top-half of the market in terms of the proposed definition of lighting quality is an important step for addressing quality. Navigant understands that multiple metrics are unable to be included in this initial version of the Criteria, but it is recommended to the CA IOUs to continue to evaluate the validity of these metrics for inclusion on a regular basis. DLC commented that several of these metrics are being considered for v5.0 of their Technical Requirements, so the next version of the Criteria could incorporate these new metrics.
20	Color Maintenance	Acuity	The Energy Star specification exempts outdoor luminaires. Please confirm that downlights for outdoor applications are exempted as well.	Outdoor downlight luminaires and retrofit kits are excluded from the scope of the Criteria. Refer to Table 4-3 for the full scope of products included in the Criteria, including indoor and outdoor designations.
21		NEMA	14. Color Maintenance: We note the ENERGY STAR Luminaires specification exempts outdoor luminaires and ask the CPUC to confirm that downlights for outdoor applications are exempted as well.	
22	Color Rendering - New Metrics and TM 30 Reporting	Signify	We agree with Navigant’s recommendation to use CRI (Ra) at present and wait until new color quality measures have been developed by the CIE and vetted and accepted by the lighting industry. TM-30 is still undergoing changes and a new version is close to publication. The new version harmonizes the TM-30 fidelity metric with the fidelity metric developed by the International Commission on Illumination (CIE). Future changes to TM-30 may come as CIE works on the gamut metric and the color vector diagram. A complete multi-metric system should be adopted and endorsed by CIE for global use before it is required or reported in specifications. It is important to note that the	Multiple stakeholders recommended including reporting requirements for TM-30 data, noting that the required reporting of TM-30 data would better enable industry to evaluate TM-30 for future specifications and versions of the Criteria. Overall, the reporting requirements in the Criteria are emphasized to generate transparency within the industry to ensure consumer satisfaction. Navigant has also clarified the reporting requirements in Section 4.2.2.5 to require the reporting of the full set of TM-30 test data, instead of only Rf and Rg data.

			CIE does not recommend their new fidelity index, CIE-Rf, for commercial purposes. Therefore, Rf, is not a replacement of the general color rendering index, Ra, neither for the rating and specification of products nor for use in minimum performance requirements. Consequently, CRI continues to be the globally recommended index for measuring and specifying color rendering of white light sources. We note the report suggests not to require reporting of Pst/SVM (the NEMA 77 metrics), with this reasoning: "Navigant recognizes this as a significant step forward for addressing flicker and improving the power quality of lighting products, but due to the early stages of industry adoption of NEMA 77-2017, it is recommended for the CA IOUs to omit these metrics from the initial version of the Criteria." The very same reasoning should apply to TM-30, as it too is in the early stages of industry adoption. Navigant should wait for the color rendering situation to stabilize before recommending reporting of a new color rendering system.	
23		NEMA	13. TM-30 data reporting: TM-30 is being revised, so to gather data in accordance with the current (2015) version will not be of any use. The emerging version (2018 est.) will have reporting requirements and other parameters worth examining, but industry does not need the CPUC's assistance or urging to gather this data regardless. Data gathering and analysis will come about as part of industry's evaluation of the new TM-30 version. Reassess this requirement when the later revision is published.	
24		Acuity	Navigant is proposing the reporting of Rf and Rg, metrics from the IES TM-30 document to "1) generate more data within the industry and 2) allow the industry to organically understand the best path forward for incorporating TM-30 in future Criteria." Rf and Rg alone are incomplete data points from TM-30 and the use of only these two numbers to understand color quality will lead the industry down the same path as CRI with very incomplete information and potentially products that do not meet consumer expectation. We recommend that the TM-30 data reporting requirement be removed.	
25	Color Rendition Requirements	General Public	I understand that CRI (& R9) is included primarily because of its widespread use, but numerous published articles have shown that typical "CRI 80" LED light sources (meeting the proposed criteria) are ranked near the bottom of those shown for preference and/or naturalness, and deemed unacceptable by approximately 1/3 of study participants. Further the combination of the proposed criteria and CRI's underlying inaccuracies (which extend beyond being an	This analysis and Criteria were developed with an understanding of the current limitations with CRI as a comprehensive color quality metric. This was a critical factor in Navigant's recommendation to use CRI in this initial version of the Criteria and allow for color metrics to be updated with industry-accepted quality metrics when available. To

			average) disqualify light sources that are rated near the top for preference and/or naturalness; these sources are deemed acceptable by as high as 95% of participants. The stated conclusion that "CRI can serve to limit the risk of allowing lower quality products" is unsupported (and contradicted) by current research. In fact, its inclusion may be harmful to lighting color quality. The latter situation may be remedied by including an “or” spec, with an alternative path to qualification using a combination of ANSI/TM-30-18 metrics (Rf, Rg, Rcs,h1) that have been shown to be effective for specifying color quality in several research studies, and as noted by “most stakeholders”. This is the current approach in WELL v2. A presentation exploring the relative performance of color rendition spec criteria is attached. Of particular relevance are slides 28, 30, and 58. See also: Zhang F, Xu H, Feng H. 2017. Toward a unified model for predicting color quality of light sources. App Opt 56(29):8186-8195 Royer MP, Wilkerson A, Wei M, Houser K, Davis R. 2016. Human perceptions of colour rendition vary with average fidelity, average gamut, and gamut shape. LR&T 49(8):966-991 Royer M, Wilkerson A, Wei M. 2017b. Human Perceptions of Color Rendition at Different Chromaticities. LR&T. DOI: 10.1177/1477153517725974. Esposito T, Houser K. 2018. Models of colour quality over a wide range of spectral power distributions. LR&T. DOI: 10.1177/1477153518765953 Royer M. 2017. Comparing Measures of Average Color Fidelity. Leukos 14(2):69-85	generate additional data within the industry, Navigant is also recommending the reporting of full TM-30-18 test data.
26	CRI Performance Criteria	General Public	Using a tiered scoring system with CRI is a bit contrived/nonsensical, because CRI is not correlated with any visual quality (e.g., naturalness, preference, vividness, acceptability). Higher is not necessarily better: products in the minimum tier may be preferred or viewed as more natural than those in tier 3. The origin of the tier thresholds is also unclear, as they are not based on research or experience. In contrast, there are research studies to support tiers when using IES TM-30-18 measures to set criteria.	Navigant agrees that there are limitations to the CRI metric, though it is still currently widely recognized as a key metric related to spectrum. CRI thresholds are also standard within similar industry specifications, and a benefit of the tiered performance Criteria system is that products can emphasize other priority metrics to gain the quality rating points needed to pass. Additionally, Navigant is incorporating reporting requirements for TM-30-18 in the final proposed Criteria.
27	TM-30 New Version and SPD Data	General Public	Any requirements for IES TM-30 should be updated to ANSI/IES TM-30-18, which is approved and currently in typeset. [Note that this is an ANSI standard, whereas CRI/R9 are not.] Further, the values considered should include, at a minimum, Rf, Rg, and Rcs,h1 (this requires no extra computation). Including only Rf and Rg is insufficient. Required reporting of the SPD would be even more useful, and no extra burden (perhaps less). There is a standardized file format for SPD data (IES TM-27 and/or IES TM-33 when it is published)	The reporting requirements for TM-30 data were updated in Section 4.2.2.5 to require full TM-30 data according to the recently updated TM-30-18. Navigant is unaware of an industry precedent of SPD data reporting with respect to specifications or standards. Should this become an industry-accepted protocol, it can be included in a future revision of the Criteria.

28	R9 Criteria	Acuity	Navigant is proposing an R9 greater zero requirement for downlights and only an R9 reporting requirement for other indoor LED products. R9 data is available for both downlights and other indoor LED products and the requirement should be the same. Either make R9 only a reporting requirement or require all products meet the R9 greater than zero requirement.	The prescriptive requirements in Section 4.2.2 leverage ENERGY STAR and DLC, and in several cases the requirements by each organization differ for some metrics. By requiring products to be ENERGY STAR certified or DLC qualified for Criteria eligibility, it is not possible to make R9 only a reporting requirement for all products as ENERGY STAR requires the R9 value to be greater than 0 for indoor downlights. For the remaining product categories, the intent of this metric within the Criteria is to 1) require reporting to generate data within the industry and 2) include as a voluntary performance metric that incentivizes a higher R9 value if the product's design emphasizes this aspect of quality. This offers flexibility (and less stringent requirements) to non-downlight products attempting to meet the Criteria.
29		NEMA	15. R9 Criteria: It does not make sense to require a mix of R9 requirements, either it should be reported for all products or greater than zero for all products, not a blend of the two. For instance, the draft proposes a requirement for R9 greater than zero for downlights and only an R9 value reporting requirement for other indoor LED products. R9 data is available for both downlights and other indoor LED products. We recommend that R9 be only a reported requirement.	
30	Dimming Criteria	Acuity	Navigant is proposing compliance with Energy Star's more comprehensive dimmability requirements (which includes testing) for downlights and the basic dimmable reporting requirements for all other LED products. This treatment is inconsistent and should be revisited.	This recommendation was made to ease burden on the CA IOUs regarding testing and verification, as well as that of manufacturers. More stringent dimming requirements for all non-downlight products would create additional certification burden on manufacturers. The test and verification recommendations provided in this Study generally attempt to leverage the ENERGY STAR and DLC testing requirements to prevent the need for additional testing.
31		NEMA	16. Dimming Criteria: The draft proposes two different metrics for products, despite the similarity of their common LED technology. For example, for downlights the draft proposes compliance with ENERGY STAR's more comprehensive dimmability requirements (which include testing) and only basic dimming reporting requirements for all other LED products. This treatment is inconsistent and should be revisited.	
32	Dimming Criteria	Signify	Section 3.3.3.5 – Controllability Table 3-22 awards additional points for products that dim to or below 0.1%. Please note that only a couple of companies make drivers that dim this low, thus these extra points favor products that use these drivers. We submit that there should be one tier that covers dimming between 10% and 1%, inclusive. No additional points should be awarded for products that dim below 1%.	Stakeholder groups indicated that dimming below 1% is a preferred feature of some products and applications, and it is also a secondary indicator of product construction quality. Therefore, the scoring structure for the dimming criteria was maintained in the final Criteria.
33	Lumen Maintenance Criteria	Acuity	Table 3-12 provides additional accrued points for products with L70 greater than 50,000 hours and L90 greater than 36,000 hours. Lumen maintenance projections (L70) above 50,000 hours do not define quality and do not ensure consumer satisfaction. Additional points should not be awarded for higher lumen maintenance projected values.	The Criteria developed in this Study are intended to be a reflection of the market at this time, instead of design recommendations for future products. Multiple stakeholder discussions indicated that product lifetime and reliability is an indicator of quality, and lumen maintenance

34		Signify	Section 3.3.3.2 - Reliability and Safety From the report we note that Tier 1 corresponds to the DLC premium level. This where the tiers should stop. Additional tiers will not incentivize manufacturers to develop products with extremely long L70 times. Just to be able to project 100,000 hour performance requires at least a year of testing. With design cycles around six months, the product under test will have been redesigned twice.	projections are the most suitable measure of product rated lifetimes at this time. In future revisions, if there are suitable metrics that also encompass product durability and construction, these will be considered for inclusion in the Criteria.
35	ISTMT Metric	NEMA	4. There are a few technical inaccuracies regarding ISTMT – this portion needs further clarification and refinement before publication. NEMA is unable to provide further clarification owing to lack of time left in this comment period.	The driver ISTMT and thermal performance requirements are unchanged from those listed by ENERGY STAR and DLC. Should these still need modification, stakeholders will have an opportunity for comment on this Part Two of the Study.
36	IP Metric Not a Quality Metric	Acuity	Ingress protection, while quantifiable and readily available information, is not a quality metric and should not be used in the program Criteria; it is a rating to help specifiers determine what product is best suited for a particular application. A higher IP rating does not ensure a better outcome or user experience and sometimes can result in an elevated price point that is not required for the particular project. An elevated ambient rating would be a better quality metric.	Navigant received feedback from stakeholders that product reliability and durability is a key aspect of quality, and at this time the IP rating is one of the few indicators of this aspect of quality. As industry-accepted metrics surrounding this area of quality are further developed, Navigant and the CA IOUs welcome feedback for incorporation in future revisions of the Criteria. Further, the IP rating metric is not a required metric for meeting the Criteria. It is optional, and products not wishing to utilize this metric to accrue points are allowed to emphasize other areas of quality. Regarding an elevated ambient rating, should there be an application of this within industry organization lighting specifications or testing bodies, it can be considered for inclusion in future versions of the Criteria.
37	IP Metric Not a Quality Metric	NEMA	8. In expansion of the preceding comment, the IP rating system is designed to help specifiers determine what product is best suited for a particular application. While the rating system provides a series of escalating numbers, it is incorrect to interpret or infer this scale implies a rising sense of quality. A higher IP rating does not ensure a better outcome or user experience and sometimes can result in an elevated price point that is not required for the particular project. We understand the current proposal intends to only have two levels of outdoor rating, by using their IP ratings, but the aforementioned intention that a higher IP number is not a “better” product is not made clear in the guidance, and it should be. Because this is a very application-specific determination, it would be better to remove IP ratings from the “quality” discussion entirely lest a less-informed entity make the mistake of copying this guidance without the benefit of understanding the IP rating system which could result in other consequences such as increased cost with no benefit, improper thermal conditions within the luminaire, etc.	
38	Prescriptive Criteria: DLC and ENERGY STAR Deviation	Signify	In several cases, the requirements between DLC and Energy Star criteria diverge. In some cases, the report recommends the stricter requirement. In other cases, products certified to Energy Star must continue to meet those requirements, while product certified to DLC do not.	ENERGY STAR and DLC requirements, although incorporated by the requirement for meeting the Criteria, are restated in Section 4.2.2 for transparency and how these metrics pertain to quality.

39	Prescriptive Criteria: Operating Frequency	Signify	From our perspective, for example, it makes no sense why a minimum operating frequency is required for downlights, but not other products. Because most LED lamps involve an electronic power supply, either operating frequency is relevant to all products or it is not. If Energy Star and DLC are the minimum requirements to be in the top 50 percent of lighting quality, then the metric is captured automatically and it can be removed as a requirement. The following table illustrates these discrepancies and our recommendations.	The operating frequency requirement was updated to include all LED products covered by the Criteria. ENERGY STAR and DLC requirements, although incorporated by the requirement for meeting the Criteria, are restated in Section 4.2.2 for transparency and how these metrics pertain to quality.
40		NEMA	3. Section 3.2.2 – Table 3-3 It is not clear why operating frequency is only relevant for LED downlights. Because most LED lamps involve an electronic power supply, either operating frequency is relevant to all products or it is not. We suggest it be removed a metric for this program. It may be argued the same is also true for color maintenance and color angular uniformity.	
41	Performance Criteria: Scoring Balance	General Public	We encourage in Phase 2 further testing of the scoring balance between the categories and a direct correlation made to intent. For example, if an intent is to encourage controllability - then it would be expected that controllability would be scaled such that it's use (along with other decisions) would result in a passing score INSTEAD of a different decision. Right now it does not seem to function in that way. Similarly - the minimum efficacy is only acceptable if both color metrics and the middle reliability is achieved - beyond that, the efficacy weighing overwhelms the balance, if the intention is to stress the color and reliability metrics (which should be limited to TM-21 constrained reported values and not unbounded calculations) then the expectation would seem appropriate for more significant emphasis.	Navigant has recommended a trial run of Criteria reporting to the CA IOUs, in which the metrics and thresholds under consideration will be re-evaluated and optimized based on a comprehensive dataset.
42	Performance Criteria: Tiered Scoring Metrics	Signify	We are surprised to see tiers as part of the criteria, both for efficacy and for lumen maintenance. We note the efficacy criteria have expanded from four to five tiers since the February workshop. Creating tiers and assigning more points to products with the highest efficacy, for example, will have the unintended consequence of favoring products with higher efficacies. An easy method to increase luminaire efficacy, for example, is to increase the lumens emitted at high angles from the luminaire. This method, however, increases glare, which decreases the quality of the lighting in a space. This is directly in conflict with what the report is trying to achieve.	Efficacy was noted by stakeholders and the CA IOUs as one of the primary indicators of quality for this Study. In the data analyzed, there are clear levels of efficacy within each of the Criteria categories, so it was deemed appropriate to reward points to tiered levels of efficacy. Although glare is not a metric suitable for inclusion in this initial version of the Criteria, Navigant understands this as a vital component of quality

43		NEMA	We note the efficacy criteria have gone from four to five tiers and that efficacy continues to be significantly over-weighted in relation to all other factors. Creating tiers and assigning more points to the highest efficacy will likely continue current misunderstandings among those less-experienced in lighting applications of favoring products with higher efficacies alone. The simplest way to improve efficacy testing results is to increase the high angle lumens from the luminaire, which increases glare. Thus, it is a fallacy to insist that high efficacy always equals better lighting quality. We urge reconsideration of the tiered system and would like to be part of the discussion. With regard to the lumen maintenance criteria in Table 3-12 and 3-24, we question the ability to reward claims beyond 50,000 hours. As explained in TM-21 there is no validity to any calculations beyond six times the tested time period. A product with an L70 of 100,000 hours, for example, will require 694 days of illuminated time in addition to the testing time which would be almost two years before a projection can be made, at which time by normal design cycles the product has been redesigned twice. As such the requirement for this guide should not include calculations beyond the standardized maximum projection which otherwise could stifle continued energy efficiency improvements. NEMA recommends additional monitoring of other reliability approaches for theses system that are under development by various standards organizations Regarding controllability, we recommend further study as to the intended encouragement that is intended. With the present points structure, it does not appear that a decision to get either 3 or 6 points would impact the crossover of 50 points in any combination of other categories. The addition of controllability as a factor is supported, but it should include more influence overall.	as well and will incorporate it within the Criteria when feasible. Additionally, Navigant has recommended a trial run of Criteria reporting to the CA IOUs, in which the metrics and scoring balances under consideration will be re-evaluated based on a comprehensive dataset.
44	Application-Dependent Quality	DLC	A second challenge (Section 2.3.3) is that many quality of light aspects are application dependent. For example, metrics for evaluating the important quality topic of glare are dependent on the physical characteristics of the area or space being lighted, the mounting height of the luminaire(s), the position of the observers in the space, and the task(s) being performed. A luminaire that may provide good lighting quality and low glare in one application may provide unacceptable lighting quality and high glare in another. That's not to say that the relative glare performance of an LED lighting product can't be evaluated at the product level without knowing the application characteristics. There are in fact metrics and methods to assess glare performance of luminaires in different applications, but it is not appropriate to establish broad minimum	Navigant agrees that application-dependent quality is needed focus area in the lighting industry. However, for this effort, the Criteria are required to be analyzed at the priority product category level for the CA IOUs perspective. In future studies, perhaps regulatory bodies and industry organizations will be enabled to engage with the DLC to address application quality.

			thresholds based on these glare metrics that all products must meet to be eligible for a Qualified Products List and utility incentives. Doing so will have the unintended consequence of restricting good lighting design while reducing lighting quality in some applications. This is where we suggest the California utilities may consider focusing their efforts to address quality. Quality is achieved in two parts: 1) with the product(s)design and 2) in how products are used in applications. The DLC will raise the bar for quality of products with V5.0 while incorporating new metrics and performance information to assess the quality in different applications. There is a need and opportunity for utilities within their program designs to address the quality piece at the application level. This would involve creating new program designs that use the new quality performance information that DLC will be provide on its QPL to incent better quality lighting at the application or project level. This is currently a gap with traditional utility lighting program designs, and a significant opportunity to increase the quality of light for utility program participants.	
45	DLC v5.0 Metrics	DLC	The DLC continually revises its specifications every year. The next major revision, SSL V5.0, is currently underway with a draft to be published in January 2019. The focus of this next revision is on Quality and Controllability of LED lighting. The purpose is to accelerate broad scale energy savings by improving the quality of light and controllability of DLC listed products. It is essential to support the dual goals of quality and efficiency to achieve the full energy efficiency benefits of LED lighting. To realize this objective, the V5.0 revision is addressing the quality topics of color quality, glare, optical distribution, flicker, and non-visual impacts. With regard to controllability, the DLC is increasing lighting control requirements of listed products while encouraging interoperability with lighting controls and networked lighting controls. A PowerPoint presentation that outlines the purpose, timelines, topics, and metrics under development for V5.0 is attached to these comments.	Navigant looks forward to reviewing the SSL V5.0 draft upon its availability and its inclusion of vital quality metrics (glare, flicker, etc.) that stakeholders have discussed during the engagement efforts of this Study.
46		DLC	As noted in the draft Criteria (Section 2.3.2), there are challenges to addressing lighting quality topics. One challenge is that the metrics to address quality of light aspects such as glare, optical distribution, and flicker currently lack industry-accepted test methods and/or are still being debated. The DLC is currently engaged with industry experts and standards organizations evaluating pathways, metrics, and test methods to address these topics with V5.0. Several options are currently under evaluation and/or development for inclusion in the first V5.0 draft.	

47	Test and Verification System Recommendations	Signify	Test and Verification Considerations – Section 3.4 We favor pathway #1, self-reporting, without certification. Since these products already need to comply with DLC or Energy Star, the initial certification has been done. There is no value added by requiring additional certification.	Testing and verification specifics were not part of the Study scope – only a framework of testing and verification considerations was provided at the request of stakeholders – and compliance protocols will be developed at later stages of implementation. The comments regarding testing and verification are noted and will be referenced should the Criteria implementation progress to that stage, though it is Navigant's recommendation to not implement the Criteria in practice and use the results of this analysis as justification to continue to reference DLC and ENERGY STAR for program incentives (see Section 5.2).
48		NEMA	5. We appreciate the idea of leveraging existing program metrics to define the CPUC luminaire requirements. We caution Navigant and the CPUC against establishing additional metrics that require a CPUC-specific reporting requirement. Such would increase burden and cost without guaranteed benefit. This blending or leveraging of existing program's requirements should be undertaken with care to assure it does not create additional burdens.	
49		NEMA	6. Section 3.4 – Test and Verification Considerations We recommend the avoidance of a parallel California-only certification requirement. Since these products are expected to already require compliance with DLC or Energy Star, the initial certification has been done. There is no value added by requiring additional certification but there would be cost and administrative impacts of redundant testing and documentation. Looking at pathways 3 and 4, we recommend careful consideration as to the means of synchronizing future modifications to this program and its influence on products in California with respect to future ENERGY STAR and DLC specification revisions to minimize unintended market confusion.	
50	Test and Verification System Recommendations	NEMA	6. The guide should more clearly state how compliant products will be reported and listed. If the existing DLC database will also house CPUC program luminaires, we hope that could be done without causing additional cost or administrative burden. If a CPUC-specific list is to be generated, we expect that it will not require additional certification testing or reporting costs, otherwise the program will incur increased costs of doing business without the guarantee of benefit for consumers. We do not support the creation of local or regional marking requirements, as these bring cost and administrative challenges.	
51	Testing and Verification System Recommendations: Luminaire Family Complexity	General Public	We recommend that Phase 2 of this project also review and report on the necessary complexity of luminaires in contrast to lamps. With luminaires, there are needs for many legitimate variations to products, often in the thousands of versions. Some of these variations impact the outlined requirements and sometimes they do not. Managing this complexity is an extremely important and challenging aspect of dealing with any qualification and to avoid an extremely burdensome system, the successes of the existing programs such as DLC should be referenced. The report should	

			identify any and all areas where additional factors beyond what is presently reported/required results, as these will have potentially exponential impacts on the number or products requiring identification and the related effort to test, document, certify, etc.	
52	Comment Period Duration	Signify	Signify appreciates the opportunity afforded by Navigant, the California investor owned utilities and the California Public Utilities Commission (CPUC) to comment on this report. When we learned of this report, only 10 calendar days remained in the comment period. We appreciate the extension granted to submit public comments. We hope that future documents will have a longer period of 45 to 60 days which is in line with comment periods from the California Energy Commission and the US Department of Energy. We also wish to note that Signify is a member of the National Electrical Manufacturers Association (NEMA) and we echo their comments on this subject.	Stakeholders will have the opportunity to comment further at later stages of the Criteria development, including during a public webinar.
53		NEMA	1. NEMA appreciates the additional time to submit comments. The initial period of 17 days is, in our member's experience, too short for a proper review of a document of this size. For comparison, the California Energy Commission provides at least 45 days; the U.S. Department of Energy offers at least 60 days. Please keep in mind that our comments are not all-encompassing due to the time limitations. We hope that this draft will enjoy at least one more comment period and request to be part of that discussion.	
54	CA IOUs Staffing Support and Bandwidth	NEMA	9. Throughout the report, one sees phrasing like: 'the IOUs should work with', or 'the IOUs should monitor'. This may be an excessive amount of work to expect from the IOUs.	Navigant understands that the level of effort with maintaining and revising the Criteria is significant, but should the Criteria be implemented, industry stakeholders have recommended regular revisions and coordination with industry organizations to maintain relevancy with an evolving LED industry. However, it is Navigant's recommendation to not implement the Criteria in practice and use the results of this analysis as justification to continue to reference DLC and ENERGY STAR for program incentives (see Section 5.2).

55	Next Steps	Signify	From our participation in the February workshop it is our understanding that this report, and Part 2, will be presented to the CPUC and they will decide how to move forward. We expect that the results of this work will be used relative to rebates in California and not to set minimum criteria to sell products in the state.	The recommendations provided in this Study are not final from legal or program incentive perspective. The primary objective was to develop a set of Criteria that quantifies a representation of the top-half of the non-residential market in terms of lighting quality. The recommendations are not directly suggested modifications to the eligibility of LED products for CA IOU energy efficiency program incentives.
56		NEMA	2. NEMA understands this is Part 1 of a two part process and will not be used as a copy/paste level guidance document for rebate or incentive programs, or to set minimum requirements to sell products in the state. We ask Navigant to confirm our understanding.	
57	Revision Cycle	Acuity	Navigant is recommending revising the Criteria on an annual basis. One year is a too short. Programs involving multiple stakeholders need at least six months to evaluate and react to updated criteria, and a one-year revision cycle does not allow time to properly evaluate the success and/or shortcomings prior to deciding if and what changes should be made. Manufacturers, a key stakeholder group, typically have completed product roadmaps a year ahead and will need time to incorporate updated Criteria to ensure the success of the program.	The directive of the project is to identify products that represent the top-half of the market in terms of lighting quality, and this initial effort is essentially a market snapshot of the products available, not products that the CA IOUs intend for manufacturers to make. Stakeholders recommended an annual revision cycle that captures the rapid growth of LED technology. This is a recommendation to the CA IOUs, and it will be implemented or modified at their discretion. In the public comments received from DLC, it was noted that they complete annual reviews and updates to their technical requirements, so the precedent exists that revisions can be made on a regular basis. In future revisions, the CA IOUs appreciate the stakeholder recommendations and will consult with NEMA and the LESA Center at RPI.
58		NEMA	7. Section 3.5 Criteria Future Revisions Plan It is unreasonable to suggest that "…the Criteria undergo annual revisions …" when neither ENERGY STAR nor DLC revise their criteria that frequently. Also, under stakeholder engagement, we suggest you add both NEMA and the Lighting Enabled Systems and Applications (LESA) Center at RPI to the list of stakeholders consulted in the future.	
59		Signify	Future Revisions – Section 3.5 It is unreasonable to suggest that "…the Criteria undergo annual revisions …" when neither ENERGY STAR nor DLC revise their criteria that frequently. If implemented, this could require a tremendous effort on the part of the IOUs, CPUC or their consultants. This could perhaps be done every two years with the cost savings used for incentives.	

Appendix B. SUMMARY OF FINDINGS AND RECOMMENDATIONS

Study ID	Study Type	Study Title	Study Manager		
		California Statewide Non-Residential LED Quality and Market Characterization Study	PG&E		
Recommendation	**Program**	**Summary of Findings**	**Additional Supporting Information**	**Best Practice / Recommendations**	**Recommendation Recipient**
1		Navigant identified several product categories – low and high bay, ambient commercial lighting and linear replacement lamps, downlights, and outdoor products – that are well-positioned in the market currently, expected to grow significantly in the next 5-7 years, and have the greatest energy savings potential based on legacy technologies currently installed.	The detailed market characterization is given in Section 3 of this Part Two report.	CA IOUs should provide program assistance to priority categories that have the most market leverage and potential energy savings impact. This is the recommended path forward to accelerate the adoption of LED technologies in these applications and achieve significant energy savings.	All CA IOUs
2		The research and analysis showed that the representation of the top-half of the market in terms of lighting quality is best identified by a combination of prescriptive, reporting, and performance criteria. In particular, the performance criteria, which is implemented through the Lighting Quality Rating described in Section 4.2.3, rewards higher performance using a tiered point structure. In addition, several industry stakeholders were in favor of the performance approach since it incentivizes increased lighting quality performance while allowing for tradeoffs between the metrics included. The results of the Criteria analysis, the proposed definition of lighting quality, and the market characterization depict a market snapshot that confirms the most suitable approach for the CA IOUs is to reference DLC and ENERGY STAR for program incentive qualification instead of implementing the Criteria in practice.	Detailed Criteria requirements are given in Section 4.2.	CA IOUs should move forward with the blended prescriptive, reporting, and performance approach. The Criteria has been vetted with key industry stakeholders to ensure LED products meeting the Criteria are of high lighting quality when compared to those qualified by the DLC and ENERGY STAR. Additionally, existing data from the DOE's LED Lighting Facts database and DLC's QPL were used to optimize the Lighting Quality Rating approach. The results of this optimization are discussed in Appendix B of Part One. CA IOUs should also utilize the LED Product Quality Evaluation Tool to analyze LED products meeting or not meeting the Criteria. The LED Product Quality Evaluation Tool should be updated annually, if the Criteria is implemented in practice, to evaluate future versions of each database, as well as additional metrics and revised	All CA IOUs

		Section 3.2.2 details that the DLC market penetration of the 2017 sales was approximately 55%, which generally aligns with the top-half of lighting quality initiative in this Study. Also, in Appendix B of Part One, Navigant identified that 39% of the indoor products passed the Criteria, and 52% of the outdoor products passed the Criteria. The vast majority of the DLC Premium products passed (98% and 97% for indoor and outdoor products, respectively), while a more limited amount of DLC Standard products passed the Criteria (15% and 38% for indoor and outdoor products, respectively). Additionally, manufacturers and other stakeholders noted during the stakeholder engagement process that the testing and verification considerations with this type of implementation would require program bandwidth and support staff that would be difficult for California to provide.		performance tolerances as needed. This update process will help to ensure that LED products available are able to meet any future revised Criteria and that any future revised Criteria continues to represent the top-half of the market in terms of the proposed definition of lighting quality. Lastly, the CA IOUs should use the outcomes of this initial Criteria analysis, paired with those of the non-residential market characterization, as justification to defer to DLC and ENERGY STAR for program incentive requirements. Navigant recommends the CA IOUs use the insights found in this evaluation as feedback to monitor DLC and ENERGY STAR developments and provide feedback where necessary to ensure lighting quality is continually emphasized by those organizations.	
3		Stakeholder feedback received at various phases of the Study suggested there could be issues with a compliance system designed for the Criteria implementation and the current lack of available data for metrics considered in the Criteria.	Stakeholder feedback is summarized in each Appendix A of Part One and Part Two.	Navigant proposes the CA IOUs to engage with stakeholders to encourage participation in a trial run of the Criteria (e.g., 6 months) prior to the CA IOUs putting it into effect, should the Criteria be implemented in practice. The threshold for incentives during this period could remain as currently structured, with the addition of manufacturers submitting the data needed for Criteria participation. After or during the trial run, the Criteria can be re-evaluated and optimized based on an accurate and up-to-date full dataset.	All CA IOUs
4		Stakeholder engagement and research showed that DLC and ENERGY STAR are the most established organizations for developing specification tolerances and thresholds that influence product design and lighting quality.	Detailed analysis on metrics is given in Section 3.2 of Part One.	Stakeholder engagement and research showed that DLC and ENERGY STAR are the most established organizations for developing specification tolerances and thresholds that influence product design and lighting quality. As such, CA IOUs should continue to reference the most current versions of the DLC Technical Requirements (currently V4.4)	All CA IOUs

				and the ENERGY STAR Program Requirements Product Specification for Luminaires (Light Fixtures) Eligibility Criteria (currently V2.1) as first levels of qualification for the Criteria. In coming months, DLC Technical Requirements v5.0 will likely be finalized (per comments received by DLC representatives on Part One of this Study), which is set to include several additional metrics related to quality. The CA IOUs should review this document when published and update references within the Criteria to DLC v5.0 if applicable.	
5		Stakeholders suggested that fully developing the structure of a testing and verification system parallel to finalizing the Criteria is vital to ensuring high quality products are adopted by customers as a result of the Criteria's implementation. Therefore, should the Criteria be implemented in practice after conferring with the CPUC, the CA IOUs should work with the CPUC and CEC to determine the most viable route to ensure product compliance.	Detailed testing and verification proposals are presented in Section 5.5.	As the process unfolds to present the Criteria to the CPUC, the CA IOUs should work with the CPUC and CEC to determine the most suitable route forward for ensuring product compliance (should the Criteria be implemented). Navigant identified three potential testing and verification pathways: 1) allow manufacturers to self-report certification data, 2) CA implement its own testing and verification system, or 3) CA could leverage the DLC reporting infrastructure (with the exclusion of downlight products).	All CA IOUs
6		Several key industry stakeholders emphasized the need for the CA IOUs to remain vigilant as new metrics and test methods become available for defining and quantifying lighting quality for LED products. In addition, stakeholders commented that revisions should be continued for the Criteria, preferably on an annual basis. The LED industry is evolving rapidly, and industry standards and metrics are continually developed to assess the performance of products coming to market.	Detailed plan for revising Criteria is presented in Section 4.4.	In order to maintain the relevancy of the Criteria, the CA IOUs should refer to Section 4.4 which described the recommended process for updating the Criteria, if implemented in practice. This Criteria Future Revisions Plan indicates the CA IOUs should 1) review new and updated metrics, test methods and industry-accepted tolerances, 2) continually engage with key stakeholders, 3) regularly update the LED Product Quality Evaluation Tool with new products, and lastly 4) propose new metrics and tolerances for consideration with the CPUC.	All CA IOUs

Appendix C. DLC AND ENERGY STAR REQUIREMENTS

The DLC Technical Requirements V4.4 document can be found at the following link and is attached: https://www.designlights.org/default/assets/File/Workplan/DLC_Technical-Requirements-Table-V4-4.pdf.

The ENERGY STAR Program Requirements Product Specification for Luminaires (Light Fixtures) Eligibility Criteria Version 2.1 document can be found at the following link and is attached: https://www.energystar.gov/sites/default/files/Luminaires%20V2.1%20Spec%20Final%20with%20Partner%20Commitments.pdf.

SSL Technical Requirements V4.4

Table 1: Technical Requirements: Luminaires

#	Category	General Application	Requirements								
			Minimum Light Output (lm)	DLC Standard			DLC Premium**			Primary Use***	Distribution
				Minimum Efficacy (lm/W)	Minimum Warranty (years)	CCT / CRI / L_{70}	Minimum Efficacy (lm/W)	Minimum Warranty (years)	CCT / CRI / L_{90} / L_{70}		
1	Outdoor	Outdoor – Low Output	250-5,000	90	5	≤5700 / ≥65 / ≥50,000	110	5	≤5700 / ≥65 / ≥36,000 / ≥50,000	• Outdoor Pole/Arm-Mounted Area and Roadway Luminaires • Outdoor Pole/Arm-Mounted Decorative Luminaires • Outdoor Full-Cutoff Wall-Mounted Area Luminaires • Outdoor Non-Cutoff and Semi-Cutoff Wall-Mounted Area Luminaires • Bollards • Parking Garage Luminaires • Fuel Pump Canopy Luminaires • Landscape/Accent Flood and Spot Luminaires • Architectural Flood and Spot Luminaires • Stairwell and Passageway Luminaires • Specialty: _____	See Primary Use Zonal Lumen Density Requirements in Table 4, below
2		Outdoor – Mid Output	5,000-10,000	95			115				
3		Outdoor – High Output	10,000-30,000	100			120				
4		Outdoor – Very High Output*	≥30,000	100			120				
5	Indoor	Interior Directional	250-4,500	65	5	≤5000 / ≥80 / ≥50,000	90	5	≤5000 / ≥80 / ≥36,000 / ≥50,000	• Wall Wash Luminaires • Track or Mono-Point Luminaires • Specialty: _____	
6		Case Lighting	≥50 lm/ft	80			125			• Display Case Luminaires • Horizontal Refrigerated Case Luminaires • Vertical Refrigerated Case Luminaires • Specialty: _____	
7		Troffer	≥1,500	100			125			• 2x2 Luminaires for Ambient Lighting of Interior Commercial Spaces • 1x4 Luminaires for Ambient Lighting of Interior Commercial Spaces • 2x4 Luminaires for Ambient Lighting of Interior Commercial Spaces • Specialty: _____	
8		Linear Ambient	≥375 lm/ft	105			130			• Direct Linear Ambient Luminaires • Linear Ambient Luminaires w/ Indirect component • Specialty: _____	
9		High Bay	≥5,000	105		≤5700 / ≥70 / ≥50,000	130		≤5700 / ≥70 / ≥36,000 / ≥50,000	• High Bay Luminaires for Commercial and Industrial Buildings • Low Bay Luminaires for Commercial and Industrial Buildings • High Bay Aisle Luminaires • Specialty: _____	

* Under the next revision to the efficacy requirements (V5.0), DLC intends to split the "Very High" outdoor lumen bin from the "High" lumen bin, and set unique efficacy requirements for each bin.
** Products seeking qualification in the DLC Premium classification will be required to pass $L_{90} \geq 36{,}000$ hours, as evaluated using TM-21. This requirement is in addition to the L_{70} requirements of the DLC Standard classification.
*** Luminaires may not qualify for DLC Premium using "Specialty: _____" as the Primary Use designation.

Table 2: Technical Requirements: Retrofit Kits **

#	Category	General Application	Requirements							
			Minimum Light Output (lm)	DLC Standard			DLC Premium***			Primary Use****	Distribution
				Minimum Efficacy (lm/W)	Minimum Warranty (years)	CCT / CRI / L_{70}	Minimum Efficacy (lm/W)	Minimum Warranty (years)	CCT / CRI / L_{90} / L_{70}		
10	Outdoor Retrofit Kit	Outdoor – Low Output	250-5,000	90	5	≤5700 / ≥65 / ≥50,000	110	5	≤5700 / ≥65 / ≥36,000 / ≥50,000	• Retrofit Kits for Outdoor Pole/Arm-Mounted Area and Roadway Luminaires • Retrofit Kits for Outdoor Pole/Arm-Mounted Decorative Luminaires • Retrofit Kits for Large Outdoor Pole/Arm-Mounted Area and Roadway Luminaires • Retrofit Kits for Outdoor Full-Cutoff Wall-Mounted Area Luminaires • Retrofit Kits for Parking Garage Luminaires • Retrofit Kits for Fuel Pump Canopy Luminaires	See Primary Use Zonal Lumen Density Requirements in Table 4, below
11		Outdoor – Mid Output	5,000-10,000	95			115				
12		Outdoor – High Output	≥10,000	100			120				
13		Outdoor – Very High Output*	≥30,000	100			120				
14	Indoor Retrofit Kit	Troffer	≥1,500	100	5	≤5000 / ≥80 / ≥50,000	125	5	≤5000 / ≥80 / ≥36,000 / ≥50,000	• Linear Retrofit Kits for 2x2 Luminaires • Integrated Retrofit Kits for 2x2 Luminaires • Linear Retrofit Kits for 1x4 Luminaires • Integrated Retrofit Kits for 1x4 Luminaires • Linear Retrofit Kits for 2x4 Luminaires • Integrated Retrofit Kits for 2x4 Luminaires	
15		Linear Ambient	≥375 lm/ft	105			130			• Retrofit Kits for Direct Linear Ambient Luminaires	
16		High-Bay	≥5,000	105		≤5700 / ≥70 / ≥50,000	130		≤5700 / ≥70 / ≥36,000 / ≥50,000	• Retrofit Kits for High Bay Luminaires for Commercial and Industrial Buildings • Retrofit Kits for Low Bay Luminaires for Commercial and Industrial Buildings	

* Under the next revision to the efficacy requirements (V5.0), DLC intends to split the "Very High" outdoor lumen bin from the "High" lumen bin, and set unique efficacy requirements for each bin.
** Retrofit Kits and Replacement Lamps must be tested inside luminaires, per the policies for those products. See Retrofit Kit Policy, Linear Replacement Lamp Policy, and Screw-base Replacement Lamp Policy for details.
*** Products seeking qualification in the DLC Premium classification will be required to pass $L_{90} \geq 36{,}000$ hours, as evaluated using TM-21. This requirement is in addition to the L_{70} requirements of the DLC Standard classification.
**** Retrofit Kits applications must designate one of the Primary Use designations listed.

Table 3: Technical Requirements: Lamps **, ***

#	Category	General Application	Requirements					
			Minimum Light Output (lm)	DLC Standard			Primary Use	Distribution
				Minimum Efficacy (lm/W)	Minimum Warranty (years)	CCT / CRI / L_{70}		
17	Linear Replacement Lamps	T8 Four-Foot Linear Replacement Lamps	In luminaire: 2 lamps: 3,000 3 lamps: 4,500 4 lamps: 6,000 Bare lamp: 1,600	In luminaire: 100 Bare lamp: 110	5	≤5000 / ≥80 / ≥50,000	• Replacement Lamps ("Plug and Play") (UL Type A) • Internal Driver/Line Voltage (UL Type B) Lamps • 2-lamp External Driver (UL Type C) Lamps • 3-lamp External Driver (UL Type C) Lamps • 4-lamp External Driver (UL Type C) Lamps • Dual Mode Internal Driver (UL Type A or B)	See Primary Use Zonal Lumen Density Requirements in Table 4, below
18		T5 Four-Foot Linear Replacement Lamps	In luminaire: 2 lamps: 3,000 3 lamps: 4,500 4 lamps: 6,000 Bare lamp: 1,600	In luminaire: 100 Bare lamp: 110	5	≤5000 / ≥80 / ≥50,000	• Replacement Lamps ("Plug and Play") (UL Type A) • Internal Driver/Line Voltage (UL Type B) Lamps • 2-lamp External Driver (UL Type C) Lamps • 3-lamp External Driver (UL Type C) Lamps • 4-lamp External Driver (UL Type C) Lamps • Dual Mode Internal Driver (UL Type A or B)	
19		T5HO Four-Foot Linear Replacement Lamps	In luminaire: 3 lamps: 7,500 4 lamps: 10,000 6 lamps: 15,000 Bare lamp: 3,200	In luminaire: 105 Bare lamp: 110	5	≤5000 / ≥80 / ≥50,000	• Replacement Lamps ("Plug and Play") (UL Type A) • Internal Driver/Line Voltage (UL Type B) Lamps • 3-lamp External Driver (UL Type C) Lamps • 4-lamp External Driver (UL Type C) Lamps • 6-lamp External Driver (UL Type C) Lamps • Dual Mode Internal Driver (UL Type A or B)	
20		T8 Two-Foot Linear Replacement Lamps	In luminaire: 2 lamps: 1,350 3 lamps: 2,000 4 lamps: 2,700 Bare lamp: 800	In luminaire: 100 Bare lamp: 110	5	≤5000 / ≥80 / ≥50,000	• Replacement Lamps ("Plug and Play") (UL Type A) • Internal Driver/Line Voltage (UL Type B) Lamps • 2-lamp External Driver (UL Type C) Lamps • 3-lamp External Driver (UL Type C) Lamps • 4-lamp External Driver (UL Type C) Lamps • Dual Mode Internal Driver (UL Type A or B)	
21		U-Bend Replacement Lamps	In luminaire: 2 lamps: 2,500 3 lamps: 3,750 Bare lamp: 1,400	In luminaire: 100 Bare lamp: 110	5	≤5000 / ≥80 / ≥50,000	• Replacement Lamps ("Plug and Play") (UL Type A) • Internal Driver/Line Voltage (UL Type B) Lamps • 2-lamp External Driver (UL Type C) Lamps • 3-lamp External Driver (UL Type C) Lamps • Dual Mode Internal Driver (UL Type A or B)	
22		T8 Three-Foot Linear Replacement Lamps	In luminaire: 2 lamps: 2,200 Bare lamp: 1,200	In luminaire: 100 Bare lamp: 110	5	≤5000 / ≥80 / ≥50,000	• Replacement Lamps ("Plug and Play") (UL Type A) • Internal Driver/Line Voltage (UL Type B) Lamps • 2-lamp External Driver (UL Type C) Lamps • Dual Mode Internal Driver (UL Type A or B)	

Table 3: Technical Requirements: Lamps **, ***, continued

#	Category	General Application	Requirements					
			Minimum Light Output (lm)	DLC Standard			Primary Use	Distribution
				Minimum Efficacy (lm/W)	Minimum Warranty (years)	CCT / CRI / L_{70}		
23	Linear Replacement Lamps	T8 Eight-Foot Linear Replacement Lamps	In luminaire: 2 lamps: 6,000 Bare lamp: 3,200	In luminaire: 100 Bare lamp: 110	5	≤5000 / ≥80 / ≥50,000	• Replacement Lamps ("Plug and Play") (UL Type A) • Internal Driver/Line Voltage (UL Type B) Lamps • 2-lamp External Driver (UL Type C) Lamps • Dual Mode Internal Driver (UL Type A or B)	See Primary Use Zonal Lumen Density Requirements in Table 4, below See Primary Use Zonal Lumen Density Requirements in Table 4, below
24	Mogul Screw-Base (E39) Replacements for HID Lamps	Outdoor – Low Output	In luminaire: 250-5,000	In luminaire: 90	5	≤5700 / ≥65 / ≥50,000	• Replacement Lamps for Outdoor Pole/Arm-Mounted Area and Roadway Luminaires (UL Type B) • Replacement Lamps for Outdoor Pole/Arm-Mounted Decorative Luminaires (UL Type B) • Replacement Lamps for Outdoor Full-Cutoff Wall-Mounted Area Luminaires (UL Type B) • Replacement Lamps for Parking Garage Luminaires (UL Type B) • Replacement Lamps for Fuel Pump Canopy Luminaires (UL Type B) • Replacement Lamps for Outdoor Pole/Arm-Mounted Area and Roadway Luminaires (UL Type C) • Replacement Lamps for Outdoor Pole/Arm-Mounted Decorative Luminaires (UL Type C) • Replacement Lamps for Outdoor Full-Cutoff Wall-Mounted Area Luminaires (UL Type C) • Replacement Lamps for Parking Garage Luminaires (UL Type C) • Replacement Lamps for Fuel Pump Canopy Luminaires (UL Type C)	
25		Outdoor – Mid Output	In luminaire: 5,000-10,000	In luminaire: 90				
26		Outdoor – High Output	In luminaire: 10,000-30,000	In luminaire: 95				
27		Outdoor – Very High Output*	In luminaire: ≥30,000	In luminaire: 95				
28		High-Bay	In luminaire: ≥5,000	In luminaire: 100	5	≤5700 / ≥70 / ≥50,000	• Replacement Lamps for High Bay Luminaires (UL Type B) • Replacement Lamps for Low Bay Luminaires (UL Type B) • Replacement Lamps for High Bay Luminaires (UL Type C) • Replacement Lamps for Low Bay Luminaires (UL Type C)	
29	Four Pin-Base Replacement Lamps for CFLs	Vertically-Mounted Lamps	In luminaire: 575 (1-lamp configuration) Bare lamp: 675	In luminaire: 65 Bare lamp: 75	5	≤5000 / ≥80 / ≥50,000	• Replacement Lamps ("Plug and Play") (UL Type A)	
30		Horizontally-Mounted Lamps	In luminaire: 800 (2-lamp configuration) Bare lamp: 675	In luminaire: 65 Bare lamp: 75	5	≤5000 / ≥80 / ≥50,000	• Replacement Lamps ("Plug and Play") (UL Type A)	
31		2G11 Base Replacement Lamps	In luminaire: 2 lamps: 1,350 3 lamps: 2,000 Bare lamp: 1,900	In luminaire: 100 Bare lamp: 110	5	≤5000 / ≥80 / ≥50,000	• Replacement Lamps ("Plug and Play") (UL Type A) • Internal Driver/Line Voltage (UL Type B) Lamps • 2-lamp External Driver (UL Type C) Lamps • 3-lamp External Driver (UL Type C) Lamps • Dual Mode Internal Driver (UL Type A or B)	

* Under the next revision to the efficacy requirements (V5.0), DLC intends to split the "Very High" outdoor lumen bin from the "High" lumen bin, and set unique efficacy requirements for each bin.

** Retrofit Kits and Replacement Lamps must be tested inside luminaires, per the policies for those products. See Retrofit Kit Policy, Linear Replacement Lamps, and Screw-base Replacement Lamp Policy for details.

*** Replacement Lamps are not eligible for the DLC Premium classification at this time.

Table 4: Primary Use Technical Requirements: Light Output and Zonal Lumen Distribution

Primary Use Letter	Primary Use Designation	Minimum Light Output (lm)	Zone/Spacing Criteria	ZLD/SC Nominal Requirement	ZLD/SC Tolerance	ZLD/SC Requirement with Tolerance
A	Outdoor Pole/Arm-Mounted Area and Roadway Luminaires	1,000	0-90°	100%	-1%	≥99%
			80-90°	≤10%	+3%	≤13%
B	Outdoor Pole/Arm-Mounted Decorative Luminaires	1,000	0-90°	≥65%	-3%	≥62%
C	Outdoor Full-Cutoff Wall-Mounted Area Luminaires	300	0-90°	100%	-3%	≥97%
			80-90°	≤10%	+3%	≤13%
D	Outdoor Non-Cutoff and Semi-Cutoff Wall-Mounted Area Luminaires	300 (0-90° zone)***	80-90°***	≤10%***	+3%	≤13%
E	Bollards	500	90-110°	≤15%	+3%	≤18%
			>110°	0%	+3%	≤3%
F	Parking Garage Luminaires	2,000	60-80°	≥30%	-3%	≥27%
			70-80°	≤25%	+3%	≤28%
G	Fuel Pump Canopy Luminaires	2,000	0-40°	≥40%	-3%	≥37%
			40-70°	≥40%	-3%	≥37%
H	Landscape/Accent Flood and Spot Luminaires	250 (<1,000)	0-90°	≥85%	-3%	≥82%
I	Architectural Flood and Spot Luminaires	1,000	0-90°	≥85%	-3%	≥82%
J	Stairwell and Passageway Luminaires	750	0-90°	≥85%‡	-3%	≥82%
K	Wall-wash Luminaires	575	0-90°	≥60%‡‡	-3%	≥57%
L	Track or Mono-Point Directional Luminaires	250	0-90°	≥85%	-3%	≥82%
M	Vertical Refrigerated Case Luminaires-center	100 lm/ft	10-90°†	≥95%†	-3%	≥92%
N	Vertical Refrigerated Case Luminaires-end	50 lm/ft	10-90°‡‡	≥95%‡‡	-5%	≥90%
O	Horizontal Refrigerated Case Luminaires	100 lm/ft	0-90°	≥95%	-3%	≥92%
P	Display Case Luminaires	50 lm/ft	0-80°	≥95%	-5%	≥90%
Q	2x2 Luminaires for Ambient Lighting of Interior Commercial Spaces	2,000	SC: 0-180°	1.0-2.0	±0.1	0.9-2.1
			SC: 90-270°	1.0-2.0	±0.1	0.9-2.1
			ZL: 0-60°	≥75%	-3%	≥72%
R	1x4 Luminaires for Ambient Lighting of Interior Commercial Spaces	1,500	SC: 0-180°	1.0-2.0	±0.1	0.9-2.1
			SC: 90-270°	1.0-2.0	±0.1	0.9-2.1
			ZL: 0-60°	≥75%	-3%	≥72%

Table 4: Primary Use Technical Requirements: Light Output and Zonal Lumen Distribution, continued

Primary Use Letter	Primary Use Designation	Minimum Light Output (lm)	Zone/Spacing Criteria	ZLD/SC Nominal Requirement	ZLD/SC Tolerance	ZLD/SC Requirement with Tolerance
S	2x4 Luminaires for Ambient Lighting of Interior Commercial Spaces	3,000	SC:0-180°	1.0-2.0	±0.1	0.9-2.1
			SC:90-270°	1.0-2.0	±0.1	0.9-2.1
			ZL:0-60°	≥75%	-3%	≥72%
T	Linear Ambient Luminaires w/ Indirect Component	500 lm/ft	90-150°	≥35%	-3%	≥32%
U	Direct Linear Ambient Luminaires	375 lm/ft	0-60°	≥40%	-3%	≥37%
V	High Bay Luminaires for Commercial and Industrial Buildings	10,000	20-50°	≥30%	-10%	≥20%
W	Low Bay Luminaires for Commercial and Industrial Buildings	5,000 (<10,000)	20-50°	≥30%	-10%	≥20%
X	High Bay Aisle Luminaires	10,000	20-50°	≥50%	-10%	≥40%
			0-20°	≥30%	-10%	≥20%
Y	Retrofit Kits for Outdoor Pole/Arm-Mounted Area and Roadway Luminaires	1,000	0-90°	100%	-1%	≥99%
			80-90°	≤10%	3%	≤13%
Z	Retrofit Kits for Outdoor Pole/Arm-Mounted Decorative Luminaires	1,000	0-90°	≥65%	-3%	≥62%
AA	Retrofit Kits for Large Outdoor Pole/Arm-Mounted Area and Roadway Luminaires	1,000	0-90°	100%	-1%	≥99%
			80-90°	≤10%	3%	≤13%
AB	Retrofit Kits for Full-Cutoff Outdoor Wall-Mounted Area Luminaires	300	0-90°	100%	-3%	≥97%
			80-90°	≤10%	3%	≤13%
AC	Retrofit Kits for Parking Garage Luminaires	2,000	60-80°	≥30%	-3%	≥27%
			70-80°	≤25%	+3%	≤28%
AD	Retrofit Kits for Fuel Pump Canopy Luminaires	2,000	0-40°	≥40%	-3%	≥37%
			40-70°	≥40%	-3%	≥37%
AE	Retrofit Kits for 2x2 Luminaires for Ambient Lighting of Interior Commercial Spaces (all Primary Use designations)	2,000	SC:0-180°	1.0-2.0	±0.1	0.9-2.1
			SC:90-270°	1.0-2.0	±0.1	0.9-2.1
			ZL:0-60°	≥75%	-3%	≥72%
AF	Retrofit Kits for 1x4 Luminaires for Ambient Lighting of Interior Commercial Spaces (all Primary Use designations)	1,500	SC:0-180°	1.0-2.0	±0.1	0.9-2.1
			SC:90-270°	1.0-2.0	±0.1	0.9-2.1
			ZL:0-60°	≥75%	-3%	≥72%
AG	Retrofit Kits for 2x4 Luminaires for Ambient Lighting of Interior Commercial Spaces (all Primary Use designations)	3,000	SC:0-180°	1.0-2.0	±0.1	0.9-2.1
			SC:90-270°	1.0-2.0	±0.1	0.9-2.1
			ZL:0-60°	≥75%	-3%	≥72%
AH	Retrofit Kits for Direct Linear Ambient Luminaires	375 lm/ft	0-60°	≥40%	-3%	≥37%

Table 4: Primary Use Technical Requirements: Light Output and Zonal Lumen Distribution, continued

Primary Use Letter	Primary Use Designation	Minimum Light Output (lm)	Zone/Spacing Criteria	ZLD/SC Nominal Requirement	ZLD/SC Tolerance	ZLD/SC Requirement with Tolerance
AI	Retrofit Kits for High Bay Luminaires for Commercial and Industrial Buildings	10,000	20-50°	≥30%	-10%	≥20%
AJ	Retrofit Kits for Low Bay Luminaires for Commercial and Industrial Buildings	5,000 (<10,000)	20-50°	≥30%	-10%	≥20%
AK	Four-Foot Linear Replacement Lamps (T8, T5: all Primary Use designations)††	In luminaire: 2 lamps: 3,000 3 lamps: 4,500 4 lamps: 6,000 Bare Lamp: 1,600	SC:0-180°	1.0-2.0	±0.1	0.9-2.1
			SC:90-270°	1.0-2.0	±0.1	0.9-2.1
			ZL:0-60°	≥75%	-3%	≥72%
AL	Four-Foot Linear Replacement Lamps (T5HO: all Primary Use designations)	In luminaire: 3 lamps: 7,500 4 lamps: 10,000 6-lamps: 15,000 Bare Lamp: 3,200	ZL: 20-50°	≥30%	-10%	≥20%
AM	Two-Foot Linear Replacement Lamps (all Primary Use designations)††	In luminaire: 2 lamps: 1,350 3 lamps: 2,000 4 lamps: 2,700 Bare lamp: 800	SC:0-180°	1.0-2.0	±0.1	0.9-2.1
			SC:90-270°	1.0-2.0	±0.1	0.9-2.1
			ZL:0-60°	≥75%	-3%	≥72%
AN	U-Bend Replacement Lamps (all Primary Use designations)††	In luminaire: 2 lamps: 2,500 3 lamps: 3,750 Bare lamp: 1,400	SC:0-180°	1.0-2.0	±0.1	0.9-2.1
			SC:90-270°	1.0-2.0	±0.1	0.9-2.1
			ZL:0-60°	≥75%	-3%	≥72%
AO	Three-Foot Linear Replacement Lamps (all Primary Use designations)††	In luminaire: 2 lamps: 2,200 Bare lamp: 1,200	0-60°	≥40%	-3%	≥37%

Table 4: Primary Use Technical Requirements: Light Output and Zonal Lumen Distribution, continued

Primary Use Letter	Primary Use Designation	Minimum Light Output (lm)	Zone/Spacing Criteria	ZLD/SC Nominal Requirement	ZLD/SC Tolerance	ZLD/SC Requirement with Tolerance
AP	Eight-Foot Linear Replacement Lamps (all Primary Use designations)††	In luminaire: 2 lamps: 6,000 Bare lamp: 3,200	0-60°	≥40%	-3%	≥37%
AQ	Screw-Base Replacements for HID Lamps in Outdoor Pole/Arm-mounted Area and Roadway Luminaires	In luminaire: 1,000	0-90°	100%	-1%	≥99%
			80-90°	≤10%	3%	≤13%
AR	Screw-Base Replacements for HID Lamps in Outdoor Pole/Arm-mounted Decorative Luminaires	In luminaire: 1,000	0-90°	≥65%	-3%	≥62%
AS	Screw-Base Replacements for HID Lamps in Outdoor Full Cut-off Wall-mounted Area Luminaires	In luminaire: 300	0-90°	100%	-3%	≥97%
			80-90°	≤10%	3%	≤13%
AT	Screw-Base Replacements for HID Lamps in Parking Garage Luminaires	In luminaire: 2,000	60-80°	≥30%	-3%	≥27%
			70-80°	≤25%	+3%	≤28%
AU	Screw-Base Replacements for HID Lamps in Fuel Pump Canopy Luminaires	In luminaire: 2,000	0-40°	≥40%	-3%	≥37%
			40-70°	≥40%	-3%	≥37%
AV	Screw-Base Replacements for HID Lamps in High Bay Luminaires for Commercial and Industrial Buildings	In luminaire: 10,000	20-50°	≥30%	-10%	≥20%
AW	Screw-Base Replacements for HID Lamps in Low Bay Luminaires for Commercial and Industrial Buildings	In luminaire: 5,000 (<10,000)	20-50°	≥30%	-10%	≥20%
AX	Vertically-Mounted Four Pin-Base Replacement Lamps for CFLs	In luminaire: 575 (1-lamp configuration) Bare lamp: 675	ZL:0-60°	≥75%	-3%	≥72%
AY	Horizontally-Mounted Four Pin-Base Replacement Lamps for CFLs	In luminaire: 800 (2-lamp configuration) Bare lamp: 675	ZL:0-60°	≥75%	-3%	≥72%
AZ	2G11 Base Replacement Lamps for CFLs	In luminaire: 2 lamps: 1,350 3 lamps: 2,000 Bare lamp: 1,900	SC:0-180°	1.0-2.0	±0.1	0.9-2.1
			SC:90-270°	1.0-2.0	±0.1	0.9-2.1
			ZL:0-60°	≥75%	-3%	≥72%

*** Lumen output and efficacy are evaluated considering the light output in the 0-90° zone only. See non-cutoff wall-mounted area luminaires details below.

† Bilateral, symmetric light distribution on two hemispheres

‡‡ One-sided, single hemisphere light distribution

‡ Bilateral for surface-mounted units, single hemisphere for corner-mounted units

†† For Type C linear replacement lamps, light output requirements out of the luminaire are dependent on the number of lamps in the kit. See Linear Replacement Lamps Policy for more details.

Power Factor and Total Harmonic Distortion:

In addition to the specific requirements above, all DLC-qualified luminaires must have a power factor of ≥0.9, and a THDi of ≤20%. This applies to every category listed in the above Technical Requirements Table V4.3. Qualified products must meet the requirements in their worst-case loading conditions.

Tolerances:

Table 5 presents tolerances that apply to all metrics listed in the above in Technical Requirements Table V4.3. These tolerances are referenced in the ENERGY STAR® Manufacturer's Guide. For zonal lumen tolerances specific to each Primary Use designation, please refer to Table 5.

FAQ: How are tolerances applied to the requirements?

Table 5: Tolerances

Performance Metric	Tolerance
Light Output	±10%
Luminaire Efficacy	-3%
Allowable CCT	Defined by ANSI C78.377-2015†
CRI	-2 points
Power Factor	-3%
Total Harmonic Distortion	+5%

†ANSI C78.377-2015 also referred to for D_{uv} and (x, y) chromaticity coordinates tolerances for indoor categories.

Allowances:

Table 6 presents allowances that apply to products with specific features, in specific categories. Additional information will be incorporated in this section as allowances are defined. To participate in the discussion around the development of these allowances, please contact info@designlights.org.

Table 6: Allowances

Feature or Performance Metric	Allowances
CCT: ≤3000K, >2700K	-3%
CCT: ≤2700K	-5%
CRI*: R_a≥ 90 (*must also conduct TM-30 testing and report results; see below for TM-30 guidance)	-5%

Allowances within Table 6 are *not* cumulative. For example, a 2700K, 90 CRI products will only be granted a 5% allowance total, not 10%.

Lumen Maintenance:

The DLC has two options for demonstrating lumen maintenance compliance.

- **Lumen Maintenance Option 1**
  Using component-level performance through the TM-21 protocols, which leverage the LM-80 performance and *in-situ* temperature of the LED device.
- **Lumen Maintenance Option 2**
  Using luminaire-level performance through TM-28 protocols, which leverage the LM-84 test performance. More information is available in the Application Instructions.

LM-80 Applicability
The DLC refers to current ENERGY STAR Program Guidance Regarding LED Package, LED Array and LED Module Lumen Maintenance Performance Data Supporting Qualification of Lighting Products when determining applicability of LM-80 data for submitted products.

L_{70} Evaluation
DLC relies on the results from the ENERGY STAR TM-21 Calculator for evaluating compliance with the lumen maintenance requirements. For products that have sufficient LM-80 data to project to 50,000 hours per the TM-21 limits of projection rules, the calculator must show a L70 of 50,000 or more. In the current version of the ENERGY STAR calculator (dated 6-18-2018), this is shown in cell I42 when "70" is entered into cell I35.

For products where the DLC required lumen maintenance period is longer than the TM-21 projection method allows, DLC will evaluate the lumen maintenance percentage at the end point for the allowed projection period. The necessary lumen maintenance minimums, which result from solving an exponential decay function for 50,000 hours, are presented in Table 7 for common end-points <50,000 hours. Refer to Table 7 for TM-21 projection requirements based on LM-80 reports less than ~8,500 hours of testing for a sample size of ≥20, or LM-80 reports based on less than ~9,500 hours of testing for a sample size of ≤19. In the current version of the ENERGY STAR calculator, this means that cell I41 must show at least the value in the table below when cell I40 is set to the appropriate time interval, based on the allowable projection period for TM-21.

Table 7: Option 1 TM-21 Projected Lumen Maintenance Requirements

Projection End Point (hours)	Required Lumen Maintenance for 50,000-Hour Products
33,000	≥79.03%
36,000	≥77.35%
38,500	≥75.98%
42,000	≥74.11%
44,000	≥73.06%
48,000	≥71.01%
49,500	≥70.25%
50,000	≥70.00%

L_{90} Evaluation for Premium Products
Products applying for DLC Premium must meet an additional lumen maintenance requirement of L_{90} ≥36,000 hours. DLC relies on the results from the ENERGY STAR TM-21 Calculator for evaluating compliance with the lumen maintenance requirements. The results in the ENERGY STAR TM-21 calculator must show a lumen maintenance value of no less than 36,000 in cell I42, when cell I35 is set to 90, to meet the Premium lumen maintenance requirement. There are no provisions for shorter projection periods for this L_{90} requirement; to qualify for Premium there must be sufficient LM-80 data to project to at least 36,000 hours per TM-21 rules.

LM-84 and TM-28
Option 2 is to conduct luminaire-level testing according to the LM-84-14 test standard and apply the TM-28-14 projection methodology. For Option 2, the DLC uses a pass/fail threshold for lumen maintenance compliance as detailed in the DLC Manufacturer's Guide, section IV.B.4.b. The projection from TM-28 must project to at least 6,000 hours and the lumen maintenance projection at the projection end point must be consistent with an L_{70} of 50,000 hours. If choosing Option 2 for lumen maintenance determination, please contact the DLC at info@designlights.org.

Tolerances
When applying the lumen maintenance in accordance with these protocols, the DLC applies a tolerance of 5% to drive currents tested under LM-80, and a 1.1°C to the temperature measured in ISTMT results.

Multiple LEDs:

Products employing multiple types of LEDs are eligible under the following conditions: 1) the types and quantities of the LED packages/modules/arrays are known, and 2) the LEDs are not dynamically controlled, other than for dimming purposes. That is, products where variable numbers of LEDs are dynamically chosen and therefore the precise construction of any given product is not defined are not eligible. Policy development for appropriate evaluation of this type of product is under consideration.

For products using multiple LED types, an LM-80, ISTMT, and TM-21 projection will be needed for each type of LED present in the product. As per normal thermal testing rules, ISTMTs must be conducted on the hottest LED of each type. Each LED must demonstrate the required L_{70} of 50,000 hours.

Driver ISTMT:

As part of the DLC Premium application process, manufacturers need to provide the following:

1. Test report from a lab that meets the DLC's Laboratory Requirements for ISTMTs. The report must include the measured temperature from the TMP_{ps}.
2. A picture of the TMP_{ps} location with an arrow indicating the thermocouple attachment point.
3. Documentation from the driver manufacturer that indicates the maximum case temperature for which the driver is designed to last ≥50,000 hours, as well as the TMP location it designates for thermal testing.
    a. Custom and integrated drivers must provide Documentation equivalent to that required for drivers from third-party vendors. Manufacturers must supply documentation indicating the maximum acceptable temperature for the driver for 50,000-hour life, as well as the TMP to be used during thermal testing and evaluation.

The luminaire passes the driver ISTMT requirements if the measured temperature at the TMP_{ps} is less than or equal to the allowable operating temperature specified by the power supply manufacturer. Drivers shall be tested *in-situ* under steady-state operating conditions, with case temperature measured at the designated TMP.

One or more additional thermocouples are attached to the power supply/driver at the TMP_{ps}. For off-the-shelf remote power supplies, manufacturers typically provide a measurement location (case temperature designated by a "dot" adjacent to a (t_c) symbol) for warranty purposes. In situations where the TMP_{ps} is not designated by the manufacturer, or where power supplies are integrated with the LED package(s), array, or module(s), luminaire manufacturers should identify the TMP_{ps} to be used for warranty purposes. Note that this includes situations where the driver/power supply is not purchased from an outside vendor, and where the driver/power supply is integrated into the luminaire or lamp.

The thermocouple tolerance shall conform to ASTM E230 Table 1 "Special Limits" (≤1.1^{0}C or 0.4%, whichever is greater).

Safety Certification:

Single Product / Family Grouping / Product Updates

1. All products are required to submit a compliance certificate from an approved safety certification organization relevant in the United States or Canada. This compliance document shall bear the manufacturers name and will be proof that the products listed have been investigated by the safety organization and found to be in compliance with the standards listed on the certificate. The name of this document varies by safety organization, however, is commonly referred to as a Certificate of Compliance or Authorization to Mark.

2. During the application process, manufacturers will be required to digitally sign an agreement confirming that the safety documentation they are providing with the application covers ALL models they wish to be listed on the QPL and that the products being sold will bear the proper markings from the safety organization.

Note: If, after qualification, the safety documentation gets updated so that any model number(s) listed on the QPL are no longer covered by the original safety certificate, it is the responsibility of the manufacturer to submit the revised documentation so that the DLC records can be updated accordingly. Failure to do so may result in the product and any associated family members or private labels of the product being delisted.

Private Label

1. All products are required to submit a compliance certificate from an approved safety certification organization relevant in the United States or Canada. This compliance document shall bear the Original Equipment Manufacturer's (OEM) name and will be proof that the products listed have been investigated by the safety organization and found to be in compliance with the standards listed on the certificate. The name of this document varies by safety organization, however, is commonly referred to as a Certificate of Compliance or Authorization to Mark.

   If the submitted compliance certificate is different from the one on file from the OEMs submission to the DLC, the OEM must update their records prior to the private label submission being formally processed.

2. In addition to a compliance certificate from the OEM, the private labeler must also submit a compliance certificate from an approved safety certification organization which bears the private labelers name and unique file number.

3. All products are required to submit a Multiple Listing correlation sheet issued by the approved safety organization which cross references the OEM model numbers with private label model numbers.

4. During the application process, manufacturers will be required to digitally sign an agreement confirming that the safety documentation provided covers ALL models they wish to be listed on the QPL and that the products being sold will bear the proper markings from the safety organization.

Note: If the safety documentation gets updated so that any model number(s) listed on the QPL are no longer covered by the original safety certificate, it is the responsibility of the manufacturer to submit the revised documentation so that the DLC records can be updated accordingly. Failure to do so may result in the product and any associated family members being delisted.

Verification of Model Numbers

The DLC will be performing a limited review of the safety documentation being submitted by the manufacturer. It is the responsibility of the applicant to verify that ALL of the model numbers that are being submitted for qualification be covered by the safety certification documents. If the model numbers being submitted are found to not have been covered by the safety certification documents that were originally submitted, the models will be removed from the QPL and further action may be taken, if necessary.

TM-30:

IES TM-30-15 is a document approved by the Illuminating Engineering Society (IES) that describes a method for evaluating light source color rendition. The method encompasses several individual measures and graphics that complement one another and provide a comprehensive characterization of how the light will affect the color appearance of objects. The three highest-level components of the system are the Fidelity Index (R_f), Gamut Index (R_g), and the Color Vector Graphic. Starting with the V4.0 Technical Requirements, the DLC will allow reporting of R_f and R_g for products on the QPL. At this time, these are optional metrics, and are not required for listing. To list these metrics for products on the QPL, using the official Excel version of the TM-30 calculation tool offered with the IES standard is required. Either basic or advanced versions of the Excel tool will be accepted. For more information on IES TM-30-15, please go to http://energy.gov/eere/ssl/tm-30-frequently-asked-questions.

Additional Guidance for Products Seeking Qualification under the "Specialty" Primary Use Designation:

This designation has been developed as an additional tool for the DLC and its Member programs to employ in seeking to identify high-quality, energy-saving LED luminaires in commercial and industrial applications for certain niche applications for which the DLC has not yet developed a specific Primary Use designation.

To prevent the "Specialty" designation from being a loophole to get around requirements in other categories, the DLC will employ a number of principles in evaluating products submitted with this classification, including the following:

1. Products with a Specialty designation must meet the intention of the broader category and general application group under which they are designated. For example, products seeking qualification with a classification of Outdoor-Low Output-Specialty: _____ must be intended for use in outdoor applications.
2. Products with a Specialty designation must meet the minimum performance specifications of the broader category under which they are designated. This includes minimum light output, efficacy, CCT, CRI, L_{70}, THD, and PF requirements.
3. Products with a Specialty designation must specify the end-use for which they are intended. For example, products that are intended to be used for stadium lighting that seek qualification under the specialty designation must indicate on the application form that their intended use is "Specialty: Stadium Lighting". DLC staff will monitor terminology and may make minor modifications to descriptor terms to ensure consistency (for example "Specialty: Stadium Lighting vs. "Specialty: Stadium Luminaire"). Changes in descriptor terms will be made in consultation with the applicant.
4. The DLC retains the right to deny access to the Specialty designation for any product it does not believe meets the intention of the designation. Judgment on eligibility will be at the sole discretion of the DLC program staff.

Seeking qualification of a product using this Primary Use designation is an acknowledgement of the rules of the program and a confirmation that the applicant agrees to abide by the decisions of the program.

Products with a Specialty designation are not eligible for DLC Premium classification.

Products seeking qualification on the QPL that would like to identify themselves as suitable for Hazardous Locations using the Specialty designations must provide documentation to demonstrate the appropriateness of their products for Hazardous Locations. Refer to the Testing and Reporting Requirements for Hazardous Location Lighting for additional details.

Additional Guidance for Reporting Requirements:

In addition to designating a Primary Use and meeting Zonal Lumen Density requirements, manufacturers submitting to the DLC need to indicate whether their products are capable of dimming and/or field-adjustability. Refer to the DLC Dimming policy for additional details.

For products that are Color Tunable, manufacturers must indicate which of the following sub-categories applies: White-Tunable and/or Warm-Dimming. For white-tunable products, manufacturers must submit appropriate LM-79 reports according to the Testing and Reporting Requirements for Color-Tunable Products and report measured CCT (K), power consumption (W), lumen output (LM) and input control signal applied. The DLC may revise the color tunable testing requirements to align with any future industry standards published with full bodied supporting data. For Warm-Dimming products, manufacturers must submit a single LM-79 report performed at the maximum setting of the dimming input control.

Manufacturers submitting products to DLC Premium will also need to indicate whether the product can be ordered with integral controls (occupancy sensors or photo sensors). The DLC will evaluate a manufacturer's claims of integral controls capability by ensuring that these features are clearly identified on the product specification sheet. DLC reviewers may check web listings and other marketing materials and reserve the right to request additional information to demonstrate integral controls capability if product specification sheets are not sufficient.

Non-Cutoff and Semi-Cutoff Wall-Mounted Area Luminaires:

In Technical Requirements Table V4.3, non-cutoff and semi-cutoff wall packs are eligible under this Primary Use designation, distinct from full-cutoff wall packs. For non-cutoff and semi-cutoff wall packs, light output, efficacy, and zonal lumen distribution requirements are evaluated based on the lumens in the 0-90° zone only, rather than total lumens produced by the luminaire. The lumen output for these products must be ≥300 lm in the 0-90° zone; the "efficacy" calculations will include only lumens in the 0-90° zone, divided by the total wattage; and the zonal lumen requirement of ≤10% light output in the 80-90° glare zone will be calculated by dividing the lumens in that zone by the lumen total in the 0-90° zone. Please note that while whether a product passes the requirements is based on the lumens in the 0-90° zone only, the general application (low, mid, high, or very-high output, and associated efficacy requirements) is determined based on the full light output from the product.

Flood and Spot Luminaires:

For Architectural and Landscape/Accent Flood and Spot Luminaires products, manufacturers must declare the NEMA Beam Classification of their luminaire in the 0-180^0 and 90-270^0 planes. The DLC will verify these claims against the IES files provided.

Table 8: NEMA Beam Classification

NEMA Beam Classification	Beam Spread Range
1	10-18°
2	18-29°
3	29-46°
4	46-70°
5	70-100°
6	100-130°
7	≥130°

Wall Wash Luminaires:

The zonal lumen criteria for this Primary Use is that ≥60% of the lumens must be produced in the "forward" hemisphere, toward the wall.

Stairwell and Passageway Lighting:

The DLC requires that products in the Stairwell and Passageway Lighting Primary Use designation meet one of the following conditions:

1. Luminaires that include integral controls for occupancy sensing and bi-level dimming.
2. Luminaires that operate off remote occupancy sensors, including wireless options, where a remote sensor(s) is sold packaged together with a luminaire(s) under a single model number or ordering code.
3. Luminaires that operate off remote occupancy sensors, including wireless options, where the luminaire and sensor are sold separately, but the luminaire has features enabling communication with a remote sensor(s).

Documentation must be provided to demonstrate compliance with one of the options above, including clear documentation of at least bi-level dimming functionality (required), and communications ability (if applicable). Features must be designated clearly in the model number.

Manufacturers must also declare whether the unit is intended to be surface-mounted or corner-mounted. All performance requirements in Technical Requirements Table V4.3 refer to the full power operating mode.

Linear Ambient Luminaires:

For the purposes of family grouping, linear ambient luminaires that are available as continuous runs:

- End cap variations are not considered optical variations for family grouping and listing purposes. These product variations may be included within a given product model number or listing as bracketed options or wildcard characters.
    - Continuous runs are considered to be multiple linear ambient luminaires connected end-to-end without breaks; end caps are defined as the finish piece applied to the either end of a continuous run.
    - End caps must be less than 3" in width. End caps that do not meet these requirements will be considered performance-affecting and may not be included in bracketing for a given model number.

DLC Linear Replacement Lamp Testing and Reporting Requirements:

The DLC will accept QPL applications for linear tube-style products intended to replace fluorescent lamps in this category. The testing and reporting requirements described in the link below are intended to evaluate the performance of the lamp itself and its performance in reference troffers, the most common application. For more information, please refer to the Testing and Reporting Requirements for Linear Replacement Lamps. Note that this category covers all LED tubes, including those that are direct replacements for fluorescent tubes and those that require modifications to the existing luminaire (such as bypassing the existing ballast). Linear replacement lamps are eligible for the DLC Standard classification only.

DLC Screw-Base Replacement Lamp Testing and Reporting Requirements:

The DLC will accept applications for screw-base replacement products intended to replace HID lamps in these categories. The testing and reporting requirements described in the link below are intended to evaluate the performance of the lamp installed in specific end-use applications. For more information, please refer to the Testing and Reporting Requirements for Screw-Base Replacements for HID Lamps. Note that this category covers only Type B and Type C replacement lamps, and qualifies only products in specific end-uses. Replacement lamps are eligible for the DLC Standard classification only.

DLC Four Pin-Base Replacement Lamp Testing and Reporting Requirements:

The DLC will accept applications for four-pin (i.e. G24q/GX24q and 2G11 base) replacement lamps. At this time, G24q/GX24q and 2G11 UL Type A lamps, and 2G11 UL type B, C, or A-B lamps are included. G24q/GX24q base UL Type B lamps (designed to operate directly using line

voltage) and UL Type C products (designed to operate utilizing a non-integral driver), as well as products with other bases (including two pin products), remain under consideration for future development.

The testing and reporting requirements described below are intended to subject the lamps to conditions found in typical luminaires in order to assure confidence in performance. For more information, please refer to the Testing and Reporting Requirements for Four Pin-Base Replacements Lamps for CFLs. Note that this category covers only Type A replacement lamps (lamps that are direct replacements for CFLs and do not require bypassing the CFL ballast). Replacement lamps are eligible for the DLC Standard classification only.

ENERGY STAR® Program Requirements for Luminaires

Partner Commitments

Following are the terms of the ENERGY STAR Partnership Agreement as it pertains to the manufacture and labeling of ENERGY STAR certified products. The ENERGY STAR Partner must adhere to the following partner commitments:

Certifying Products

1. **Comply with current ENERGY STAR Eligibility Criteria**, which define performance requirements and test procedures for Luminaires. A list of eligible products and their corresponding Eligibility Criteria can be found at www.energystar.gov/specifications.
2. **Prior to associating the ENERGY STAR name or mark with any product**, obtain written certification of ENERGY STAR certification from a Certification Body recognized by EPA for Luminaires. As part of this certification process, products must be tested in a laboratory recognized by EPA to perform Lamp testing. A list of EPA-recognized laboratories and certification bodies can be found at www.energystar.gov/testingandverification.

Using the ENERGY STAR Name and Marks

3. Comply with current ENERGY STAR Brand Book, which define how the ENERGY STAR name and marks may be used. Partner is responsible for adhering to these guidelines and ensuring that its authorized representatives, such as advertising agencies, dealers, and distributors, are also in compliance. The ENERGY STAR Brand Book are available at www.energystar.gov/logouse.
4. Use the ENERGY STAR name and marks only in association with certified products. Partner may not refer to itself as an ENERGY STAR Partner unless at least one product is certified and offered for sale in the U.S. and/or ENERGY STAR partner countries.
5. Provide clear and consistent labeling of ENERGY STAR certified Luminaires. The ENERGY STAR mark must be clearly displayed on the front or primary display panel of the product packaging, in product literature (i.e., user manuals, spec sheets, etc.) and on the manufacturer's Internet site where information about ENERGY STAR certified models is displayed.

Verifying Ongoing Product Certification

6. Participate in third-party verification testing through a Certification Body recognized by EPA for Luminaires, providing full cooperation and timely responses. EPA/DOE may also, at its discretion, conduct tests on products that are referred to as ENERGY STAR certified. These products may be obtained on the open market, or voluntarily supplied by Partner at the government's request.

Providing Information to EPA

7. Provide unit shipment data or other market indicators to EPA annually to assist with creation of ENERGY STAR market penetration estimates, as follows:
   - 7.1. Partner must submit the total number of ENERGY STAR certified Luminaires shipped in the calendar year or an equivalent measurement as agreed to in advance by EPA and Partner. Partner shall exclude shipments to organizations that rebrand and resell the shipments (unaffiliated private labelers).
   - 7.2. Partner must provide unit shipment data segmented by meaningful product characteristics (e.g., type, capacity, presence of additional functions) as prescribed by EPA.
   - 7.3. Partner must submit unit shipment data for each calendar year to EPA or an EPA-authorized third party, preferably in electronic format, no later than March 1 of the following year.

Submitted unit shipment data will be used by EPA only for program evaluation purposes and will be closely controlled. If requested under the Freedom of Information Act (FOIA), EPA will argue that the data is exempt. Any information used will be masked by EPA so as to protect the confidentiality of the Partner.

8. Report to EPA any attempts by recognized laboratories or Certification Bodies (CBs) to influence testing or certification results or to engage in discriminatory practices.
9. Notify EPA of a change in the designated responsible party or contacts within 30 days using the My ENERGY STAR Account tool (MESA) available at www.energystar.gov/mesa.

Performance for Special Distinction

In order to receive additional recognition and/or support from EPA for its efforts within the Partnership, the ENERGY STAR Partner may consider the following voluntary measures, and should keep EPA informed on the progress of these efforts:

- Provide quarterly, written updates to EPA as to the efforts undertaken by Partner to increase availability of ENERGY STAR certified products, and to promote awareness of ENERGY STAR and its message.
- Consider energy efficiency improvements in company facilities and pursue benchmarking buildings through the ENERGY STAR Buildings program.
- Purchase ENERGY STAR certified products. Revise the company purchasing or procurement specifications to include ENERGY STAR. Provide procurement officials' contact information to EPA for periodic updates and coordination. Circulate general ENERGY STAR certified product information to employees for use when purchasing products for their homes.
- Feature the ENERGY STAR mark(s) on Partner website and other promotional materials. If information concerning ENERGY STAR is provided on the Partner website as specified by the ENERGY STAR Web Linking Policy (available in the Partner Resources section of the ENERGY STAR website), EPA may provide links where appropriate to the Partner website.
- Ensure the power management feature is enabled on all ENERGY STAR certified displays and computers in use in company facilities, particularly upon installation and after service is performed.
- Provide general information about the ENERGY STAR program to employees whose jobs are relevant to the development, marketing, sales, and service of current ENERGY STAR certified products.
- Provide a simple plan to EPA outlining specific measures Partner plans to undertake beyond the program requirements listed above. By doing so, EPA may be able to coordinate and communicate Partner's activities, provide an EPA representative, or include news about the event in the ENERGY STAR newsletter, on the ENERGY STAR website, etc. The plan may be as simple as providing a list of planned activities or milestones of which Partner would like EPA to be aware. For example, activities may include: (1) increasing the availability of ENERGY STAR certified products by converting the entire product line within two years to meet ENERGY STAR guidelines; (2) demonstrating the economic and environmental benefits of energy efficiency through special in-store displays twice a year; (3) providing information to users (via the website and user's manual) about energy-saving features and operating characteristics of ENERGY STAR certified products; and (4) building awareness of the ENERGY STAR Partnership and brand identity by collaborating with EPA on one print advertorial and one live press event.
- Join EPA's SmartWay Transport Partnership to improve the environmental performance of the company's shipping operations. The SmartWay Transport Partnership works with freight carriers, shippers, and other stakeholders in the goods movement industry to reduce fuel consumption, greenhouse gases, and air pollution. For more information on SmartWay, visit www.epa.gov/smartway.
- Join EPA's Green Power Partnership. EPA's Green Power Partnership encourages organizations to buy green power as a way to reduce the environmental impacts associated with traditional fossil fuel-based electricity use. The partnership includes a diverse set of organizations including Fortune 500 companies, small and medium businesses, government institutions as well as a growing number of colleges and universities. For more information on Green Power, visit www.epa.gov/greenpower.

ENERGY STAR® Program Requirements
Product Specification for Luminaires (Light Fixtures)

Eligibility Criteria
Version 2.1

Following is the Version 2.1 product specification for ENERGY STAR certified Luminaires. A product shall meet all of the identified criteria if it is to earn the ENERGY STAR.

To certify a luminaire for ENERGY STAR, first determine which requirements in this document are applicable to the specific luminaire. ENERGY STAR requirements are specific to luminaires classified by the program as directional or non-directional. This specification is generally organized by the requirements, not by luminaire type such as indoor or outdoor, or by light source technology. Partners are advised to review each section, and take note of exceptions where specific performance criteria need not be evaluated; for instance, some color exceptions are in place for outdoor luminaires.

Luminaires which do not fall into the specific directional scope default to non-directional classification.

- Directional luminaires (**evaluated using luminaire photometry**):
  - **specific scope** itemized in the Specification Scope & Luminaire Classification section
  - evaluated using luminaire photometry (i.e. lumens delivered from luminaire per input watt), accounting for luminaire optics
  - shall also meet specified minimum light output and zonal lumen density requirements
  - solid state (LED) luminaire types featuring inseparable components (no user replaceable/upgradeable LED light engine or integrated LED lamp) and not otherwise itemized in the directional scope shall be considered inseparable SSL luminaires and evaluated using luminaire photometry
  - luminaire types not meeting the above criteria default to non-directional classification, described below

- Non-directional luminaires (**evaluated using source photometry**):
  - **examples** provided in the Specification Scope & Luminaire Classification section
  - evaluated using source photometry (i.e. lumens delivered from the light source per input watt), including system performance of lamp and ballast, LED light engine, ENERGY STAR certified compact fluorescent lamp or LED lamp
  - luminaires not classified above as directional are evaluated as non-directional as long as the light source is removable and can be tested by an applicable test method identified in this specification

1 SPECIFICATION SCOPE & LUMINAIRE CLASSIFICATION

The ENERGY STAR Luminaires specification ("this specification") covers luminaire types outlined in this section. This specification is limited to residential type lighting products, however to the extent that products that fall under the scope of this specification are sold into the commercial market, they may be included and listed appropriately for the applicable end user. Certification is limited to luminaires below a total input power of 250 watts intended to be connected directly to the electric power grid. Refer to the Definitions section in Section 4 for definitions of each directional luminaire type detailed below. Questions about scope may be directed to an EPA recognized Certification Body or lighting@energystar.gov.

1.1 Excluded Products:

- Commercial outdoor lighting (e.g. street and area, wall packs, canopy)
- High or low bay luminaires
- Recessed troffers and other linear fluorescent fixtures
- Luminaire types typically employed for general office illumination such as linear pendants and panel lighting
- HID sources or their SSL replacements
- Socket adapters or converters
- LED lamps intended to replace linear fluorescent, pin-based compact fluorescent or high-intensity discharge lamps.
- Products incorporating power-consuming features in the on or off state which are not related to control of illumination (e.g., luminaires with integral security cameras or speakers, and portable desk task lights with a USB charger).

Ceiling fan light kits should be certified under the ENERGY STAR specification for Ceiling Fans (https://www.energystar.gov/products/lighting_fans/ceiling_fans/partners).

1.2 Included Products:

LUMINAIRE TYPES MEASURED WITH LUMINAIRE PHOTOMETRY		
Inseparable SSL Luminaires	Luminaires **not listed below as directional** with solid state light sources that do not fit the definition of lamp or light engine	
DIRECTIONAL LUMINAIRES		
Limited to the following types:	**Includes:**	
Accent Lights	Line-voltage directional track lighting	
	Track heads	
Cove Mount and Under cabinet Lights		
Downlights	Downlight Retrofit Kits	Surface Mount
	Recessed	Pendant Mount
Outdoor Lighting	Post mount	Wall Mount
	Pendant Mount	Security Lighting
	Porch Lights	
Portable Desk Task Lights		
LUMINAIRE TYPES MEASURED WITH SOURCE PHOTOMETRY		
NON-DIRECTIONAL LUMINAIRES (including but not limited to)		
Ventilation Fan Light Kits (Ceiling fan light kits are covered under the Ceiling Fan and Light Kits Specification)	Portable	
Wrapped Lens	Linear Strip	
Wall Sconces & Retrofits	Outdoor Ceiling or Close-to-Ceiling Mount, Porch or Post mount	
Decorative Pendants	Bath Vanity	
Ceiling Mount & Retrofits	Chandeliers	

2 EFFECTIVE DATE

The ENERGY STAR Luminaires Version 2.0 specification shall take effect on June 1, 2016. To certify a product for ENERGY STAR, the model shall meet the ENERGY STAR specification in effect on its date of manufacture. The date of manufacture is specific to each unit and is the exact date on which a unit is considered to be completely assembled.

3 FUTURE SPECIFICATION REVISIONS

EPA reserves the right to change this specification should technological and/or market changes affect its usefulness to consumers, industry, or the environment. In keeping with current policy, revisions to the specification are arrived at through industry discussions. In the event of a specification revision, please note that ENERGY STAR certification is not automatically granted for the life of a product model.

While this document currently refers to industry standards and test procedures for fluorescent and solid state sources, as new technologies emerge that have equal or better performance to the levels proposed here, consistent with a technology neutral approach, EPA may amend the program requirements by adding additional requirements, standards, and test procedures.

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4 DEFINITIONS

Accent Light (Luminaire): A directional luminaire employed to emphasize a particular object or surface feature, or to draw attention to a part of the field of view (adapted from ANSI/IES RP-16-17: "Accent Lighting"). This includes line-voltage directional track lighting.
ANSI: American National Standards Institute.
Aperture Size (downlights): The maximum distance between the points inside the luminaire where light escapes the luminaire.
ASTM: American Society for Testing of Materials.
Ballast: A device used with an electric-discharge lamp to obtain the necessary circuit conditions (voltage, current, and wave form) for starting and operating. (ANSI/IES RP-16-17)
Bath Vanity Luminaire: Wall-mounted luminaires located adjacent to a mirror.
Beam Angle: The angle in degrees, between the two opposite directions in which the average intensity is 50% of the center beam intensity as measured in at least two rotational planes, 90° from each other, around and through the beam axis. (ANSI C78.379-2006)
Ceiling / Close-to-Ceiling Mount Luminaire: Ceiling-mounted luminaires that direct less than 90% of light downward and are not intended to accent an object or an area within a space.
Chandeliers: Decorative, often branched, luminaires suspended from the ceiling incorporating multiple light sources.
CIE: Commission Internationale de l'Eclairage (International Commission on Illumination).
Color Rendering Index (CRI): A measure of the degree of color shift objects undergo when illuminated by the light source, as compared with the color of those same objects when illuminated by a reference source of comparable color temperature. (ANSI/IES RP-16-17)
Color Shifting Dimming Luminaire: A luminaire with dimming capability designed to simulate the behavior of incandescent lamps where the chromaticity gradually shifts to a lower value as the product is dimmed. This function is not considered color tunable for the purposes of this specification, unless it can also be tuned to different colors at full output.
Color Tunable Luminaire: For the purpose of this specification, a color tunable luminaire has functionality that allows the end user to alter the color appearance of the light generated by the luminaire. This tuning must include white light that is capable of meeting the specification's color requirements, and can alter the color appearance along the black body curve, or may also extend to colors beyond the ANSI defined correlated color temperature ranges (e.g. 2700K and 5000K) outside of the seven step MacAdam ellipse or the ANSI quadrangles.
Compact Fluorescent Lamp (CFL): A fluorescent lamp with a small diameter glass tube (T5 or smaller) that is folded, bent, or bridged to create a long discharge path in a small volume. The lamp designs generally include an amalgam and a cold chamber, or a cold spot, to control the mercury vapor pressure and light output. (ANSI/IES RP-16-17)
Connected Luminaire: A luminaire or retrofit which includes elements or instructions (hardware and software or firmware) required to enable communication in response to consumer-authorized energy or performance related commands and complies with all requirements for connected in the specification. These elements may be resident inside or outside of the base luminaire or retrofit.
Correlated Color Temperature (CCT): The absolute temperature of a blackbody whose chromaticity most nearly resembles that of the light source. (ANSI/IES RP-16-17).
Cove Mount (Luminaire): Lighting comprising light sources shielded by a ledge or horizontal recess, and distributing light over the ceiling and upper wall. (Adapted from ANSI/IES RP-16-17: "Cove Lighting") For purposes of this specification, cove mount luminaires feature luminaire optics over the lamps, LED packages, arrays or modules, LED light engines or integrated LED lamps.
CSA: Canadian Standards Association.
Decorative Pendant (Luminaire): Suspended luminaires that are not intended to accent an object or an area within a space, and typically employ blown glass, or colorful glass elements.
Direct Lighting: Lighting involving luminaires that distribute 90% to 100% of the emitted light in the general direction of the surface to be illuminated. This term usually refers to light emitted in a downward direction. (ANSI/IES RP-16-17)
Directional Applications: See Direct Lighting.
Directional Luminaires: See Direct Lighting.
Down Light or Downlight (Luminaire): A small direct-lighting unit that directs the light downward and can be recessed, surface mounted, or suspended (ANSI/IES RP-16-17). See definition of Direct Lighting for additional information. For purposes of this specification, this definition includes downlight retrofit kits but does not include linear fluorescent troffers or linear luminaire forms such as linear fluorescent pendants, typically used to illuminate office spaces.
Downlight Retrofits: A type of luminaire intended to install into an existing downlight, replacing the existing light source and related electrical components, typically employing an ANSI standard lamp base, either integral or connected to the downlight retrofit by wire leads, and is a retrofit kit classified or certified to UL 1598C. This category does not include self-ballasted lamps, which are covered by the ENERGY STAR Lamps Specification, or products that utilize the existing ballast or transformer.
Electronic Ballast: A device which operates at a supply frequency of 50 or 60 Hz and operates the lamp at frequencies greater than 10 kHz. (ANSI standard C82.13-2002)
Enclosed fixture or enclosed luminaire: A luminaire that contains enclosed lamp compartment(s) where ventilation openings are less than 3 square inches per lamp in the lamp compartment or where the cross-sectional area of the opening of the lamp compartment is less than the maximum cross sectional area of the lamp compartment (adapted from UL 1598 Fig 7.2.1).
Floor Lamp (Luminaire): a portable luminaire on a high stand, suitable for standing on the floor. (ANSI/IES RP-16-17)
IEC: International Electrotechnical Commission.
IES: Illuminating Engineering Society.
Input Power: The power consumption in watts of a ballast or driver and a light source system operating in a normal or active mode, as determined in accordance with the test procedure (ANSI Standard 82.2-2002)
Inseparable SSL Luminaire: A luminaire featuring solid state lighting components (i.e. LEDs and driver components) which cannot be easily removed or replaced by the end user, thus requiring replacement of the entire luminaire. Removal of solid state lighting components would require (for instance) the cutting of wires, use of a soldering iron, or damage to or destruction of the luminaire. This definition does not encompass luminaires which feature LED light engines or integrated LED lamps which are user replaceable / upgradeable without the cutting of wires or the use of solder, or the specific residential luminaire types designated "directional" in the scope of this document.

Integrated LED Lamp: An integrated assembly composed of light emitting diode (LED) packages (components) or LED arrays (modules), as well as an LED driver, an ANSI standard base, and other optical, thermal, mechanical and electrical components. The device is intended to connect directly to the branch circuit through a corresponding ANSI standard lamp-holder (socket). (ANSI/IES RP-16-17: "LED lamp, integrated")
Lamp: A generic term for a manufactured source created to produce optical radiation. By extension, the term is also used to denote sources that radiate in regions of the spectrum adjacent to the visible." (ANSI/IES RP-16-17)
Lamp-Ballast Platform: A pairing of one ballast with one or more lamps that can operate simultaneously on that ballast. A unique platform is defined by the manufacturer and model number of the ballast and lamp(s) and the quantity of lamps that operate on the ballast. A lamp-ballast platform also may refer to a lamp with an integral ballast, such as a GU24 based integrated lamp.
Lampholder: A component of a luminaire which supplies power to the lamp and also holds the lamp in place.
LED: See Light Emitting Diode.
LED Array or Module: An assembly of LED packages (components), or dies on a printed circuit board or substrate, possibly with optical elements and additional thermal, mechanical, and electrical interfaces that are intended to connect to the load side of a LED driver. Power source and ANSI standard base are not incorporated into the device. The device cannot be connected directly to the branch circuit. (ANSI/IES RP-16-17)
LED Control Circuitry: Electronic components designed to control a power source by adjusting output voltage, current, or duty cycle to switch or otherwise control the amount and characteristics of the electrical energy delivered to an LED package (component) or an LED array (module). LED control circuitry does include a power source. (ANSI/IES RP-16-17)
LED Driver: A device comprised of a power source and LED control circuitry designed to operate an LED package (component), an LED array (module), or an LED lamp. (ANSI/IES RP-16-17)
LED Driver Case Temperature Measurement Point (TMP_C): A location on an LED driver case, designated by its manufacturer, which will have the highest temperature of any point on the driver case during normal operation.
LED Light Engine: An integrated assembly composed of LED packages (components) or LED arrays (modules), as well as an LED driver and other optical, thermal, mechanical and electrical components. The device is intended to connect directly to the branch circuit through a custom connector compatible with the LED luminaire for which it was designed. It does not use an ANSI standard base (ANSI/IES RP-16-17). For purposes of this specification, light engines that rely on the luminaire for optical control, and/or thermal management, assemblies featuring remote-mounted drivers ("non-integrated"), and/or GU24 based integrated SSL sources not in the scope of the ENERGY STAR Lamps specification shall also be considered LED light engines.
LED Luminaire: A complete lighting unit consisting of LED-based light emitting elements and a matched driver together with parts to distribute light, to position and protect the light emitting elements, and to connect the unit to a branch circuit. The LED-based light emitting elements may take the form of LED packages (components), LED arrays (modules), an LED Light Engine, or LED lamps. The LED luminaire is intended to connect directly to a branch circuit. (ANSI/IES RP-16-17)
LED Package: An assembly of one or more LED dies that includes wire bond or other type of electrical connections, possibly with an optical element and thermal, mechanical, and electrical interfaces. Power source and ANSI standardized base are not incorporated into the device. The device cannot be connected directly to the branch circuit. (ANSI/IES RP-16-17)
LED Temperature Measurement Point (TMP_{LED}): A location on an LED package/module/array, designated by its manufacturer, which provides a surrogate temperature measurement location for the actual LED junction. The TMP_{LED} may be a solder joint at the board attachment site, a point on the LED package case, or a location on the board of an LED module or array.
Light Emitting Diode (LED): A p-n junction semiconductor device that emits incoherent optical radiation when forward biased. The optical emission may be in the ultraviolet, visible, or infrared wavelength regions. (ANSI/IES RP-16-17)
Linear Strip Luminaire: A surface mounted luminaire with an elongated aspect ratio and either no optics over the light source(s) or individual optics over each light source.
Line-Voltage Track Light (Luminaire): See Accent Light definition. Includes luminaires interoperable with line-voltage track installed without a transformer or power supply.
Lumen Maintenance: Luminous flux maintenance (often referred to as "lumen maintenance") is the remaining luminous flux output (typically expressed as a percentage of the initial luminous flux output) at any selected elapsed operating time. Luminous flux maintenance (or "lumen maintenance") is the converse of luminous flux depreciation (or "lumen depreciation"). (ANSI/IES LM-80-15).
Lumens per Watt (lm/W): The quotient of the total luminous flux emitted by the total light source power input. It is expressed in lm/W. (adapted from ANSI/IES RP-16-17: "Luminous Efficacy of a Source of Light")
Luminaire (Light Fixture): A complete lighting unit consisting of lamp(s) and ballast(s) (when applicable) together with the parts designed to distribute the light, to position and protect the lamps, and to connect the lamp(s) to the power supply (ANSI/IES RP-16-17).
Luminaire Efficacy: The luminous flux delivered by a luminaire, divided by its input power.
MacAdam Color Ellipse: A series of ellipses around the chromaticity coordinates of a number of different colors. Each ellipse sets the boundary at which a given percentage of people are able to determine that two colors, one with the chromaticity coordinates at the center of the ellipse, and one with chromaticity coordinates on the ellipse, are just noticeably different. (IES Handbook 9th Edition)
Measured value: The directly measured value from testing equipment for a given unit under test.
Nadir: The angle pointing directly downward from the luminaire, or zero degrees.
NEMA: National Electrical Manufacturers Association.
Non-Directional Application: For purposes of this ENERGY STAR specification, luminaire types which are not designated directional. See Direct Lighting definition.
Non-Directional Luminaire: See Non-Directional Application.
NRTL: Nationally Recognized Testing Laboratory as recognized by OSHA's NRTL Program, which is a part of OSHA's Directorate of Technical Support.
Optics: Include reflectors, baffles, lenses and/or diffusers, all of which control the light distribution and the appearance of the lighted luminaire.
OSHA: Occupational Safety & Health Administration.
Outdoor Pendant Luminaire: An outdoor suspended luminaire.
Outdoor Porch Luminaire: An outdoor ceiling, surface or wall-mounted luminaire.

Outdoor Post-Mounted Luminaire: An outdoor luminaire supported by a post inserted into the ground and mounted between 4 feet and 10.5 feet above grade.
Outdoor Security Luminaire: Wall mounted luminaires intended to light areas immediately adjacent to a building's perimeter.
Photocontrol or Light-Activated Switch: A photoelectric switch that controls lighting by the level of daylight luminance (ANSI/IES RP-16-17), also referred to as a photosensor.
Platform: See Lamp-Ballast Platform.
Portable Desk Task Light (Luminaire): A light fixture resting on a desk that directs light to a specific surface or area to provide illumination for visual tasks such as reading and writing, and employs a NEMA 1-15P or 5-15P plug for its electrical connection.
Portable Floor Task Light (Luminaire): A light fixture resting on the floor that directs light to a specific surface or area to provide illumination for visual tasks such as reading and writing, and employs a NEMA 1-15P or 5-15P plug for its electrical connection.
Portable Luminaire: A lighting unit that is not permanently fixed in place. (ANSI/IES RP-16-17)
Power Factor: The power input in watts divided by the product of ballast input voltage and input current of a fluorescent lamp ballast, as measured under test conditions. (ANSI Standard C82.2–2002 (R2016))
Power Source: A transformer, power supply, battery, or other device capable of providing current, voltage, or power within its design limits. This device contains no additional control capabilities. (ANSI/IES RP-16-17: "LED Power Source")
Rated Lumen Maintenance Life (L_p): The elapsed operating time over which the LED light source will maintain the percentage, p, of its initial light output, e.g. L_{70} (hours): Time to 70% lumen maintenance. (IES TM-21-11)
Reported value: The value reported for purposes of compliance with DOE and/or ENERGY STAR requirements according to the criteria in each applicable section.
Residential Luminaire: A luminaire marketed and intended to be used in a residential environment notwithstanding use in commercial, business and industrial environments. (Adapted from FCC 47 CFR parts 15 and 18)
Run-up Time: The time needed after switching on the supply for the lamp to reach 80.0% of its stabilized luminous flux. (ANSI C78.5-2003 (R2015))
Secondary Optics: Materials modifying the distribution or amount of light from, but not integral to a light source, including but not limited to diffusers, reflectors, and total internal reflection optics.
Solid State Lighting (SSL): The term "solid state" refers to the fact that the light is emitted from a solid object—a block of semiconductor—rather than from a vacuum or gas tube, as in the case of an incandescent and fluorescent lighting. There are two types of solid-state light emitters: inorganic light-emitting diodes (LEDs) or organic light-emitting diodes (OLEDs). (Sandia National Laboratories)
Standby Mode: The condition in which energy-using product is connected to a main power source; and offers one or more of the following user-oriented or protective functions: to facilitate the activation or deactivation of other functions (including active mode) by remote switch (including remote control), internal sensor, or timer; or continuous functions, including information or status displays (including clocks) or sensor-based functions. (US DOE)
Standardized Color Ellipse: A MacAdam color ellipse defined by center chromaticity coordinates (CIE x, y) and a measure of certainty for detecting a color difference specified in standard deviation units called steps. (ANSI C78.376-2014)
Surface Mount Retrofit Kits: A type of solid state lighting product intended to replace existing light sources and systems including incandescent and fluorescent light sources in previously installed luminaires that already comply with safety standards. These kits replace the existing light source and related electrical components, and are classified or certified to UL 1598C. This may employ an ANSI standard lamp base, either integral or connected to the retrofit by wire leads. This category does not include self-ballasted lamps, which are covered by the ENERGY STAR Lamps Specification, or products that utilize the existing ballast or transformer.
Table Lamp (Luminaire): A portable luminaire with a short stand suitable for standing on furniture. (ANSI/IES RP-16-17)
Torchiere or Torchère (Luminaire): An indirect floor lamp that sends all or nearly all of its light upward. (ANSI/IES RP-16-17)
TMP_C: see LED Driver Case Temperature Measurement Point.
TMP_{LED}: see LED Temperature Measurement Point.
Trim: The part of a downlight that covers the ragged edge of the ceiling cut-out. The trim may be a separate ring, or trim ring, or it may be integrated with the optics (i.e., a self-flanged reflector). A trim can be airtight or non-airtight.
UL: Underwriters Laboratories.
Under-Cabinet Luminaire: A luminaire installed below an upper cabinet to direct light down to the work surface of a countertop or desk for task lighting.
Wall Sconce (Luminaire): A wall mounted luminaire not intended to accent an object or a task area within a space.
Wrapped Lens Luminaire: A surface mounted luminaire with an elongated aspect ratio and a single optic covering the light source that directs less than 90% of light downward.

5 TEST CRITERIA

When testing luminaires, the methods of measurement identified for each performance requirement in the "Methods of Measurement and/or Reference Documents" column of the performance requirements tables presented within this specification shall be used to determine ENERGY STAR certification.

All tests shall be conducted with the product connected to a supply circuit of rated frequency. For products with multiple operating voltages, the product shall be operated at 120 volts throughout testing. If the product is not rated for 120 volts, it shall be operated at the highest rated voltage. For dimmable or multi-power products, measurements shall be taken at the highest wattage setting listed for the model, unless otherwise specified. IES LM-9, LM-65 and LM-66 are applied to both hot and cold cathode lamps, and LM-65 and LM-66 apply to induction lamps.

5.1 Testing Color Tunable Luminaires

For the purpose of this specification, a color tunable luminaire has functionality that allows the end user to alter the color appearance of the light generated by the luminaire. This tuning must include white light that is capable of meeting the specification's CCT requirements, and can include the ability to alter the color appearance along the black body curve, or may also extend to colors beyond the ANSI defined correlated color temperature ranges. When testing color tunable luminaires, photometric performance testing (per section 9) shall be performed at an undimmed state, and testing should be performed as follows:

- All tests and evaluations shall be performed at the Least Efficient white light setting included in this specification (Section 9.3).
- Additionally, watts, lumens, chromaticity, and CRI shall be tested and reported for Default and Most Consumptive white light settings as applicable (if different from least efficient white light setting).

In order to facilitate compliance testing, the partner shall provide detailed instructions for the control settings or control signals (as applicable) for reaching the least efficient, default, and most consumptive modes.

5.2 Certified Lighting Subcomponent Database

The Certified Subcomponent Database (CSD) supports certification of ENERGY STAR Luminaires by providing partners with third-party certified performance data for lighting subcomponents. The use of the CSD is optional for luminaire manufacturers. It is intended to streamline the certification process; subcomponents are not required to be listed on the CSD to be employed in an ENERGY STAR certified luminaire.

The CSD is designed to contain certified performance data for illumination related subcomponents such as: fluorescent lamps, fluorescent ballasts, fluorescent lamp-ballast platforms, and LED light engines, and can be found at www.energystar.gov/csd.

5.2.1 Listing Subcomponents:

Subcomponents in this database are not ENERGY STAR qualified as a result of being listed and:

- May not carry any of the Program's certification or promotional marks on the products, on product packaging, or in associated literature either printed or electronic.
- May not be referred to as ENERGY STAR qualified, certified, rated, or approved.
- May be referred to as "listed on the ENERGY STAR CSD".

To have subcomponents listed on the CSD, manufacturers must follow the third-party certification procedures and have products tested at an EPA-recognized laboratory, and the test data certified by an EPA-recognized certification body.

- Subcomponent manufacturers' test laboratories must provide the same test reports required by the Luminaires specification, and the sample sizes for subcomponents must follow the required sample sizes in the specification.
- If the subcomponent meets the Luminaires specification performance levels attributable to the subcomponent, the CB may certify the subcomponent data for listing on the CSD.
- When luminaire manufacturers provide materials for ENERGY STAR certification, they can reference the CSD for performance data of subcomponents used in their luminaires.

5.2.2 Using Subcomponents:

Partners that utilize the subcomponents in their luminaire may only reference performance metrics applicable to the specific type of luminaire, and its classification as a directional or non-directional luminaire.

5.2.3 Testing LED Light Engines without Integrated Heat Sinks

When performing LM-82 testing of LED light engines that will rely on the luminaire for heat dissipation, it is permissible to use a representative heat sink that provides similar heat dissipation to the luminaire that the LED light engine is going to be installed in.

6 PRODUCT CERTIFICATION

6.1 Product Families

Grouped product submissions for ENERGY STAR certification shall meet the following requirements:
Certified products within a product family shall be identical to the tested, representative model with the exception of allowed variations listed in the table below. The representative model shall be the variation expected to have the greatest difficulty meeting the performance requirements outlined in this specification. **Any configuration included in a family grouping that shares the same model number is representative of the performance of all configurations; any sampled configuration (e.g., downlight with black reflector/trim finish) that fails to meet the requirements during verification testing will result in a failed determination for all product configurations sharing the same model number.**

Allowable Variations Within Product Families		
Luminaire Attribute	**Allowable Variation**	**Additional Test Data Required for Each Variant[1]**
Ballast/Driver (no change in nominal wattage or current)	Allowed so long as variations will not negatively impact luminaire's compliance with any performance criteria in this specification.	Thermal measurements of each variation may be required (e.g. ballast case temperature or TMP_C).
Correlated Color Temperature (CCT) (also review Light Source variation below)	Allowed so long as the lamp series or LED package/module/array series (and associated drive current), ballast or driver, and thermal management components are identical, and so long as variations will not negatively impact luminaire's compliance with any performance criteria in this specification. The representative model shall be the version within the product family with the lowest CCT for SSL products and the highest CCT for discharge products. Partner shall use different luminaire model numbers to distinguish between models shipped with light sources of varying CCTs.	None
Electrical Connection (Downlight Retrofit Kits)	Allowed (e.g. E26 and GU24).	None
Finish	Luminaire body color/pigment.	None
Heat Sink / Thermal Management Components	Not allowed.	None
Housing/ Chassis	Allowed so long as the light source or lampholder, ballast or driver, and heat sink (as applicable) are integrated into housing / chassis variations in such a way that the thermal performance of the luminaire is not degraded by changes to the housing / chassis.	Engineering rationale or thermal measurements of each variation may be required (e.g. ballast case temperature, TMP_{LED}, or TMP_C).
Light Source[2] (refers to the make and/or model of the source; also review CCT below)	Allowed so long as variations will not negatively impact luminaire's compliance with any performance criteria in this specification.	• Certified performance data from additional light source if separable • Integrating sphere test for inseparable product

[1] Testing required to document the additional test data listed in this table shall be performed by an EPA-recognized laboratory; further data to support a partner's engineering rationale for the worst-case variant does not.
[2] Partners may not retroactively add variations to a product family unless requirements in Table 1 are still met. For example, if the representative model tested is a SSL product with a 3000 Kelvin nominal CCT, partner may not retroactively add a 2700 Kelvin model without additional testing, as this was not the lowest CCT initially tested.

Allowable Variations Within Product Families		
Luminaire Attribute	**Allowable Variation**	**Additional Test Data Required for Each Variant[1]**
Mounting	Allowed. Luminaire photometry test reports generated for outdoor post-mounted luminaires may be used to certify outdoor porch (wall-mounted), outdoor ceiling or close-to-ceiling mounted and outdoor pendant luminaires within the same product family, in place of the source photometry requirements, so long as the bill of materials for each luminaire type is identical except for mounting hardware.	None
Product Wattage[3] (directional luminaires)	For SSL products: • The LED package, array, or module model must not change, although CCT remains an allowable variation. • The only performance change to the luminaire is to a driver that provides a different drive current to the LED package, array or module. • The model tested should be the highest wattage, highest CRI, and lowest CCT variant.	• LED drive current measurement • Integrating sphere scan to represent performance of variants including: o CCT o Lumen Output o CRI o Power Consumption o Chromaticity
	For Fluorescent products: • The lamp wattage may change, but not the general type or configuration. Example: A 32W triple tube pin based fluorescent representing a 26W triple tube pin based fluorescent would be acceptable, but not representing a 26W twin tube fluorescent. • The only performance change to the luminaire is to the lamp (or lamp and ballast) with a lower wattage. • The model tested should be the highest wattage, highest CRI, and highest CCT variant.	• Certified lamp data for variants • Integrating sphere scan to represent performance of variants including: o CCT o Lumen Output o CRI o Power Consumption o Chromaticity
Reflector / Trim	Allowed so long as luminaire light output exceeds that of the darkest or least efficient reflector variation.	Luminous flux for each basic trim or for the reflector variation with the darkest or least efficient finish should be reviewed.
Shade / Diffuser	Allowed so long as neither luminaire light output nor air flow are reduced.	None

6.2 Significant Digits and Rounding

a. Measurements shall be recorded at the resolution of the test instrumentation for each unit in the sample set.
b. All calculations shall be carried out on a per unit basis with directly measured (unrounded) values.
c. Compliance with the specification limits shall be evaluated against the reported value for each model.
d. Rounding is defined as follows:
    a. A fractional number at or above the midpoint between two consecutive decimal places or whole numbers shall be rounded up to the higher of the two decimal places or whole numbers; or
    b. A fractional number below the midpoint between two consecutive decimal places or whole numbers shall be rounded down to the lower of the two decimal places or whole number.

6.3 Solid State Lumen Maintenance Performance Data

Content and application of IES LM-80 reports for LED luminaires shall comply with the ENERGY STAR Requirements for the Use of LM-80 Data.

[3] When wattage as a variation is used, changes to optics and LED package, array or module (where applicable) are not permitted, as these changes would result in a change in distribution which must be re-evaluated against the luminaire specific requirements. The additional models would still require an integrating sphere LM-79 test to verify other photometric and electrical performance requirements. Each wattage variation should be listed individually.

7 METHODS OF MEASUREMENT AND REFERENCE DOCUMENTS

Organization	Identifier	Description
ANSI/IEEE	C62.41.1-2002	IEEE Guide on the Surge Environment in Low-Voltage (1000 V and Less) AC Power Circuits
ANSI/IEEE	C62.41.2-2002	IEEE Recommended Practice on Characterization of Surges in Low-Voltage (1000V and Less) AC Power Circuits
ANSI	C78.5-2003 (R2015)	Specifications for Performance of Self-ballasted Compact Fluorescent Lamps (Reaffirmed 2015)
ANSI	C78.81-2010 or C78.81-2016	Double-Capped Fluorescent Lamps—Dimensional and Electrical Characteristics
ANSI	C78.376-2014	Specifications for the Chromaticity of Fluorescent Lamps
ANSI	C78.377-2015 or C78.377-2017	Specifications for the Chromaticity of Solid State Lighting Products
ANSI	C78.901-2014 or C78.901-2016	Single-Based Fluorescent Lamps—Dimensional and Electrical Characteristics
ANSI/ANSLG	C81.61-2009 (R2014) or C81.61-2017	Specifications for Bases (Caps) for Electric Lamps (Reaffirmed 2014)
ANSI/ANSLG	C81.62-2009 (R2014) or C81.62-2017	Lampholders for Electric Lamps (Reaffirmed 2014)
ANSI	C82.2-2002 (R2016)	Method of Measurement of Fluorescent Lamp Ballasts (Reaffirmed 2016)
ANSI	C82.11-2011 or C82.11-2017	High-Frequency Fluorescent Lamp Ballasts
ANSI/ANSLG	C82.16-2015	Light Emitting Diode Drivers—Methods of Measurement
ANSI	C82.77-10-2014	Harmonic Emission Limits—Related Power Quality Requirements for Lighting Equipment
ANSI/UL	153-2002 or 153-2014	Standard for Safety of Portable Electric Luminaires
ANSI/UL	935-2009	Standard for Safety of Fluorescent-Lamp Ballasts
ANSI/UL	1310-2010	Standard for Safety of Class 2 Power Units
ANSI/UL	1574-2004	Standard for Safety of Track Lighting Systems
ANSI/UL	1598-2008	Standard for Safety of Luminaires
ANSI/UL	1598B-2010	Standard for Supplemental Requirements for Luminaire Reflector Kits for Installation on Previously Installed Fluorescent Luminaires
ANSI/UL	1598C	Light-Emitting Diode (LED) Retrofit Luminaire Conversion Kits
ANSI/UL	1993-2012 or 1993-2017	Standard for Safety of Self-Ballasted Lamps and Lamp Adapters
ANSI/UL	2108-2004 or 2108-2015	Standard for Low-Voltage Lighting Systems
ANSI/UL	8750-2009 or 8750-2015	Standard for Light Emitting Diode (LED) Equipment for Use in Lighting Products
ASTM	E283-04(2012)	Standard Test Method for Determining Rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors Under Specified Pressure Differences Across the Specimen (Reapproved 2012)
CIE	Pub. No. 13.3-1995	Method of Measuring and Specifying Color Rendering of Light Sources
CIE	Pub. No. 015:2004	Colorimetry
EU	Directive 2002/95/EC	Directive 2002/95/EC of the European Parliament and of the Council of 27 January 2003 on the Restriction of the Use of Certain Hazardous Substances In Electrical and Electronic Equipment
FCC	CFR Title 47 Part 15	Radio Frequency Devices
FCC	CFR Title 47 Part 18	Industrial, Scientific, and Medical Equipment
IEC	60061-1 (2012)	Lamp Caps and Holders Together with Gauges for the Control of Interchangeability and Safety – Part 1: Lamp Caps
IEC	60081 Amend 4 Ed 5.0 (2010)	Double-capped Fluorescent Lamps - Performance Specifications
IEC	60901 (2011)	Single-capped Fluorescent Lamps - Performance Specifications
IEC	62301 ED.2.0 B:2011	Household electrical appliances - Measurement of standby power
IEC	61347-2-3-am2 ed1.0 b.2011	Amendment 2 - Lamp Control Gear - Part 2-3: Particular Requirements for A.C. Supplied Electronic Ballasts for Fluorescent Lamps
IEC	62321 Ed. 1.0	Electrotechnical Products - Determination Of Levels Of Six Regulated Substances (lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls, polybrominated diphenyl ethers)
IEEE	1789-2015	Recommending Practices for Modulating Current in High Brightness LEDs for Mitigating Health Risks to Viewers
IES	LM-9-09	Electric and Photometric Measurements of Fluorescent Lamps
IES	LM-10-96	Photometric Testing of Outdoor Fluorescent Luminaires
IES	LM-31-95	Photometric Testing of Roadway Luminaires Using Incandescent Filament and High Intensity Discharge (HID) Lamps
IES	LM-40-10	Life Testing of Fluorescent Lamps
IES	LM-41-14	Approved Method for Photometric Testing of Indoor Fluorescent Luminaries
IES	LM-46-04	Photometric Testing of Indoor Luminaires Using High Intensity Discharge or Incandescent Filament Lamps
IES	LM-49-12	Life Testing of Incandescent Filament Lamps
IES	LM-58-13	Method for Spectroradiometric Measurement Methods for Light Sources
IES	LM-65-14	Life Testing of Compact Fluorescent Lamps
IES	LM-66-14	Electrical and Photometric Measurements of Single-Ended Compact Fluorescent Lamps
IES	LM-79-08	Electrical and Photometric Measurements of Solid-State Lighting Products
IES	LM-80-08 and its Addendum A	Measuring Lumen Maintenance of LED Light Sources
ANSI/IES	LM-80-15	Measuring Luminous Flux and Color Maintenance of LED Packages, Arrays and Modules

Organization	Identifier	Description
IES	LM-82-12	Method for the Characterization of LED Light Engines and Integrated LED Lamps for Electrical and Photometric Properties as a Function of Temperature
IES	LM-84-14	Measuring Luminous Flux and Color Maintenance of LED Lamps, Light Engines, and Luminaires
ANSI/IES	RP-16-17	Nomenclature and Definitions for Illuminating Engineering
IES	TM-21-11 and its Addendum B	Projecting Long Term Lumen Maintenance of LED Sources
IES	TM-28-14	Projecting Long-Term Luminous Flux Maintenance of LED Lamps and Luminaries
NEMA	LSD 45-2009	Recommendations for Solid State Lighting Sub-Assembly Interfaces for Luminaires
NEMA	77-2017	Temporal Light Artifacts: Test Methods and Guidance for Acceptance Criteria
NEMA	SSL 7A-2013 or SSL 7A-2015	Phase Cut Dimming for Solid State Lighting: Basic Compatibility

8 SHIPPING WITH ENERGY STAR CERTIFIED LAMPS:

All lamps that ship with a luminaire must meet the ENERGY STAR lamp specification effective on the date of manufacture of luminaire and be included in the luminaire certification documentation.

Additional requirements for enclosed or recessed luminaires:

- Enclosed luminaires may not ship with a lamp marked with the restriction “not for use in totally enclosed fixtures” or similar.
- Recessed luminaires may not ship with a lamp marked with the restriction “not for use in recessed fixtures” or similar.
- For enclosed and recessed luminaires, an in situ measurement of ambient air temperature inside the fixture must be taken by locating a thermocouple halfway between the surface of the bulb and the interior surface of the fixture. In situ air temperature must not exceed the temperature at which the lamp’s life testing was performed.

8.1 Directional Luminaires Shipped with ENERGY STAR Certified Lamps

To satisfy the requirements of this specification, directional luminaires shipping with ENERGY STAR certified lamps shall meet the requirements outlined in sections 9.2, 13, 14, 16, 17, and 18 and be packaged with ENERGY STAR certified lamp(s).

8.2 Non-Directional Luminaires Shipped with ENERGY STAR Certified Lamps

To satisfy the requirements of this specification, non-directional luminaires shall either:

1. Meet the requirements outlined in this section and be packaged with ENERGY STAR certified lamp(s) that meet the requirements in this section,

   OR

2. Meet the relevant requirements in Sections 9 through 18.

Requirement	ENERGY STAR Requirements	Methods of Measurement and/or Reference Documents
Source Efficacy	≥ 65 lm/W per lamp All lamp permutations (makes and models) employed in a given luminaire model shall meet this requirement.	ENERGY STAR Lamps Specification
Source Minimum Light Output (initial)	Source shall provide a minimum of 800 lumens. Exception: • Outdoor porch and bath vanity luminaires featuring ≥ 3 heads shall provide a minimum of 450 lumens per head. • Chandeliers, decorative pendants, wall sconces, and other multi-head indoor luminaires shall provide a minimum of 250 lumens per head.	ENERGY STAR Lamps Specification
Safety Rating	Luminaire must meet applicable safety rating in section 14. Additionally, the lamp used must be suitable for the luminaire type it will be shipped with, e.g. a lamp shipped with an enclosed fixture must be safety tested in a totally enclosed situation and may not be rated or labeled “not for use in totally enclosed fixtures” or similar.	ANSI/UL 1993-2012 or 2017, and ANSI/UL 8750-2009 or 2015
Product Packaging & Labeling	Luminaire must comply with section 16. Unless shipped with lamps directly installed, ENERGY STAR certified lamps shipped with luminaires must comply with lamps packaging requirements.	See Section 16
Warranty	Luminaire must comply with section 17	See Section 17
Toxics	Luminaire must comply with section 18	See Section 18
Enclosed Fixture Testing	See Section 8.	

Note: For this certification pathway, many performance requirements are fulfilled through the certification of the lamp. For non-directional fixtures, lamp efficacy, minimum light output and CCT performance can be referenced on the ENERGY STAR Lamps product listing. Certain luminaire specific requirements (as noted above) still apply to the luminaire.

9 PHOTOMETRIC PERFORMANCE REQUIREMENTS

9.1 Luminous Efficacy and Output: NON-DIRECTIONAL Luminaires

Luminaire types not classified as directional in the Scope section of this specification shall be evaluated as non-directional, based on source photometric performance. The performance values in this section pertain to the performance of the source (system including ballast or driver) within a luminaire.

Source Type	ENERGY STAR Requirements		Methods of Measurement and/or Reference Documents	Supplemental Testing Guidance
	Source Efficacy (initial)	Source Minimum Light Output (initial)		
Fluorescent • **compact** • **circline**	≥ 65 lm/W per lamp-ballast platform All lamp and ballast permutations (makes and models) employed in a given luminaire model shall meet this requirement.	Lamp-ballast platform(s) shall provide a minimum of 450 total lumens. Exemption: Lamp-ballast platform(s) utilized in decorative pendants, wall sconces/single head bath vanity shall provide a minimum of 250 total lumens in situ.	**Methods of Measurement:** IES LM-9-09 (circline) IES LM-66-14 (compact non-self-ballasted)	Laboratory test results shall be produced using the specific models of lamp and ballast that will be used in production. Luminaires with ballast(s) capable of operating multiple fluorescent lamp types shall be tested with the lamp model shipped with the luminaire. **Sample Size**: 1 sample of each lamp-ballast model combination. **Passing Test**: Sample shall pass.
Solid State: • **LED Light engine**	Replaceable LED light engine ("source") efficacy shall meet or exceed the values detailed below, as determined by comparing the in situ (installed in the luminaire) T_b value to the source's LM-82 test report. ≥ 65 lm/W per light engine	Installed in the luminaire, LED light engine(s) in situ shall provide a minimum of 450 total lumens. Exemption: LED light engines utilized in decorative pendants, wall sconces/single head bath vanity shall provide a minimum of 250 total lumens in situ.	**Methods of Measurement:** IES LM-82-12 In situ temperature measurement: ANSI/UL 153:2002 (Sections 124-128A) ANSI/UL 1574:2004 (Section 54) ANSI/UL 1598:2008 (Sections 19.7, 19.10-16)	Laboratory test results shall be produced using the specific models of LED package, LED module or LED array and LED driver (i.e. LED light engine) that will be used in production. In situ temperature measurement value shall be determined in accordance with ANSI/UL 153:2002 (Sections 124-128A), ANSI/UL 1574:2004 (Section 54), or ANSI/UL 1598:2008 (Sections 19.7, 19.10-16), as applicable. LM-82 test reports shall detail luminous efficacy, luminous flux, chromaticity coordinates, CCT, and CRI values at all tested temperatures. Linear interpolation shall be employed to determine LED light engine or module ("source") photometric performance at temperatures between the LM-82 reported temperatures higher and lower than the in situ temperature. Luminaires incorporating more than one source shall have all sources installed and operational during in situ temperature testing. **Sample Size**: 1 sample of each lamp-driver model combination. **Passing Test**: Sample, tested in situ (installed in luminaire), shall pass.
Solid State: • **Surface-mounted retrofit for diffused wall sconces**	≥ 65 lm/W per retrofit	Retrofit kit shall provide a minimum of 250 lumens. Retrofit kit shall deliver a minimum of 80% of total lumens between 0-90 degrees from center of the beam.	**Method of Measurement:** IES LM-79-08	Products in this category should be tested at the line voltage for which the product is rated. If the product is rated for multiple voltages, the product shall be tested at the most consumptive voltage. **Sample Size**: 1 sample of retrofit kit **Passing Test**: Sample shall pass.
Solid State: • **Surface mounted retrofits for diffused ceiling mounted lights**	≥ 65 lm/W per retrofit	Retrofit kit shall provide a minimum of 800 lumens. Retrofit kit shall deliver a minimum of 80% of total lumens between 0-90 degrees from center of the beam.	**Method of Measurement:** IES LM-79-08	Products in this category should be tested at the line voltage for which the product is rated. If the product is rated for multiple voltages, the product shall be tested at the most consumptive voltage. **Sample Size**: 1 sample of retrofit kit **Passing Test**: Sample shall pass.

9.2 Luminous Efficacy, Output and Zonal Lumen Density: DIRECTIONAL Luminaires

Luminaire types classified as directional in Section 1 shall be evaluated based on luminaire photometry. The performance values in this section pertain to the performance of the entire luminaire, including optical losses.

Luminaire Type	ENERGY STAR Requirements			Methods of Measurement and/or Reference Documents	Supplemental Testing Guidance
	Luminaire Efficacy (initial)	Luminaire Minimum Light Output (initial)	Luminaire Zonal Lumen Density Requirement		
Cove or Under Cabinet Mount	50 lm/W	Luminaire shall deliver a minimum of 125 lumens per lineal foot. The minimum required light output (in lumens) is calculated by dividing the measured luminaire length in inches by 12, then multiplying the result by 125.	Referring to the plane perpendicular to the length of the luminaire, the luminaire shall deliver a minimum of 60% of total lumens within the 0-60° zone (symmetric about the nadir).	**Methods of Measurement:** IES LM-41-14 IES LM-79-08 **Reference Document:** ANSI/UL 1598C	Laboratory test results shall be produced using the complete luminaire and the specific models of lamp and ballast or LED package, LED module or LED array and LED driver that will be used in production. Fluorescent luminaires with ballast(s) capable of operating multiple fluorescent lamp types shall be tested with the lamp model shipped with the luminaire. The equation for minimum light output divided by the length of the luminaire applies to all luminaire configurations. For rectangular geometries the "measured luminaire length" is the longest dimension of the luminaire. For circular geometries the "measured luminaire length" is the diameter. For downlights, one trim ring and one reflector may be used. For downlight retrofits: the retrofit product shall be installed in a can size within the dimensions and limitations prescribed in the ANSI\UL1598C safety listing. The test report shall note the can model tested. For luminaires with multiple mounting orientations, the luminaire shall be tested in the orientation designated by the partner. **Sample Size**: 1 complete luminaire. **Passing Test**: The luminaire shall pass. Products that have the International Dark Sky Fixture Seal of Approval must be listed at http://www.darksky.org
Downlights: • Recessed • Surface • Pendant	55 lm/W	≤ 4.5" aperture: 345 lumens > 4.5" aperture: 575 lumens	Luminaire shall deliver a minimum of 75% of total lumens within the 0-60° zone (axially symmetric about the nadir)		
Downlight retrofits:	60 lm/W				
Accent Lights including: • Track light luminaires • Line voltage track heads	55 lm/W	Luminaire shall deliver a minimum of 200 lumens per head.	Luminaire shall deliver a minimum of 80% of total initial lumens within the 0-60° zone (axially symmetric about the center of the beam).		
Outdoor, Wall-, Porch-, Pendant-, Post-Mounted and Security Luminaires (Note: for post mounting between 4 feet and 10.5 feet above grade)	60 lm/W	Luminaire shall deliver a minimum of 300 lumens.	Luminaire shall deliver 95% of total lumens within the 0°-85° zone (symmetric about the nadir). Luminaire shall not emit more than 0.5% of the overall light output above 90°. Exempt: Products that have the International Dark Sky Fixture Seal of Approval.	**Methods of Measurement:** IES LM-10-96 (fluorescent) IES LM-79-08 (solid state)	
Portable Desk Task	50 lm/W	Luminaire shall deliver a minimum of 200 lumens.	Luminaire shall deliver a minimum of 60% of total lumens within the 0-75° zone (symmetric about the center of the beam).		
Inseparable SSL Luminaire (applies to SSL luminaire types not otherwise noted in this table)	70 lm/W	Luminaire shall deliver a minimum of 200 lumens.	None.	**Method of Measurement:** IES LM-79-08	

9.3 Correlated Color Temperature (CCT): All Indoor Luminaires (Exempt: Outdoor Luminaires and Luminaires shipped with ENERGY STAR certified Lamps)

Source Type	ENERGY STAR Requirements	Methods of Measurement and/or Reference Documents	Supplemental Testing Guidance
Fluorescent • **compact** • **circline**	Lamps shipped with luminaires shall have one of the following nominal correlated color temperatures (CCT): • 2700 Kelvin • 3000 Kelvin • 3500 Kelvin • 4000 / 4100 Kelvin • 5000 Kelvin Lamps shipped with luminaire shall consistently meet the above requirement, as verified by data provided by the lamp vendor to the luminaire partner.	**Methods of Measurement:** IES LM-9-09 (circline) IES LM-66-14 (compact non-self-ballasted) **Calculation:** CIE 15.2004 **Reference Document:** ANSI C78.376-2014	Laboratory test results shall be produced using the specific lamp model that will operate in the luminaire and either the ballast model that will operate in the luminaire or a commercially-available ballast model that meets the applicable ANSI ballast requirements, if applicable, for the light source being tested. **Sample Size**: 1 sample of each lamp model shall be tested. **Passing Test**: The lamp tested shall fall within a 7-step MacAdam ellipse for the designated CCT, with ellipses constructed using the Objective Chromaticities detailed in Table 1 of ANSI C78.376-2014, and the referenced MacAdam publication.
Solid State	The luminaire, retrofit kit, or replaceable LED light engine shall be capable of providing at least one of the following nominal correlated color temperatures (CCTs): • 2700 Kelvin • 3000 Kelvin • 3500 Kelvin • 4000 Kelvin • 5000 Kelvin The luminaire, retrofit kit, or replaceable LED light engine or module chromaticity shall also fall within the corresponding 7-step chromaticity quadrangles as defined in ANSI C78.377-2015 or C78.377-2017.	**Methods of Measurement:** IES LM-79-08 IES LM-82-12 **Calculation:** CIE 15.2004 **Reference Document:** ANSI C78.377-2015 or C78.377-2017	For downlights, one trim ring and one reflector may be used. Non-directional: LED light engine or module ("source") CCT shall meet the requirement as determined by comparing the in situ (installed in the luminaire) T_b value to the LM-82 test report. In situ temperature measurement value shall be determined in accordance with ANSI/UL 153:2002 (Sections 124-128A), ANSI/UL 1574:2004 (Section 54), or ANSI/UL 1598:2008 (Sections 19.7, 19.10-16), as applicable. LM-82 test reports shall detail luminous efficacy, luminous flux, chromaticity coordinates, CCT and CRI values for all tested temperatures. Linear interpolation shall be employed to determine source photometric performance at temperatures between the LM-82 reported temperatures higher and lower than the in situ temperature. Luminaires incorporating more than one source shall have all sources installed and operational during in situ temperature testing. **Sample Size**: 1 complete luminaire (directional), or 1 source and 1 luminaire (non-directional). **Passing Test**: The luminaire, retrofit kit, or source (when installed in the luminaire) shall pass.

9.4 Color Rendering Index: All Indoor Luminaires (Exempt: Outdoor Luminaires and Luminaires shipped with ENERGY STAR certified Lamps)

Source Type	ENERGY STAR Requirements	Methods of Measurement and/or Reference Documents	Supplemental Testing Guidance
Fluorescent • **compact** • **circline**	Lamps shipped with luminaires shall meet or exceed $R_a \geq 80$ and report R_9.	**Methods of Measurement:** IES LM-9-09 (circline) IES LM-66-14 (compact) CIE 13.3-1995	Laboratory test results shall be produced using the specific lamp model that will operate in the luminaire and either the ballast model that will operate in the luminaire or a commercially-available ballast model that meets the applicable ANSI ballast requirements, if applicable, for the light source being tested. **Sample Size**: 1 sample of each lamp model shall be tested. **Passing Test**: The sample shall achieve the required color rendering index value.
Solid State	The luminaire, retrofit kit, or LED light engine shall be capable of meeting or exceeding $R_a \geq 80$ and $R_9 > 0$.	**Methods of Measurement:** IES LM-79-08 (directional) IES LM-82-12 **Reference Documents:** In situ temperature measurements (non-directional): ANSI/UL 153:2002 (Sections 124-128A) ANSI/UL 1574:2004 (Section 54) ANSI/UL 1598:2008 (Sections 19.7, 19.10-16) CIE 13.3-1995	For downlights, one trim ring and one reflector may be used. Non-directional: LED light engine ("source") CRI shall meet the requirement as determined by comparing the in situ (installed in the luminaire) T_b value to the LM-82 test report. In situ temperature measurement value shall be determined in accordance with ANSI/UL 153:2002 (Sections 124-128A), ANSI/UL 1574:2004 (Section 54), or ANSI/UL 1598:2008 (Sections 19.7, 19.10-16), as applicable. LM-82 test reports shall detail luminous efficacy, luminous flux, chromaticity coordinates, CCT and CRI values for all tested temperatures. Linear interpolation shall be employed to determine source photometric performance at temperatures between the LM-82 reported temperatures higher and lower than the in situ temperature. Luminaires incorporating more than one source shall have all sources installed and operational during in situ temperature testing. **Sample Size**: 1 complete luminaire, retrofit kit, or 1 source and 1 luminaire (non-directional). **Passing Test**: The luminaire, retrofit kit, or source (when installed in the luminaire) shall pass.

9.5 Color Angular Uniformity: Directional Solid State Indoor Luminaires Only (Exempt: Outdoor Luminaires and Luminaires shipped with ENERGY STAR certified Lamps)

ENERGY STAR Requirements	Methods of Measurement and/or Reference Documents	Supplemental Testing Guidance
Throughout the beam angle, the variation of chromaticity shall be within a total linear distance of 0.006 from the weighted average point on the CIE 1976 (u',v') diagram.	**Methods of Measurement:** IES LM-79-08 IES LM-58-13 CIE 15: 2004	Vertical angular scanning resolution shall be 1 degree on the 0 and 90 degree vertical planes, and Δ u',v' distance shall be reported for each vertical angle measured. Only the measurements within the beam angle are evaluated for color angular uniformity. Downlights that utilize interchangeable trims may be tested without a trim to demonstrate compliance with the color angular uniformity requirement. This applies to the color angular uniformity requirement only and does not extend to other photometric requirements. **Sample Size**: 1 complete luminaire. **Passing Test**: The luminaire shall pass.

10 LUMEN MAINTENANCE AND RATED LIFE REQUIREMENTS

10.1 Lumen Maintenance: All Luminaires (Exempt: Luminaires shipped with ENERGY STAR certified Lamps)

Source Type	ENERGY STAR Requirements	Methods of Measurement and/or Reference Documents	Supplemental Testing Guidance
Fluorescent • **compact** • **circline**	For lamps indicated on the luminaire packaging or shipped with the luminaire, the lamp shall have an average rated lumen maintenance of at least 80% of initial lamp lumens at 40% rated lamp life.	**Methods of Measurement:** IES LM-40-10 IES LM-09-09 (Circline) IES LM-65-14 IES LM-66-14 (Compact)	Laboratory test results shall be produced using the specific lamp model that will operate in the luminaire and either the ballast model that will operate in the luminaire or a commercially-available ballast model that meets the applicable ANSI ballast requirements, if applicable, for the light source being tested. **Sample Size**: ≥ 3 samples of each lamp model shall be tested. **Passing Test**: ≥ 100% of the samples shall achieve the required lumen maintenance value.
Solid State **Option 1:** **Luminaire, Retrofit kit, LED Light Engine** **LED Package, Module or Array**	The LED package(s) /module(s)/array(s), including those incorporated into luminaires, retrofit kits and LED light engines, shall meet the following L_{70} rated lumen maintenance life values, in situ: • L_{70}(6k) ≥ 25,000 hours for indoor • L_{70}(6k) ≥ 35,000 hours for outdoor • L_{70} ≥ 50,000 hours for inseparable luminaires	**Method of Measurement:** **Option 1:** Lumen Maintenance: IES LM-80-08 and its Addendum A or ANSI/IES LM-80-15 Lumen Maintenance Projection Method: IES TM-21-11 and its Addendum B CCT Calculation: CIE 15.2004 ANSI/UL 153:2002 (Sections 124-128A) ANSI/UL 1574:2004 (Section 54) ANSI/UL 1598:2008 (Sections 19.7, 19.10-16) **Reference Documents:** Chromaticity Specifications: ANSI/NEMA/ANSLG C78.377-2011 Lumen Maintenance: ENERGY STAR TM-21 Calculator	**Luminaire Sample Size**: 1 complete luminaire, retrofit kit or LED light engine. **LM-80 Sample Size:** Minimum sample size of 20 units for LED packages, or 10 units for LED arrays or LED modules, for each T_S and drive current combination (refer to IES TM-21-11, section 4.2). Each sample set may be composed entirely of one nominal CCT, or may be split between no more than two adjacent nominal CCT values as outlined in ANSI C78.377 (e.g. 2700K and 3000K, or 3000K and 3500K). **Passing Test**: All of the conditions below shall be met. If any of the conditions are not met, the component performance option may not be used and the applicant shall use Option 2, below, for compliance. 1. In the sample luminaire, the in situ TMP_{LED} temperature is less than or equal to the temperature specified in the LM-80 test report for the corresponding or higher drive current, within the manufacturer's specified operating current range. 2. The drive current measured in the luminaire is less than or equal to the drive current specified in the LM-80 test report at the corresponding temperature or higher. 3. The TM-21 lumen maintenance life projection report projects an L_{70} meeting or exceeding requirements. Lumen maintenance projections must support all LED colors used. Compliance with the above shall be documented with a TM-21 lumen maintenance life projection report as detailed in TM-21, section 7. The report shall be generated using data from the LM-80 test report for the employed LED package/module/array model ("device"), the forward drive current applied to each device, and the in situ TMP_{LED} temperature of the hottest device in the luminaire. In addition to LM-80 reporting requirements, the following information shall be reported: • sampling method and sample size (per LM-80) • test results for each T_S and drive current combination • description of device including model number and whether device is an LED package, module or array (see Definitions) • ANSI target, and calculated CCT value(s) for each device in sample set • Δ u'v' chromaticity shift value on the CIE 1976 diagram for each device in sample set • a detailed rationale, with supporting data, for application of results to other devices (e.g. LED packages with other CCTs) Access to the TMP_{LED} for the hottest LED may be accomplished via a minimally sized hole in the luminaire housing, tightly resealed with a suitable sealant if created for purposes of testing. All thermocouple attachments and intrusions to luminaire housing shall be photographed. Important information regarding LM-80 test reports, their application, and provisions for successor subcomponents are detailed in the ENERGY STAR Requirements for the Use of LM-80 Data.

Source Type	ENERGY STAR Requirements	Methods of Measurement and/or Reference Documents	Supplemental Testing Guidance
Solid State **Option 2:** **Luminaire, Retrofit kit or LED Light Engine**	The LED luminaires, retrofit kits, and LED light engines, shall meet the following L_{70} rated lumen maintenance life values, in situ: • L70 ≥ 25,000 hours for indoor • L70 ≥ 35,000 hours for outdoor • L70 ≥ 50,000 hours for inseparable luminaires	**Option 2:** **Methods of Measurement:** Lumen Maintenance: IES LM-84-14 Lumen Maintenance Projection Method: IES TM-28-14 – Projection Method 1, Direct Extrapolation CCT Calculation: CIE 15.2004 ANSI/UL 153:2002 (Sections 124-128A) ANSI/UL 1574:2004 (Section 54) ANSI/UL 1598:2008 (Sections 19.7, 19.10-16) ANSI/UL 1598C-2014 **Reference Document:** Chromaticity Specifications: ANSI/NEMA/ANSLG C78.377-2011	Directional: luminaire or retrofit kit shall be operated continuously in accordance with ANSI/UL 1598-2008, ANSI/UL 1598C-2014, ANSI/UL 1574-2004, ANSI/UL 153-2002, or 2014 during the testing; any deviations from this shall be reported. Non-directional: LED light engines ("source") or retrofit kit shall be operated continuously in situ (installed in the luminaire), with the luminaire operating in accordance with ANSI/UL 153-2002 or 2014, ANSI/UL 1574-2004, ANSI/UL 1598C-2014 or ANSI/UL 1598-2008 during the testing. Luminaires incorporating more than one source shall have all sources installed and operational during the testing. During initial and final measurements, T_b temperature shall be controlled to match T_b temperature measured when source is operated in situ. Test reports shall detail efficacy, luminous flux, chromaticity coordinates, CCT, and CRI values at all test intervals. Test intervals shall be conducted according to IES TM-28-14 §4.2 with a maximum interval length of 1,000 hours. Lumen maintenance projections must support all LED colors used. **Sample Size**: According to IES TM-28-14 – §5.1.5 Directional: 3 or more complete luminaires or retrofit kits. For downlights, one trim ring and one reflector may be used with the 3 luminaire samples. Non-directional: 3 or more sources or retrofit kits and the necessary number of luminaires required to operate the sources continuously in situ. **Passing Test**: All luminaires or sources shall pass.

10.2 Light Source Life: All Luminaires (Exempt: Luminaires shipped with ENERGY STAR certified Lamps)

Source Type	ENERGY STAR Requirements	Methods of Measurement and/or Reference Documents	Supplemental Testing Guidance
Fluorescent • **compact** • **circline**	≥ 10,000 hours for luminaires shipping with other fluorescent lamps Conditional certification may be granted if both of the following are met: 1. Testing has been completed for at least 40% of rated life. 2. A date for testing completion has been established by the test laboratory. Conditional certification shall be immediately withdrawn if final testing results do not meet the above requirement.	**Methods of Measurement:** IES LM-40-10 (circline) IES LM-65-14 (compact)	Laboratory test results shall be produced using the specific lamp model that will operate in the luminaire and either the ballast model that will operate in the luminaire or a commercially-available ballast model that meets the applicable ANSI ballast requirements, if applicable, for the light source being tested. **Sample Size**: ≥ 3 samples of each lamp model shall be tested. **Passing Test**: ≥ 50% of the sample set shall be functioning at the lifetime requirement.
Solid State	The LED package(s) / LED module(s) / LED array(s), including those incorporated into LED light engines or retrofit kits, shall meet the following L_{70} lumen maintenance life values (refer to Lumen Maintenance Requirements in the preceding section): • ≥ 25,000 hours for indoor luminaires • ≥ 35,000 hours for outdoor luminaires • ≥ 50,000 hours for inseparable luminaires Lumen maintenance life projection claims in excess of the above requirements shall be substantiated with a TM-21 or TM-28 lumen maintenance life projection report.		

10.3 Color Maintenance: Solid State Indoor Luminaires Only (Exempt: Outdoor Luminaires and Luminaires shipped with ENERGY STAR certified Lamps)

ENERGY STAR Requirements	Methods of Measurement and/or Reference Documents	Supplemental Testing Guidance
Luminaire change in chromaticity coordinates from 0-hour measurement, at any measurement point during operation, shall be ≤ a total linear distance of 0.007 on the CIE 1976 u'v' diagram. All units must meet this requirement. The change of chromaticity at each measurement point over the tested hours of operation shall be ≤ 0.007 on the CIE 1976 (u',v') diagram, as demonstrated by either: • the IES LM-80 test report for the employed LED package/array/module model, or a comparison of luminaire chromaticity data in LM-84 reports	**Methods of Measurement:** IES LM-80-08 and its Addendum A or IES LM-80-15 or IES LM-84-14 **Reference Documents:** Interim operation: ANSI/UL 153-2002 or 2014 ANSI/UL 1574-2004 ANSI/UL 1598-2008 ANSI/UL 1598C-2014	Laboratory test results shall be produced using the specific models of lamp or LED package, LED module or LED array and LED driver that will be used in production. For the LM-84 option, luminaire or retrofit kit shall be operated continuously in accordance with ANSI/UL 1598-2008, ANSI/UL 1598C, ANSI/UL 1574-2004, or ANSI/UL 153-2002 or 2014 during the testing period; any deviations from this shall be reported. See section 10.1 for testing intervals when using IES LM-84-14. **Sample Size (LM-80 option)**: same as Lumen Maintenance, Option 1. **Sample Size (LM-84 option)**: same as Lumen Maintenance, Option 2. **Passing Test (LM-80 option)**: for all LM-80 samples, at any measurement point, the distance of the chromaticity coordinates from the initial (zero-hour) chromaticity coordinates shall not exceed 0.007 at the temperature(s) adjacent to the measured in situ TMP_{LED} temperature, and at the corresponding drive current. *Example 1: an LM-80 test report provides data at T_S = 55 °C, 85 °C and 105 °C, and the measured in situ TMP_{LED} temperature value is 89 °C. Neither the 85 °C nor the 105 °C LM-80 data may show chromaticity shift exceeding 0.007 at any measurement point from zero through 6,000 hours, for the corresponding drive current. The LM-80 chromaticity data at 55 °C is disregarded.* *Example 2: an LM-80 test report provides data at T_S = 58 °C, 87 °C and 106 °C, and the measured in situ TMP_{LED} temperature value is 53 °C. The LM-80 data at 58 °C may not show chromaticity shift exceeding 0.007 at any measurement point from zero through 6,000 hours, for the corresponding drive current. The LM-80 chromaticity data at 87 °C and 106 °C is disregarded.* **Passing Test (LM-84 option)**: the distance of the chromaticity coordinates from the initial chromaticity coordinates shall not exceed 0.007 at any measurement point.

11 ELECTRICAL PERFORMANCE REQUIREMENTS

11.1 Source Start Time: All Luminaires (Exempt: Outdoor Luminaires and Luminaires shipped with ENERGY STAR certified Lamps)

Source Type	ENERGY STAR Requirements	Methods of Measurement and/or Reference Documents	Supplemental Testing Guidance
Fluorescent **Solid State**	Light source shall remain continuously illuminated within 750 milliseconds of application of electrical power.	**Method of Measurement:** ENERGY STAR Start Time Test Method **Reference Document:** ANSI C82.11-2011 or 2017 Section-5.2	Laboratory test results shall be produced using the specific models of lamp and ballast or LED package, LED module or LED array and LED driver that will be used in production. **Sample Size**: 1 sample of each lamp-ballast model combination, or LED package/LED module/LED array and LED driver model combination shall be tested. **Passing Test**: Sample shall pass.
Connected Luminaires All sources	Light source shall remain continuously illuminated within 1 second of application of electrical power.		

11.2 Source Run-Up Time: All Fluorescent Luminaires (Exempt: Solid State, Outdoor Luminaires, and Luminaires shipped with ENERGY STAR certified Lamps)

ENERGY STAR Requirements	Methods of Measurement and/or Reference Documents	Supplemental Testing Guidance
Reported value of time for lamps to reach 80% of stabilized lumen output after application of electrical power shall be ≤ 45 seconds	**Method of Measurement:** ENERGY STAR Run Up Time Test Method	Laboratory test results shall be produced using the specific models of lamp and ballast that will be used in production. Measurements shall be taken at the end of 100 hours of seasoning. The reported value shall be the average measured values of units tested, rounded to the nearest second. **Sample Size**: 1 sample of each lamp-ballast model combination. **Passing Test**: Sample shall pass.

11.3 Power Factor: All Luminaires (Exempt: Luminaires shipped with ENERGY STAR Lamps)

Source Type	ENERGY STAR Requirements	Methods of Measurement and/or Reference Documents	Supplemental Testing Guidance
Fluorescent • **compact** • **circline**	Total luminaire input power ≤ 5 watts: PF ≥ 0.5 Total luminaire input power > 5 watts: PF ≥ 0.5	**Method of Measurement:** C82.77-10:2014	Laboratory test results shall be produced using the specific models of lamp and ballast or LED package, LED module or LED array and LED driver that will be used in production. **Sample Size**: ≥ 1 samples of each model combination shall be tested. **Passing Test**: all samples shall pass.
Solid State	Total luminaire input power ≤ 5 watts: PF ≥ 0.5 Total luminaire input power > 5 watts: PF ≥ 0.7		

11.4 Transient Protection: All Luminaires (Exempt: Luminaires shipped with ENERGY STAR certified Lamps)

ENERGY STAR Requirements	Methods of Measurement and/or Reference Documents	Supplemental Testing Guidance
Ballast or driver shall comply with ANSI/IEEE C62.41.1-2002 and ANSI/IEEE C62.41.2-2002, Category A operation. The line transient shall consist of seven strikes of a 100 kHz ring wave, 2.5 kV level, for both common mode and differential mode.	**Method of Measurement:** None referenced **Reference Documents:** ANSI/IEEE C62.41.1-2002 ANSI/IEEE C62.41.2-2002 Category A Location.	Laboratory test results shall be produced using the specific models of ballast, LED package, LED module or LED array and LED driver combination that will be used in production. **Sample Size**: ≥ 1 samples of each ballast model, LED package, LED module or LED array and LED driver model combination, or LED light engine shall be tested. **Passing Test**: All samples shall pass. Unit power may be cycled as necessary to determine if UUT is still operational.

11.5 Standby Power Consumption: All Luminaires (Exempt: Luminaires shipped with ENERGY STAR certified Lamps)

ENERGY STAR Requirements	Methods of Measurement and/or Reference Documents	Supplemental Testing Guidance
Luminaires shall not draw power in the off state. Exceptions: • Luminaires with integral motion sensors, occupancy sensors or photosensors, or connected functionality may draw up to 0.5 watts in standby mode. • Luminaires with energy saving features i.e. integral motion sensors, occupancy sensors or photosensors and connected functionality may draw up to 1 watt in standby mode. • Power supplies connected to multiple luminaires may draw up to 1.5 watts in standby mode. • External power supplies (EPS) employed to power luminaires shall meet the level V or higher performance requirements under the International Efficiency Marking Protocol and include the level V or higher marking on the EPS.	**Method of Measurement:** IEC 62301 ED.2.0 B-2011 **Reference document:** International Efficiency Marking Protocol http://www.regulations.gov/#!documentDetail;D=EERE-2008-BT-STD-0005-0218	Laboratory test results shall detail standby power consumption to the tenth of a watt.

11.6 Operating Frequency: All Luminaires

Source Type	ENERGY STAR Requirements	Methods of Measurement and/or Reference Documents	Supplemental Testing Guidance
Fluorescent • **compact** • **circline**	20 to 33 kHz or ≥ 40 kHz	**Method of Measurement:** ANSI C82.2-2002	Laboratory test results shall be produced using the specific ballast model that will operate in the luminaire. **Sample Size**: 1 samples of each ballast model shall be tested. **Passing Test**: Sample shall pass.
Solid State	Frequency ≥ 120 Hz Note: This performance characteristic addresses problems with visible flicker due to low frequency operation and applies to steady-state as well as dimmed operation. Dimming operation shall meet the requirement at all light output levels.	**Method of Measurement:** None referenced **Reference Document:** IEEE PAR1789	Laboratory test results shall be produced using the specific luminaire, or LED light engine used in the luminaire. Light output waveform shall be measured with a photodetector with a rise time of 10 microseconds or less, transimpedance amplifier and oscilloscope. Employed equipment models and method of measurement shall be documented. Temporal response, amplification and filtering characteristics of the system shall be suitably designed to capture the photometric waveform. Digitized photometric waveform data and an image of the relative photometric amplitude waveform shall be recorded. Measured data shall be recorded to a digital file with an interval between each measurement no greater than 0.00005 sec (50 microseconds) corresponding to an equipment measurement rate of no less than 20 kHz, and capture at least 1 second of data. **Sample Size**: 1 luminaire, LED light engine, or retrofit kit shall be tested.

11.7 Flicker: All Luminaires (Exempt: Luminaires shipped with ENERGY STAR certified Lamps)

<table>
<tr><th>ENERGY STAR Requirements</th><th>Methods of Measurement and/or Reference Documents</th><th>Supplemental Testing Guidance</th></tr>
<tr>
<td>The following flicker-related metrics shall be reported for certifications as of September 1, 2018:
• Short Term Flicker Indicator (P_{st})
• Stroboscopic Visibility Measure (SVM)

Optional: meet NEMA 77-2017 for temporal light modulation limits.

These requirements address problems with visible flicker due to low frequency operation and applies to steady-state as well as dimmed operation.</td>
<td>Method of Measurement:
NEMA 77-2017

Reference Document:
IEEE PAR1789</td>
<td>Sample Size: 1 luminaire, LED light engine, or retrofit kit shall be tested.

Laboratory test results shall be produced using the specific luminaire, or LED light engine used in the luminaire.

For luminaires not marketed as dimmable, measurements shall be taken at full light output.

For luminaires marketed as dimmable, measurements shall be taken at the dimmed levels recommended in NEMA 77.

The reported values of P_{st} and SVM shall be the highest value measured.

For the purposes of ENERGY STAR, the waveform digitizer (e.g., oscilloscope) used to capture the waveform data used for the calculation of the reported metrics must have:
<table>
<tr><th colspan="2">Parameter</th><th>Units</th><th>Value</th></tr>
<tr><td rowspan="2">Dynamic range of waveform amplitude</td><td>P_{st}</td><td></td><td>≥ 1000:1 (60 dB)</td></tr>
<tr><td>SVM</td><td></td><td>≥ 100:1 (40 dB)</td></tr>
<tr><td rowspan="2">Sampling Time</td><td>P_{st}</td><td>Seconds</td><td>≥ 180</td></tr>
<tr><td>SVM</td><td>Seconds</td><td>≥ 1</td></tr>
<tr><td rowspan="2">Sampling Rate</td><td>P_{st}</td><td>kHz</td><td>≥ 10</td></tr>
<tr><td>SVM</td><td>kHz</td><td>≥ 20</td></tr>
<tr><td rowspan="2">Temporal bandwidth (-3 dB cutoff frequency)</td><td>P_{st}</td><td>kHz</td><td>≥ 0.5</td></tr>
<tr><td>SVM</td><td>kHz</td><td>≥ 5</td></tr>
</table>
Waveform data shall be submitted in CSV format to support the reported values of P_{st} and SVM</td>
</tr>
</table>

12 LUMINAIRE SERVICEABILITY REQUIREMENTS

12.1 Light Source Replaceability: All Luminaires (Exempt: Inseparable and Directional Luminaires, Retrofit Kits, and Luminaires shipped with ENERGY STAR certified Lamps)

Source Type	ENERGY STAR Requirements	Methods of Measurement and/or Reference Documents
Fluorescent • **compact** • **circline**	The luminaire's lampholder(s) shall be designed to accept lamps with ANSI/IEC standardized lamp base configurations for each lamp input power for which the luminaire and packaging is labeled.	**Reference Document:** Lampholder configuration: ANSI/IEC C81.62-2009 (R2014) or 2017
Solid State: Non-Directional • **LED light engine** • **Retrofit kits**	LED light engines or retrofit kits shall make use of electrical interconnects that allow for consumer replacement of the engine or kit without the cutting of wires or the use of solder. Wire nuts and other reusable connectors are allowed. Luminaires that cannot meet this requirement are to be evaluated as inseparable SSL luminaires (see directional luminaire requirements below and throughout this specification).	**Reference Document:** NEMA LSD 45-2009

12.2 Ballast/Driver Replaceability: All Luminaires (Exemption: Inseparable SSL Luminaires and Luminaires shipped with ENERGY STAR certified Lamps)

Source Type	ENERGY STAR Requirements
Fluorescent • **compact** • **circline**	Ballasts or drivers shall be accessible and removable by an electrician without the cutting of wires and without damage to the luminaire housing, trim, decorative elements or the carpentry (e.g., ceiling drywall) to which the luminaire is attached. Instructions shall be provided with the luminaire, detailing guidance on ballast or driver replacement by a "qualified electrician". Exceptions: 1. Luminaires employing self-ballasted lamps 2. Line voltage directional track lights 3. Solid state cove mount luminaires 4. Under cabinet luminaires 5. Retrofit kits
Solid State: Directional	
Solid State: Non-Directional	See Source Replaceability Requirements.

13 THERMAL PERFORMANCE REQUIREMENTS

13.1 Maximum Measured Ballast or Driver Case Temperature: All Luminaires

This performance characteristic is separate and distinct from safety requirements and can be measured by an EPA recognized laboratory. Partners may update product certifications on an ongoing basis to document modifications, including changes in maximum recommended ballast or driver case temperature. Revisions to the maximum recommended ballast or driver case temperature value may not, however, be made after product verification testing has begun, until the product has been confirmed to pass.

Source Type	ENERGY STAR Requirements	Methods of Measurement and/or Reference Documents	Supplemental Testing Guidance
Fluorescent • **compact** • **circline**	Ballast case temperature measured at thermal equilibrium, at the hot spot location provided by the ballast manufacturer, shall not exceed the maximum recommended ballast case temperature, as provided by ballast manufacturer, during *in situ* (installed in the luminaire) operation. Exceptions: • Indoor portable luminaires using lamps, where the lamp is centered between a shade that is open on the top and bottom.	**Reference Documents:** ANSI/UL 153:2002 (Sections 124-128A) ANSI/UL 1574:2004 (Section 54) ANSI/UL 1598:2008 (Sections 19.7, 19.10-16).	Laboratory test results shall be produced using the specific lamp and ballast models that will be used in production. Laboratory test results shall be produced using the luminaire with the highest operating temperature among all luminaires in a product family being certified (as applicable). **Sample Size**: 1 luminaire shall be tested. **Passing Test**: Measured temperature at the hot spot location provided by the ballast manufacturer shall be less than or equal to the manufacturer recommended maximum.
Solid State: Directional Non-Directional • **replaceable LED light engine or ENERGY STAR certified lamp**	At the temperature measurement point for the hottest location on the driver case (TMP_C as detailed by the driver manufacturer), the measured driver case temperature at thermal equilibrium shall not exceed the driver manufacturer's maximum recommended temperature during in situ (installed in the luminaire) operation.	**Reference Documents:** ANSI/UL 153:2002 (Sections 124-128A) ANSI/UL 1574:2004 (Section 54) ANSI/UL 1598:2008 (Sections 19.7, 19.10-16)	Laboratory test results shall be produced using the specific models of LED package, LED module or LED array and LED driver that will be used in production. Laboratory test results shall be produced using the luminaire with the highest operating temperature among all luminaires in a product family being certified (as applicable). **Sample Size**: 1 luminaire shall be tested, or 1 source sample shall be tested in situ (installed in the luminaire). **Passing Test**: Measured temperature at the TMP_C shall be less than or equal to the manufacturer recommended maximum.
Solid State: • **retrofit kits (surface mounted and recessed)**	At the temperature measurement point for the hottest location on the driver case (TMP_C as detailed by the driver manufacturer), the measured driver case temperature at thermal equilibrium shall not exceed the driver manufacturer's maximum recommended temperature during in situ (installed in the luminaire) operation.	**Reference Document:** ANSI/UL 1598C	Laboratory test results shall be produced using the specific models of LED package, LED module or LED array and LED driver (i.e. LED light engine) ("source") that will be used in production. Luminaire retrofit kit shall be tested in the worst case thermal condition for which it is rated per ANSI/UL1598C-2014. Recessed downlight retrofit kits shall be tested in the worst-case thermal environment that the product is rated for per ANSI/UL1598C-2014. **Sample Size**: 1 sample shall be tested in situ per the included manufacturer provided installation instructions in a representative luminaire per UL1598C-2014. **Passing Test**: Measured temperature at the TMP_c shall be less than or equal to the manufacturer recommended maximum.

13.2 Recessed Downlight Thermal Performance

Source Type	ENERGY STAR Requirements	Methods of Measurement and/or Reference Documents	Supplemental Testing Guidance
All Source Types	**Insulation contact (Type IC):** Recessed downlights marketed as Type IC shall be approved for zero clearance insulation cover by an OSHA NRTL laboratory. **Airtight construction:** Recessed downlight housings or certified/listed accessories marketed as airtight shall exhibit leakage less than 2.0 cubic feet per minute (CFM) at 75 Pascals (or 1.57 lbs/ft^2) when tested in accordance with ASTM E283-04(2012), and shall be sealed with a gasket or caulk.	**Reference Documents:** ANSI/UL 1598-2008 ASTM E283-04(2012)	See packaging section for packaging requirements related to IC and airtight products.

14 SAFETY REQUIREMENTS

14.1 Luminaire Safety: All Luminaires

Luminaire Type	Source Type	ENERGY STAR Requirements	Methods of Measurement and/or Reference Documents	Supplemental Testing Guidance
Portable Luminaires	**Fluorescent** • **compact** • **circline**	Demonstrate compliance with ANSI/UL 153-2002 or 2014.	**Reference Documents:** ANSI/UL 153-2002 or 2014	Documentation shall be produced by an OSHA NRTL laboratory. Connected products must continue to comply with the applicable product safety standards – the addition of the functionality shall not override existing safety protections and functions.
	Solid State	Demonstrate compliance with ANSI/UL 153-2002 or 2014 and ANSI/UL 8750-2009 or 2015.	**Reference Documents:** ANSI/UL 153-2002 or 2014 and ANSI/UL 8750-2009 or 2015	
Indoor & Outdoor Hardwired Luminaires	**Fluorescent** • **compact** • **circline**	Demonstrate compliance with ANSI/UL 1574-2004, ANSI/UL 1598-2008, ANSI/UL 2108-2004 or 2015, as applicable.	**Reference Documents:** ANSI/UL 1574-2004 ANSI/UL 1598-2008 ANSI/UL 2108-2004 or 2015	
	Solid State	Demonstrate compliance with ANSI/UL 1574-2004, ANSI/UL 1598-2008, ANSI/UL 1598C-2014, ANSI/UL 2108-2004 or 2015, ANSI/UL 8750-2009 or 2015, as applicable.	**Reference Documents:** ANSI/UL 1574-2004 ANSI/UL 1598-2008 ANSI/UL 1598C-2014 ANSI/UL 2108-2004 or 2015 ANSI/UL 8750-2009 or 2015	
Retrofit Kits	**Solid State**	Demonstrate compliance with ANSI/UL 8750-2009 or 2015 – LED Component ANSI/UL 1598C-2014 – LED Retrofit	**Reference Documents:** ANSI/UL 8750-2009 or 2015 – LED Component ANSI/UL 1598C-2014 – LED Retrofit	

14.2 Electronic Ballast or Driver Safety: Ballasts, Drivers and "Non-Edison Base Fluorescent Adapters"

Source Type	ENERGY STAR Requirements	Methods of Measurement and/or Reference Documents	Supplemental Testing Guidance
Fluorescent • **compact** • **circline**	Demonstrate compliance with ANSI/UL 935-2009, ANSI/UL 1310-2010, ANSI/UL 1993-2012 or 2017, as applicable. Demonstrate compliance with CSA 22.2 Number 74, or IEC 61374-2-3-am2 ed1.0 b.2006, as appropriate.	**Reference Documents:** ANSI/UL 935-2009 ANSI/UL 1310-2010 ANSI/UL 1993-2012 or 2017	Documentation shall be produced by an OSHA NRTL laboratory. Connected products must continue to comply with the applicable product safety standards – the addition of the functionality shall not override existing safety protections and functions.
Solid State: Non-Directional • **replaceable LED light engine**	Demonstrate compliance with ANSI/UL 1310-2010, ANSI/UL 2108-2004 or 2015, or ANSI/UL 8750-2009 or 2015, as applicable.	**Reference Documents:** ANSI/UL 1310-2010 ANSI/UL 2108-2004 or 2015 ANSI/UL 8750-2009 or 2015	
Solid State: Directional	Demonstrate compliance with ANSI/UL 1310-2010, ANSI/UL 2108-2004 or 2015, or ANSI/UL 8750-2009 or 2015, as applicable.	**Reference Documents:** ANSI/UL 1310-2010 ANSI/UL 2108-2004 or 2015 ANSI/UL 8750-2009 or 2015	

15 CONTROL REQUIREMENTS: Luminaires Employing any Control Mechanism

15.1 Dimming: All Luminaires Marketed as Dimmable (Exempt: Luminaires shipped with ENERGY STAR certified Lamps)

Source Type	ENERGY STAR Requirements	Methods of Measurement and/or Reference Documents	Supplemental Testing Guidance
Fluorescent • **compact** • **circline**	The luminaire and its components shall provide continuous dimming from 100% to 20% of light output. At minimum light output, the luminaire shall not emit noise above 24 dBA when measured within one meter of the luminaire.	**Method of Measurement:** None Referenced **Reference Document:** NEMA SSL 7A-2013 or 2015	Laboratory test results shall be produced using the specific lamp and ballast models that will be used in production. **Sample Size**: 1 sample of the luminaire shall be tested. **Passing Test**: the sample shall pass.
Solid State	The luminaire and its components shall provide continuous dimming from 100% to 20% of light output. At minimum light output, the luminaire shall not emit noise above 24 dBA when measured within one meter of the luminaire.		Laboratory test results shall be produced using the models of LED package, LED module or LED array and LED driver combination that will be used in production. The test should be performed at the lowest dimming level recommended by partner. **Sample Size**: 1 sample of the complete luminaire, retrofit kit, or LED light engine shall be tested. **Passing Test**: the sample shall pass.

15.2 Products with Connected Functionality – Optional (Exempt: Luminaires shipped with ENERGY STAR certified Lamps)

Source Type	ENERGY STAR Requirements	Methods of Measurement and/or Reference Documents	Supplemental Testing Guidance
All source types	Product must continue to comply with the applicable product safety standards – the addition of the functionality shall not override existing safety protections and functions. Must comply with section 11.5 Standby Power	**Method of Measurement:** None	Connected products without color tuning capabilities shall be tested at full power for all applicable requirements. Connected products with color tuning capabilities shall be tested under the conditions specified under Section 5.1. Compliance with connected functionality requirements shall be demonstrated through examination of product and/or product documentation.

15.2.1 Connected Product Criteria:

To be recognized as connected, a “connected luminaire” (or retrofit) shall include the base luminaire or retrofit kit plus elements (hardware and software or firmware) or instructions required to enable communication in response to consumer-authorized energy or performance related commands (e.g. instructions for downloading a mobile application, Bluetooth syncing guidance) and shall meet the requirements in sections 15.2.2-15.2.6. These elements may be resident inside or outside of the base luminaire. Connected luminaires typically communicate with controls via a radio frequency system, although some versions use other methods (such as DMX or DALI). The specific design and implementation of the connected luminaire is at the partner’s discretion provided it is interoperable with other devices and enables economical, consumer-authorized third party access to the functions provided for in sections 15.2.3, 15.2.4, and 15.2.5.

15.2.2 Open-access

To enable interconnection with the product; an interface specification, Application Programming Interface (API) or similar documentation shall be made available to interested parties that enables section 15.2.3, 15.2.4 and 15.2.5 connected functionality, and includes accuracy, units and measurement intervals for Energy Consumption Reporting.

15.2.3 Energy Consumption Reporting

The product shall be capable of interconnecting with consumer authorized entities to communicate data representative of its interval energy consumption. It is recommended that data be reported in watt-hours for intervals of 15 minutes, however, representative data may also be reported in alternate units and intervals as specified in the partner’s interface specification or API.

15.2.4 Operational Status Reporting

At a minimum, the product shall be capable of providing the on/off status to energy management systems and other consumer authorized devices, services or applications via a communication link.

15.2.5 Remote Management

The product shall be capable of receiving and responding to energy management system or other consumer authorized remote requests, via devices, services or applications, similar to hard-wired consumer controllable functions.

15.2.6 Information to Consumers

If additional devices, services, and/or infrastructure are required to activate the product’s connected capabilities, prominent labels, or other forms of consumer notifications shall be displayed at the point of purchase and in the product literature. (e.g. “This product has Z-wave control capability and requires interconnection with a Z-wave controller to enable local lighting control.”)

16 PRODUCT LABELING & PACKAGING REQUIREMENTS:

16.1 Labeling & Packaging: All Luminaires

Source Type	ENERGY STAR Requirements

All	• Packaging and marketing claims shall represent the product consistent with its certification.
	• Packaging shall clearly describe the nominal color designation of the lamp in units of Kelvin (e.g. 2700K, 3000K) and may display recommended corresponding nomenclature as outlined below. This can also be met through use of a Lighting Facts label (as applicable).
	  ◦ 2700 – Soft White
	  ◦ 3000 – Warm White
	  ◦ 3500 – Neutral White
	  ◦ 4000/4100K – Cool White
	  ◦ 5000K – Daylight
	
	For luminaires shipped with lamps containing mercury:
	• Both the lamp and the luminaire packaging shall have a label indicating mercury content which must be managed and disposed of properly, and shall reference: www.epa.gov/cfl
	
	For outdoor luminaires:
	Packaging shall indicate the minimum (lowest) starting temperature for the lamp and ballast platform of the luminaire.
	
	For luminaires marketed as dimmable:
	• Luminaire packaging shall indicate dimming range (as applicable), a list or web site address with compatible dimmers or other controls, and known incompatibilities with dimmers, occupancy or vacancy sensors, timing devices or other external lighting controls, or a message noting limitations and web site address to find out more specific information. Partner shall periodically review this packaging language to determine if updates are needed. Partner is encouraged to also maintain an up to date web address where additional compatibility information is detailed.
	• Step dimming capability, if employed, shall be clearly indicated.
	
	Optional certification marking:
	While not a requirement for certification, EPA recommends partners provide a conspicuous ENERGY STAR certification mark (e.g. sticker, hangtag) on certified luminaires themselves:
	• to facilitate building inspectors confirming certification status of installed luminaires
	• to provide out-of-the-box marketing of a luminaire's ENERGY STAR certification
	• to demonstrate to consumers a partner's commitment to advancing energy efficiency in lighting

All directional luminaires	Demonstrate the light distribution of the luminaire on a cut sheet, marketing materials or packaging.
Recessed downlight fixtures	**For recessed downlight luminaires that are insulation-contact (Type IC) rated:** Packaging shall clearly state this rating. Sample language: "IC-rated for direct contact with insulation". **For recessed downlight luminaires that are airtight (AT) certified:** Packaging shall indicate that the luminaire permits air leakage less than 2.0 CFM at 75 Pascals when tested in accordance with ASTM E283-04(2012). Sample language: "Certified airtight per ASTM E283-04." If marketed as airtight, the luminaire itself shall include a label certifying "airtight", or similar designation, to show air leakage less than 2.0 CFM at 75 Pascals when tested in accordance with ASTM E283-04(2012). The label shall be clearly visible to a building inspector. Installation instructions shall be included listing all components of the assembly that will be necessary to ensure an airtight installation and how the components should be properly installed. For example, depending on the method used to achieve airtight installation, the instructions should alternatively show how a gasket is to be attached, what type of caulk to use and how it should be applied, or which certified airtight trim kits are designed to be installed with the luminaire housing. Partners selling recessed downlights are strongly encouraged to employ a packaging method ensuring that shipped lamps remain with the luminaire during drywall installation and painting (e.g. taping the lamp carton to the inside of the canister, employing shrink wrapping of the canister aperture to enclose the lamp carton within, employing a compression-fitted cardboard insert to enclose the lamp carton within the canister).

16.2 Light Source Shipment: Directional and Non-Directional Luminaires

Source Type	ENERGY STAR Requirements	Methods of Measurement and/or Reference Documents
Fluorescent • **compact** • **circline**	All luminaires shall be shipped with a lamp for each lampholder. All lamps that ship with a luminaire must be included in the certification documentation. Lamps shall utilize an ANSI/IEC standardized lamp base configuration. In addition, lamp dimensions and electrical parameters shall either: 1. Meet the requirements of an ANSI/IEC standardized lamp specification sheet if an applicable standard exists; or, 2. If no ANSI/IEC lamp standard exists, provide* a lamp manufacturer specification sheet that describes the following: a. Lamp description, including: i. Lamp model number, ii. Nominal wattage, iii. Bulb designation / lamp size (e.g. T4), and iv. Lamp base type as defined by ANSI/ANSLG C81.61-2009 (R2014) or C81.61-2017; or IEC 60061-1(e.g. 2G13, GR10q), starting circuit application (i.e., rapid start, preheat, etc.). b. Dimensional characteristics, including diagram. c. Lamp operating characteristics, including: approximate wattage (W), voltage (V), and current (A).	**Reference Documents:** Lamp base configuration: ANSI/ANSLG C81.61-2009 (R2014) or C81.61-2017 Lamps compliant with an ANSI-IEC standard (for lamp dimensions and electrical parameters): For compact fluorescent lamps: ANSI C78.901-2014 or 2016; IEC 60901 Lamps not compliant with an ANSI-IEC standard (for lamp dimensions and electrical parameters): ANSI C78.901-2014 or 2016; (used as a reference for the format and type of information required on a custom lamp specification sheet)
Solid State: Non-Directional • **LED light engine**	Complete light source components shall be provided with the luminaire or retrofit kit. Optional: The luminaire certification may indicate compliance with a Zhaga book if the light engine utilized is on the Zhaga Consortium's Certified Products Database.	**Reference Document:** Recommendations outlined in NEMA LSD 45-2009 shall be followed.
Solid State: Directional		**Reference Document:** Zhaga Consortium's Certified Products Database http://www.zhagastandard.org/products/certified/

*Use the ANSI lamp data sheets found in ANSI C78.901-2014 (or C78.901-2016) and ANSI/ANSLG C78.81-2010 (or C78.61-2016) as a reference for the format and type of information requested.

17 WARRANTY REQUIREMENTS: All Luminaires

Note: Partners must provide a copy of the actual luminaire warranty that is included with the product packaging. Partner is solely responsible for honoring warranty; intermediate parties (e.g. showrooms, electrical distributors, retailers) are not responsible for warranty requirements.

Source Type	ENERGY STAR Requirements
Fluorescent • **compact** • **self-ballasted compact** • **circline**	For luminaires incorporating replaceable ballasts, a written warranty shall be included with luminaire packaging at the time of shipment which covers repair or replacement of defective parts of the luminaire housing, mounting hardware, optics, ballast and trim for a minimum of 3 years from the date of purchase. Self-ballasted lamps shipped with the luminaire shall carry a minimum 3 year warranty, based on usage of no less than 3 hours per day. For luminaires incorporating non-replaceable ballasts, the above warranty requirement is extended to 5 years.
Solid State	For luminaires incorporating replaceable drivers, a written warranty shall be included with luminaire packaging at the time of shipment which covers repair or replacement of defective parts of the luminaire housing, mounting hardware, optics, driver and trim for a minimum of 3 years from the date of purchase. Retrofit kits and Integrated LED lamps shipped with the luminaire shall carry a minimum 3 year warranty. For luminaires incorporating non-replaceable drivers, the above warranty requirement is extended to 5 years. Warranty language shall place no limitations on coverage based on duration of luminaire operation (e.g. hours per day).

18 Lighting Toxics Reduction Requirements: All Luminaires

Source Type	ENERGY STAR Requirements	Method of Compliance
All Source Types	Luminaires and lamps shall not exceed hazardous substance concentrations set for in the European Union's (EU) Restriction of the Use of Certain Hazardous Substances (RoHS) Directive, 2003. Luminaires and lamps shall not exceed: • 0.1% by weight in homogenous material (1000 ppm): Mercury, Lead, Hexavalent Chromium, PBB (polybrominated biphenyls), and PBDE (polybrominated diphenyl ethers) • 0.01% by weight in homogenous material (100 ppm): Cadmium A list of RoHS exemptions that will be accepted by the ENERGY STAR program that may be relevant to luminaires and lamps is detailed below: <u>Exemptions</u>: 1. Mercury in single capped (compact) fluorescent lamps not exceeding (per burner): a. Lamps ≤ 23.0 rated watts shall contain ≤ 2.5 milligrams (mg) mercury per lamp b. Lamps ≥ 23.0 rated watts shall contain ≤ 3.0 milligrams (mg) mercury per lamp 2. Lead in glass of fluorescent tubes not exceeding 0.2% by weight 3. Lead in high melting temperature type solders (i.e. lead-based alloys containing 85% by weight or more lead) 4. Electrical and electronic components containing lead in a glass or ceramic other than dielectric ceramic in capacitors, e.g. piezoelectronic devices, or in a glass or ceramic matrix compound 5. Cadmium and its compounds in electrical contacts 6. Lead in solders to complete a viable electrical connection between semiconductor die and carrier within integrated circuit flip chip packages 7. Lead with PbBiSn-Hg and PbInSn-Hg in specific compositions as main amalgam and with PbSn-Hg as auxiliary amalgam in very compact energy saving lamps. 8. Cadmium in color-converting II-IV LEDs (< 10 µg Cd per mm^2 of light-emitting area) for use in solid state illumination or display systems.	For purposes of third-party certification, lamp toxics documentation shall not be reviewed when products are initially certified or during verification testing. Instead partner shall maintain documentation on file to demonstrate that certified products meet these requirements. EPA reserves the right to request this documentation at any time. For the purposes of documenting mercury content, the following test procedure shall be used: IEC 62554 Ed 1.0 Sample Preparation for Measurement of Mercury Level in Fluorescent Lamps (2011-08-19). For materials other than mercury, partner may rely on component suppliers to provide certification or declaration documents to show that homogenous materials used in lamps comply with the requirement. Alternatively, partner may have components tested in accordance with IEC 62321 or other appropriate analytical technique to verify that homogenous materials do not exceed the concentration limits of the six regulated substances. Handheld XRF analyzers/scanners may also be used to verify compliance.

END OF SPECIFICATION