ASSIST recommends: Striving for Application-specific Evaluation Methods

N. Narendran, Jean Paul Freyssinier, Yutao Zhou, and Jennifer Taylor

Lighting Research Center
Rensselaer Polytechnic Institute, Troy, NY 12180
www.lrc.rpi.edu

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Invited Paper
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Lighting Research Center, Rensselaer Polytechnic Institute, 21 Union St., Troy, NY, 12180, USA

ABSTRACT

The ASSIST recommends program has actively promoted application-specific methods for testing and evaluating LED lighting technology to allow for easy comparison with traditional lighting. Recent work has produced alternative methods for evaluating outdoor lighting, including parking lot luminaires and the visual effectiveness of lighting.

INTRODUCTION

The need for LED lighting standards has gained urgency and momentum in the last three years, with 2008 being called “The Year of LED Standards”[1][2], following that year’s publishing of the Illuminating Engineering Society of North America’s LM-79 (electrical/photometric measurements), LM-80 (measuring lumen maintenance), RP-16 (nomenclature/definitions), and ANSI’s C78.377 (chromaticity specifications). Presently, a number of organizations are driving and/or influencing the standards-setting process (e.g., IESNA, NEMA, ANSI, CIE, NIST, UL, etc.), and one of those is the Alliance for Solid-State Illumination Systems and Technologies, better known as “ASSIST.”

Established in 2002, ASSIST conducts research and other activities to advance and promote LED technology. Its sponsors include LED and lighting corporations, government, and energy-efficiency organizations from the United States, United Kingdom, and Asia. ASSIST’s major goal has been to facilitate the broad adoption of reliable, energy-efficient LED technology by original equipment manufacturers and specifiers. Research, education, and industry collaboration have been key activities of the program, which seeks to reduce many of the technical hurdles standing between LEDs and their acceptance. As part of these activities, ASSIST has developed a publication program called *ASSIST recommends* to provide a set of formal recommendations to the LED and lighting communities about issues important for the reliable performance of LED lighting and its comparison to other light source technologies. The publications include recommendations for LED life definition, testing and measurement, best practice guides for different lighting applications, and recommendations for selecting LED lighting. Unlike traditional procedures that require products to be tested under standardized, ideal conditions, *ASSIST recommends* methods call for evaluating products under conditions similar to those found in the application environment, where the light source could experience much different temperatures and may perform poorly as a result. Testing products by intended application also allows for apples-to-apples comparisons of product performance because test methods have been developed from a technology-neutral standpoint. *ASSIST recommends* publications are developed under the guidance of ASSIST sponsors using research conducted by the Lighting Research Center.

COMPONENTS, SYSTEMS & APPLICATIONS

In the past seven years, ASSIST has transitioned its research, activities, and *ASSIST recommends* publications as LED technology has advanced, from the component level to the system level and now to the application level. The first *ASSIST recommends*, “LED Life for General Lighting,”[3] was published in early 2005 and was developed over a two-year period, originating with long-term LED life research that began at the Lighting Research Center in the late 1990s. The publication provided guidance on measuring the useful life and lumen maintenance of LED packages and systems. The recently published IESNA LM-80 has its basis in the ASSIST LED Life publication.

The second and third publications were the first application-based methods recommended by ASSIST. Specifically, these publications provided performance testing methods for under-cabinet lighting[4] and directional/down lighting[5] that could be applied to any light source technology, not just LEDs. The idea promoted was that product comparisons across technologies could be made only if the test methods were technology-neutral. To develop technology-neutral methods, the application environment had to be considered.

The fourth and fifth *ASSIST recommends* dealt with two new and growing indoor applications for white LEDs, decorative lighting[6] and refrigerator/freezer display case lighting.[7] These guides provided methods for estimating performance, again using the application environment as a basis for testing. In the case of decorative lighting, ASSIST provided a method[6] for luminaire manufacturers to quickly estimate the performance of LED light engines and integrated LED lamps for use in a variety of decorative luminaires, such as pendants, chandeliers, wall sconces, table and floor lamps. Full photometric testing of decorative lighting is costly and rarely conducted, but estimation methods are needed because one LED product may not perform the same in each luminaire, given differences in housing, materials, shades, and other luminaire components that make up a decorative luminaire. For refrigerator/freezer display case lighting, ASSIST provided guidance on estimating the cold temperature performance of luminaires designed to light the interiors of display cases holding refrigerated and frozen items.[7] The method is intended for any light source technology, and a scaling factor is applied to estimate the performance at the freezer's operating temperature.

EVALUATING OUTDOOR LIGHTING

In the past year, outdoor lighting has gained new attention as a promising application for LEDs, with manufacturers now producing LED parking lot, roadway, and area luminaires. Given concerns about light pollution, the desire for energy conservation and reduced maintenance costs, and new research on mesopic vision, LEDs are a seemingly ideal source to meet all these demands. In early 2009, ASSIST released two publications related to outdoor lighting: an alternative evaluation method for luminaires used in parking lot applications[8]; and a guide on how to compare the visual effectiveness of different light sources for nighttime applications for optimum energy efficiency.[9]

The objective of both publications was to develop methods that help users analyze the performance of outdoor luminaires and select good-quality products. A good-quality outdoor lighting product will cater to the application's lighting needs (i.e., light level, uniformity, and contrast), will be economical (both first and ongoing costs), and will provide good peripheral vision, low glare, and little or no light trespass or light pollution.

Parking Lot Lighting Evaluation Metric

ASSIST's parking lot luminaire metric, called lighting system application efficacy (LSAE)[8], builds on the concept of *application efficacy*[10], which considers the total lumens reaching a task area. The LSAE metric counts only the lumens that reach a target area and meet the application lighting requirements, divided by the total input power to the luminaire. The application environment is considered highly important because high luminous efficacy does not necessarily translate to energy savings if light is wasted by directing it where it is not wanted or needed. ASSIST's metric is based on the fact that a well-designed luminaire should direct most of the lumens to the task area and meet the light level requirements of the application. The ASSIST metric is technology-neutral and is applicable to luminaires of any light source technology.

The LSAE parameters include: 1) the task area, defined by the vertical and lateral distribution of the given luminaire (e.g., Type III medium); 2) the illuminance on the task area, which should fall within IES guidelines (e.g., RP-20-98[11]) for minimum and maximum illuminance and uniformity ratios; 3) the total flux falling on the task area that meets the illuminance and uniformity requirements; 4) luminaire input power; and 5) light source spectrum. It is important to note that LSAE does not make changes to existing standards and recommendations for outdoor illuminance and uniformity levels, but simply incorporates them into the calculation.

Using a given luminaire's IES file and a selected mounting height (e.g., 30 ft), calculations are run to determine the illuminance on a predetermined task plane, which is drawn as a grid with 2.5 ft × 2.5 ft grid cell spacing. Next, the number of grid cells meeting the illuminance criteria is determined; all cells not meeting the criteria are considered non-conforming cells. The application luminous flux is then determined by multiplying the flux meeting the application requirements in each cell (all cells added up) by the percentage of conforming cells (i.e., the percentage coverage area). Then this application flux is divided by the luminaire's input power to determine the total LSAE.

Because the outcome is dependent on the mounting height, it is possible to find an optimum mounting height so that the illuminance criteria are met in the largest coverage area to minimize the number of luminaires needed for a given area. Furthermore, while the current metric considers only one luminaire per pole, it is possible to apply the metric to pole configurations with multiple luminaires. Although the LSAE value changes as a function of the number of luminaires on a pole, the rank order of multiple luminaire types does not. In other words, the LSAE of a single luminaire can be used as a metric to discriminate among different luminaires of the same distribution type. Furthermore, the LSAE metric is applicable to an entire parking lot.

LSAE Comparison for Six Luminaires

To show the utility of the LSAE metric, a comparison among six commercially available luminaires was conducted. LSAE values were calculated and the optimum mounting height for each luminaire determined. The number of luminaires necessary to illuminate a 600-ft by 400-ft parking lot was then calculated using commercial software. The criteria in each case corresponded to IES-RP-20-98[11]; that is, a minimum illuminance of 0.2 fc and a 20-to-1 max-to-min ratio. The configuration in all cases was two luminaires per pole at the optimum mounting height determined during the LSAE calculations. Table 1 summarizes the characteristics of the luminaires and the resulting metrics, including average illuminance, total number of luminaires, total input power, and lighting power density. Fig. 1 shows lighting power density (W/ft^2) as a function of the LSAE measure for the six luminaires. LSAE values plotted show a correlation between higher efficacy and lower lighting power density, meaning that within a specific application, it is possible to compare and rank order luminaires. Overall, LSAE accurately predicts energy use and ability to meet IESNA recommendations for an application.

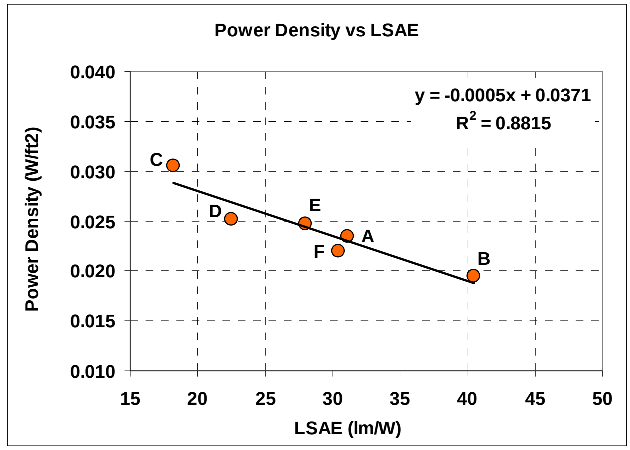

Fig. 1. Power density as function of LSAE.

Table 1. LSAE for six commercially available outdoor luminaires.

Sample	IESNA classification		Mounting height [ii]	LSAE [iii]	Number of luminaires [iv]	Average illuminance	Max:min ratio	Total input power (W)	Lighting power density (W/ft^2)
A	III	very short	40 ft	31 lm/W	30	1.16 fc	13	5640	0.0235
B	III	short	30 ft	41 lm/W	32	1.28 fc	13	4672	0.0195
C	III	medium	30 ft	18 lm/W	40	1.68 fc	21	7320	0.0305
D	III	medium	30 ft	22 lm/W	32	1.28 fc	15	6048	0.0252
E	III	medium	30 ft	28 lm/W	32	1.44 fc	20	5920	0.0247
F	II	medium	35 ft	30 lm/W	32	1.34 fc	10	5280	0.0220

[i] IES file of the luminaires sampled [ii] Optimum mounting height is determined as the height of maximal LSAE
[iii] Online calculator available at http://director.lightingresearch.org/parkinglot/default.aspx
[iv] Total number of luminaires needed to meet IES RP-20-98 criteria of minimum 0.2 fc and 20:1 max:min ratio for the predetermined area, as determined using AGi32 software (Lighting Analysts, Littleton, Colorado USA, www.agi32.com).

Visual Efficacy

In addition to LSAE, ASSIST also considers the "visual effectiveness" of the light source[9], with its method based on the proposed unified system of photometry.[12] The goal of the unified system of photometry is to allow for the specification of a luminous stimulus for any spectral power distribution and at any light level. One impetus for this system was psychophysical studies showing that the visual effectiveness of some light sources used in nighttime applications are misestimated by conventional photometry in terms of energy efficiency and visual safety. A unified system of photometry would help to more accurately characterize light sources at any light level, facilitating the specification of effective lighting systems for different applications, including those used outdoors at night.

Visual sensitivity changes with light level and spectrum, but conventional photometry, which is based entirely upon the photopic luminous efficiency function, does not account for increased visual sensitivity to short wavelengths under low light levels (i.e., mesopic). To address this issue, researchers have developed mathematical models to characterize light sources at any light level. The unified system of photometry[12] integrates both the scotopic and photopic luminous efficiency functions into a system that can be utilized across the entire range of light levels available to the human visual system. This system differentially weights the scotopic and photopic luminous efficiency functions depending on light level and is based upon psychophysical studies of human vision and preserves the fundamental tenet of additivity required of any luminous efficiency function from scotopic to photopic through the mesopic region.

The publication gives details for choosing among commercially available light sources to deliver the same unified, rather than photopic, photometric quantity. By considering the base light level required for the application and the chosen light source's scotopic-to-photopic (S/P) ratio, other light sources with the same unified luminance can be determined. Although this method is not currently approved by IESNA, in general, a high S/P ratio allows for the lowering of photopic light levels.

SUMMARY

ASSIST recommends provides a set of formal recommendations to the LED and lighting communities about issues important for the reliable performance of LED lighting and its comparison to other technologies. Some publications have been the basis for several standards documents. Additionally, the concepts and methods proposed have been used by other organizations in the United States and around the world.

1. LSAE measures luminaire efficacy when it meets recommended IESNA criteria for
    a. absolute minimum illuminance and
    b. illuminance uniformity ratios

at a given mounting height for an area determined by the luminaire's IESNA lateral and vertical types.

2. LSAE is designed for single or multiple luminaires of any light source on a pole and for an entire parking lot.
3. LSAE can be used to evaluate roadway luminaires as well by simply changing the lighting criteria.
4. LSAE = (flux that meets criteria) × (percent coverage) ÷ input power
5. Flux that meets criteria = flux that meets IES RP-20-98 recommended uniformity ratios and minimum illuminance levels
6. Percent coverage = area of the beam where the flux meets the criteria in a predetermined task plane following the luminaire's lateral and vertical classification types (e.g., IESNA Type III medium) divided by the total area of the predetermined task plane.
7. The area of the task plane is a function of the luminaire's IES classification.
8. LSAE considers luminaire mounting height (all calculations are specific to the mounting height of interest in feet or meters).
9. Input power = total input power to the luminaire

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