NLPIP
NATIONAL LIGHTING PRODUCT INFORMATION PROGRAM

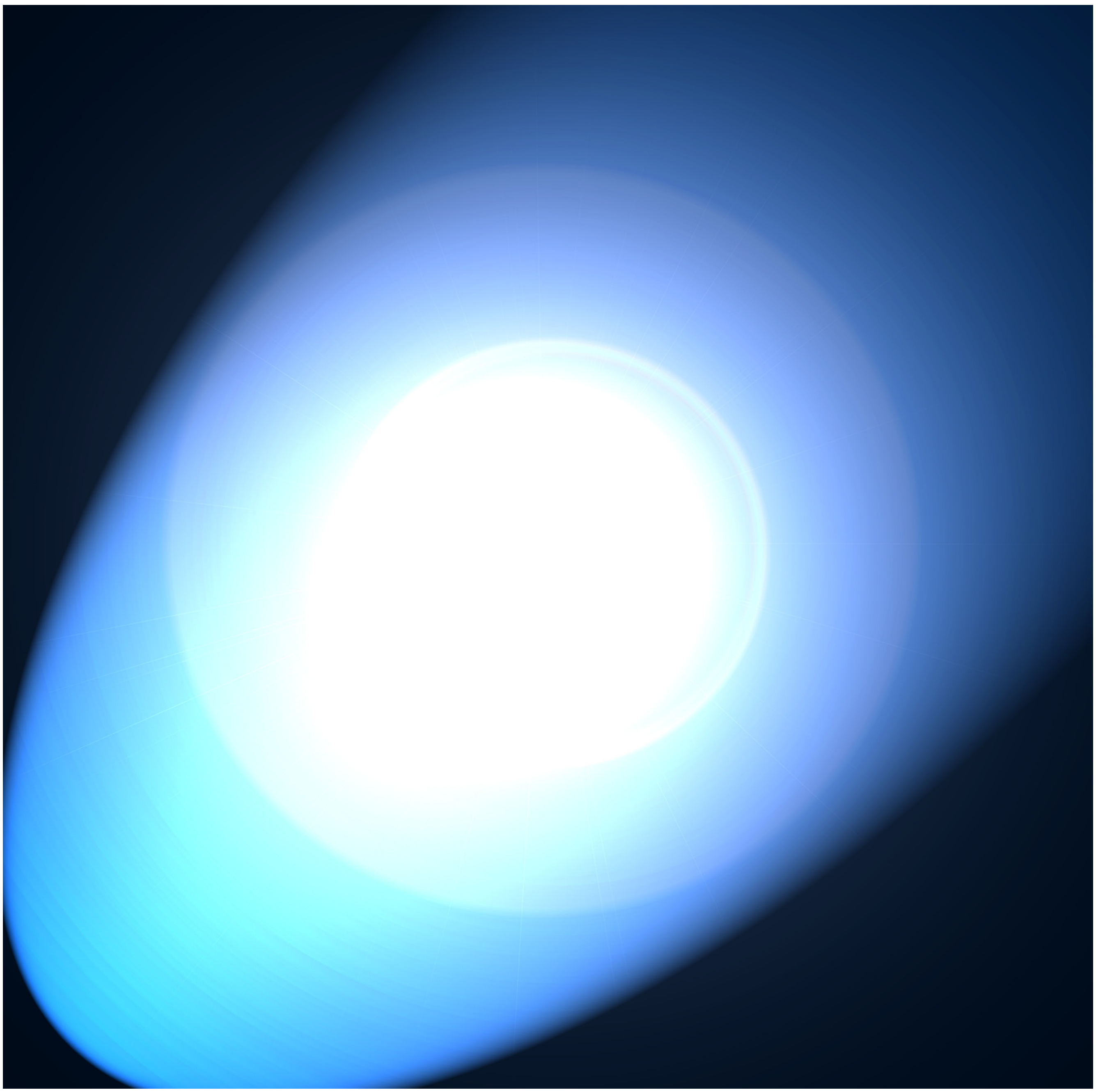
Specifier Reports

The objective source of lighting product information

Streetlights for Collector Roads

Volume 13 Number 1, September 2010 (Rev. 2, November 2010)

NLPIP's response to comments made about this publication can be found at:
http://www.lrc.rpi.edu/programs/NLPIP/SR_StreetlightResponses.asp



NLPIP
NATIONAL LIGHTING PRODUCT INFORMATION PROGRAM

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About NLPIP

The National Lighting Product Information Program (NLPIP) was established in 1990. NLPIP is administered by the Lighting Research Center (LRC), the world's leading university-based center devoted to lighting excellence.

NLPIP's mission is to help lighting specifiers and other lighting decision-makers choose wisely by providing the most complete, up-to-date, objective, manufacturer specific information available on energy-efficient lighting products. Priority is given to information not available or easily accessible from other sources. NLPIP tests lighting products according to accepted industry procedures or, if such procedures are not available or applicable, NLPIP develops interim tests that focus on performance issues important to specifiers or end users.

In 1998, NLPIP Online debuted at www.lrc.rpi.edu/programs/nlpip, making the information provided by NLPIP even more accessible to lighting specifiers and other interested people. NLPIP Online includes PDF files of *Specifier Reports, Lighting Answers, and Lighting Diagnostics*.

To ensure its continued objectivity, NLPIP does not accept funding from manufacturers.

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Contents

Abstract

The National Lighting Product Information Program (NLPIP) at Rensselaer Polytechnic Institute's Lighting Research Center (LRC) purchased 14 streetlights, identified by a specifier survey, between July and October 2009. Four used high pressure sodium (HPS), one used induction, eight used light-emitting diodes (LEDs), and one used pulse-start metal halide (PSMH) light sources. NLPIP determined how many of each type of streetlight were needed to illuminate 1.0 mile (1.6 kilometer [km]) of a collector roadway to meet the design criteria specified by the American National Standards Institute (ANSI)/Illuminating Engineering Society of North America (IESNA) RP-8-00 (R2005), the *American National Standard Practice for Roadway Lighting* (referred to as RP-8 below). NLPIP then calculated power demand and costs per mile.

NLPIP found that:

- On average, the LED streetlights and the induction streetlight could be spaced only about one half the distance of the HPS and PSMH streetlights and still meet the RP-8 lighting criteria. If an HPS or PSMH streetlight system just meeting RP-8 is replaced with the LED or induction streetlights tested in this report on a one-for-one basis, the streetlight system will not meet RP-8.
- The life cycle cost per mile is dominated by the initial and installation cost of the poles, not the initial cost of streetlights or any potential energy or maintenance cost savings. Because of the narrower pole spacing required to meet RP-8, the life cycle cost of the LED streetlights tested for this study is up to twice that of the HPS and PSMH streetlights tested.
- On average, the LED streetlights require 1% and 10% less power per mile than the HPS streetlights tested in staggered and single-sided layouts, respectively. On average, the LED streetlights require 8% and 24% less power than the PSMH streetlight tested in single-sided and staggered layouts, respectively.
- The street-side lumens metric is a useful parameter for comparing streetlight layout costs.
- At the illuminance levels typical of collector roadways, power requirements for "white light" sources are 3% to 19% lower than HPS sources based on models of mesopic photometry.

Introduction

Streetlights with light-emitting diodes (LEDs) and induction lamps are being marketed as effective replacements for high pressure sodium (HPS) streetlights for new construction and retrofit applications. Some claims regarding LED and induction streetlights include assertions that these streetlights provide significant energy savings, improve lighting uniformity and distribution, and reduce maintenance costs compared to HPS streetlights.

Many municipalities are in the process of installing LED streetlights. The American Recovery and Reinvestment Act of 2009 (ARRA) is distributing US$275 billion in federal contracts, grants and loans to spur economic growth and enhance infrastructure. Municipalities across the United States have applied for ARRA funding to replace their current streetlights with LED and induction streetlights. (Recovery.gov)

Recently, there have been many LED street lighting demonstrations (for example, see the U.S. Department of Energy GATEWAY program). Some of these demonstrations present incomplete and potentially misleading comparisons with incumbent technologies.[1] A complete comparison should demonstrate the system's performance compared to alternative technologies that meet all of the required performance criteria. Evaluations should be measured or simulated excluding ambient light and should include consideration of the full system costs.

To provide an accurate comparison of existing technology, the National Lighting Product Information Program (NLPIP) purchased and performed photometric evaluations of 14 streetlights that use HPS, pulse-start metal halide (PSMH), or induction lamps, or use LED modules (IES 2008a). Using typical mounting heights, NLPIP analyzed these streetlights for light output and distribution, energy use, spectral effects on visual performance, discomfort glare, and economic factors.

This report does not include evaluations of streetlights for local roadways, which have lower recommended light levels, decorative streetlights such as "lantern" or "acorn" styles, or high mast lighting, which are streetlights mounted at heights of 60 feet (ft) (18.3 meters [m]) or higher, more commonly used along major highways.

[1] NLPIP's response to comments made on October 6, 2010 by the Pacific Northwest National Laboratory can be found at: http://www.lrc.rpi.edu/resources/newsroom/pdf/ResponseToPNNL_10-13-10.pdf

Streetlight Selection

NLPIP used a combination of surveys of lighting specifiers, analyses of typical roadway geometry, and the services of manufacturer representatives to determine the streetlights to evaluate for this study.

Identifying the Base-Case Criteria

NLPIP relied on previous survey results (Mara et al. 2005) to identify the 150-watt (W) HPS, full cutoff streetlight as the most frequently installed streetlight used to illuminate collector roads. Using the American Association of State Highway and Transportation Officials design policy (AASHTO 2004), NLPIP determined that the most appropriate optical distribution for collector road widths is an Illuminating Engineering Society (IES) Type III, medium distribution. Therefore, NLPIP used a 150W HPS, Type III, medium, full cutoff optical distribution as the base-case criteria for this analysis.

Identifying Brands to Purchase

NLPIP conducted two online surveys in June 2009—one of lighting specifiers (including members of the IES Roadway Lighting Committee and personnel at various departments of transportation and electric utilities) and another general survey of individuals interested in outdoor lighting (who had previously downloaded the NLPIP *Specifier Report: Parking and Area Lighting*)—in order to determine prevailing beliefs about outdoor lighting. The specifiers provided information about which streetlights they most often specified, which types of streetlights they were currently evaluating, and their opinions on current issues related to street lighting systems. Respondents provided names and descriptions of 72 luminaires. Figure 1 shows the 59 conventional streetlights mentioned, listed by manufacturer. The two most frequently specified manufacturers were GE Lighting and American Electric Lighting. Specifiers who responded that LED streetlights were ready for roadway lighting at the time of the survey (June 2009) or would be ready within two years (by 2011) were asked to provide up to three LED brands that they were evaluating or specifying. In total, 32 LED streetlights were listed by specifiers. Figure 2 shows the LED streetlights mentioned by manufacturer. Similarly, specifiers who thought induction streetlight technology was or would be ready within two years were asked to name up to three brands they were evaluating or specifying. Twelve specifiers responded, yielding two streetlight products, US Lighting Tech and Philips Lumec.

Figure 1. Most specified conventional streetlights, listed by manufacturer

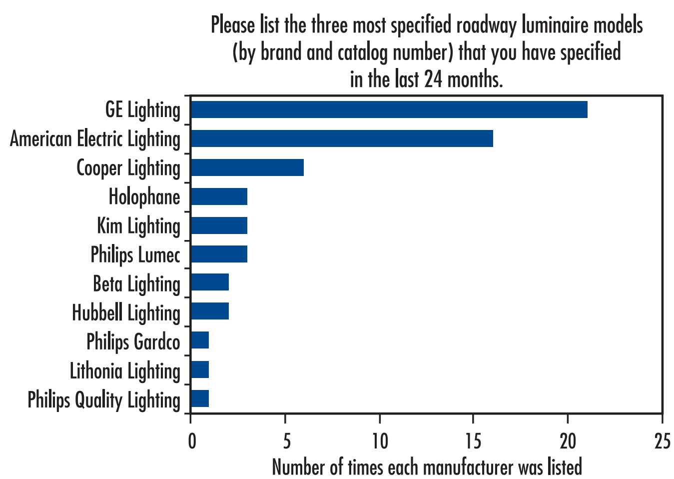
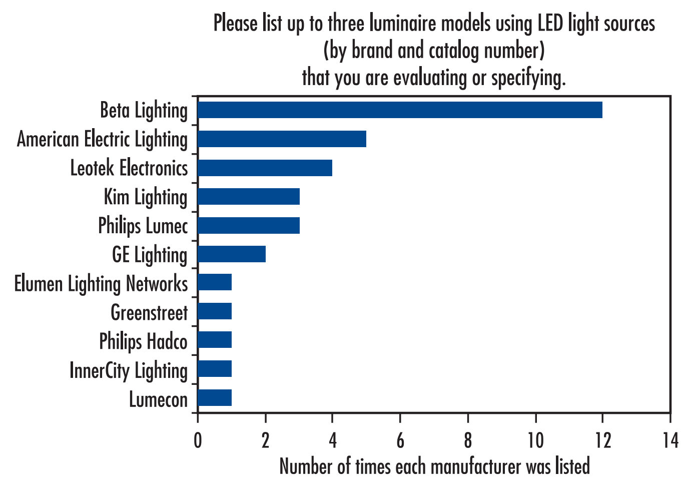


Figure 2. Most evaluated or specified LED streetlights, listed by manufacturer



Identifying Streetlight Models to Purchase

For this report, NLPIP evaluated 14 streetlights, purchased between July and October 2009, using the testing and calculation methodologies detailed in Appendix A. These streetlights included four HPS, eight LED, one induction, and one PSMH streetlight. Details, including the prices NLPIP paid, are shown on the data sheets in Appendix B.

Many lighting specifiers rely on the services of manufacturers' representatives to assist them in selecting streetlights. Therefore, NLPIP asked Albany, NY-area representatives of the identified brands to select streetlight models that were equivalent to a "Type III, medium, 150W HPS cobra head, full cutoff, at 25 ft (8.2 m) mounting height with the correlated color temperature (CCT) option that provides the highest lumens." Representatives provided the catalog number and pricing of their products to local distributors for NLPIP to purchase.

NLPIP purchased four HPS cobra head streetlights meeting NLPIP's base-case criteria. NLPIP purchased streetlights from the top three manufacturers listed in the 2009 specifier survey (Figure 1). The next three most frequently mentioned streetlights were referenced equally, so NLPIP selected the fourth streetlight from a manufacturer who was not represented in the LED and induction product selection in order to have a variety of manufacturers represented in this report.

NLPIP purchased a cobra head streetlight from GE Lighting with a 175W PSMH lamp in order to provide a "white light" alternative to LED and induction streetlights. NLPIP chose a 175W PSMH lamp because it provided rated lumens closest to the 150W HPS lamp. The GE Lighting brand was selected because it was the manufacturer listed the most frequently as a source of conventional cobra head streetlights.

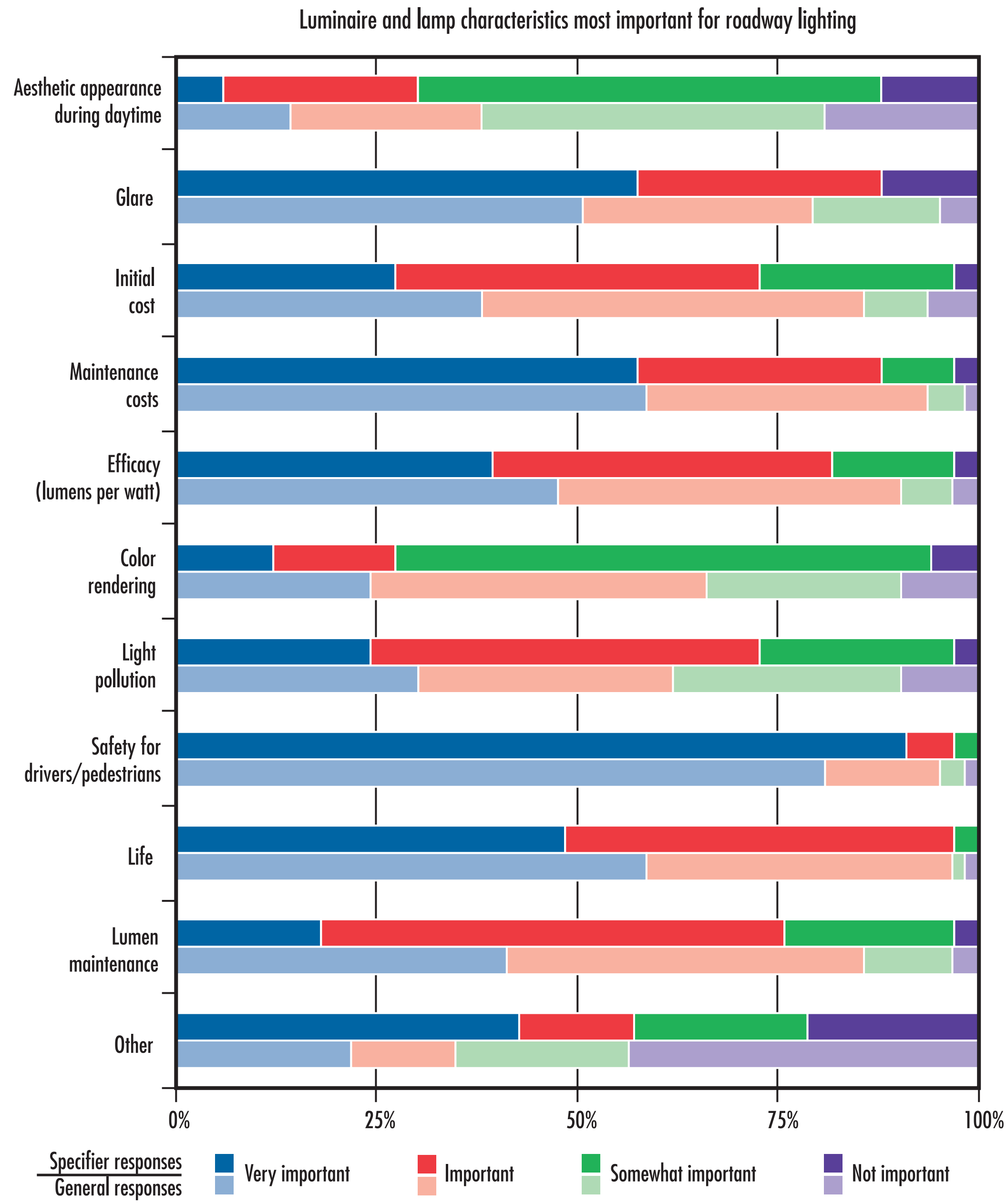
Neither of the two induction streetlights mentioned in the specifier survey were purchased. The US Lighting Tech streetlight was ordered but not shipped by the manufacturer. The Philips Lumec streetlight was determined by the manufacturer's representative not to be an equivalent, full cutoff streetlight. Consequently, NLPIP conducted an internet search of induction streetlight pilot demonstrations across the United States. The sole manufacturer who had a representative sales force was chosen (Visionaire); NLPIP then asked the local manufacturer's representative to specify an induction streetlight using the same process described above.

Important Street Lighting Characteristics

When NLPIP surveyed outdoor lighting specifiers and other professionals in June 2009, participants were asked to rate the importance of ten characteristics related to street lighting installations, as shown in Figure 3. Specifiers identified safety for drivers and pedestrians, overall costs, efficacy, lumen maintenance, life and glare as the most important streetlight characteristics. NLPIP used the issues rated as most important to determine how to compare the streetlights.

The survey results showed that safety was the respondents' most important criterion when evaluating streetlights. Therefore, NLPIP assumed the evaluated streetlights would be used in a system that meets a nationally accepted roadway lighting standard: American National Standards Institute (ANSI)/Illuminating Engineering Society of North American (IESNA) RP-8-00 (R2005), the *American National Standard Practice for Roadway Lighting.* (Hereinafter, the preceding publication will be referred to as RP-8.) NLPIP determined the number of pole-mounted streetlights required per mile to meet the RP-8 standard and then used these findings to compare power densities and life cycle costs. Respondents indicated that they were concerned with glare, which NLPIP interpreted as a concern for glare as an issue for driver and pedestrian safety. To address glare, NLPIP used a glare metric given in RP-8 to evaluate disability glare and also calculated discomfort glare using a mathematical model developed by Brons et al. (2008), Bullough et al. (2008), and Bullough (2009). Measurement of streetlight life was beyond the scope of this study, but the economic impacts of life are addressed in the life cycle cost analysis.

Figure 3: Importance of characteristics of streetlight installations rated by outdoor lighting specifiers and general respondents



Pole Spacing

Photometric testing was conducted from September through December 2009 at Intertek, an independent laboratory in Cortland, NY, under contract with NLPIP. Detailed results of these tests are shown in the data sheets in Appendix B. In order to determine pole spacings, the following design criteria were used:

- **The design was based on RP-8 lighting criteria.** Because the survey of lighting professionals identified driver and pedestrian safety as the most important metric of streetlight installations, NLPIP turned to the national standard RP-8 for designing safe streetlight systems. Recommended light levels are also provided in *Roadway Lighting Design Guide* GL-6 (AASHTO 2005), but this standard is derived from RP-8. RP-8 calls for continuous lighting along a roadway, rather than lighting only at conflict points such as intersections. The recommended RP-8 lighting criteria are shown in Table 1. *Roadway Lighting Design Guide* GL-6 recommends the same lighting criteria for a collector road with medium pedestrian traffic (described as "intermediate area" by AASHTO [2005]), with the exception of average pavement illuminance, which is 0.8 footcandles (fc) (8.6 lux [lx]), rather than 0.9 fc (9.7 lx).

Table 1. Recommended Illuminance and Luminance Criteria for Collector Roads with Medium Pedestrian Conflict

Metric	RP-8 Criteria
Average Pavement Illuminance (E_{avg})	0.9 fc (9.7 lx)
Average to Minimum Pavement Illuminance Ratio (E_{avg}:E_{min})	4.0:1
Average Pavement Luminance (L_{avg})	0.6 cd/m^2 *
Average to Minimum Pavement Luminance Ratio (L_{avg}:L_{min})	3.5:1
Maximum to Minimum Pavement Luminance Ratio (L_{max}:L_{min})	6.0:1
Maximum Veiling Luminance to Average Pavement Luminance Ratio (L_{vmax}:L_{avg})	0.4:1

* candelas per square meter

- **The simulated roadway was a collector road** (servicing traffic between local and major roadways) with medium pedestrian conflict, a term used in RP-8 to identify roads that have pedestrian traffic typical of urban areas with libraries and neighborhood shops. The width of the simulated road was 48 ft (14.6 m) per AASHTO geometric design policy (2004).
- **The RP-8 illuminance method criteria were met.** RP-8 provides three different methods for lighting roadways—illuminance, luminance, and small target visibility—and allows the lighting practitioner to select which one of the three methods the lighting system will meet. NLPIP selected the illuminance method because it produced the widest pole spacing for the simulated roadway and therefore resulted in lower costs and power demand. When using the illuminance method, RP-8 requires a lighting design to meet all three of the following criteria: be above a minimum average illuminance, below a maximum average-to-minimum uniformity ratio, and below a maximum veiling luminance ratio limit (disability glare).

Relative Photometry vs. Absolute Photometry

In the lighting industry, relative photometry is used to characterize the light output for all luminaires and light sources except for LEDs. Light output from LED luminaires and light sources is characterized using absolute photometry. NLPIP used relative photometry for the HPS and PSMH streetlights and absolute photometry for the LED and induction streetlights for the pole spacing analysis. See Appendix A for more information.

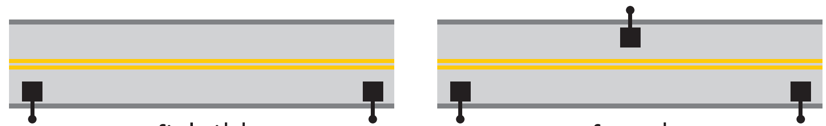
The rated light output from the HPS, PSMH, and induction streetlights is based on relative photometric data provided by manufacturers. The rated light output is determined by scaling the measured (absolute) light output when operated on a particular ballast to the light output that would be expected if a "reference" ballast were used. For example, a 150W HPS lamp rated at 16,000 lumens might actually produce 14,400 lumens when operated on a magnetic ballast that might be used in the installation. In a streetlight that is, for example, 80% efficient based upon the ratio of the measured bare lamp lumens to the measured luminaire lumens, the streetlight would be rated, and expected, to produce 12,800 lumens. In fact, the streetlight for this particular lamp/ballast combination would only produce 11,520 lumens. A roadway lighting design based upon the rated luminaire lumens would deliver lower levels of illuminance than expected.

NLPIP tests showed that the measured lumens of the four HPS lamp and magnetic ballast combinations (measured independently of the streetlight) were, on average, 10% lower (with a range from 3% higher to 21% lower) than their rated lamp lumens. Because the differences between actual and rated light output for emerging technologies like LED streetlights are unknown, the precision of rated light output claims for LED streetlights should likewise be treated with skepticism.

NLPIP suggests using absolute photometric testing to achieve greater accuracy in predicting light levels than that afforded by relative photometry. Several measurements of the same model of streetlight should be performed in order to assess consistency.

- **Both single-sided and staggered layouts were analyzed**, as illustrated in Figure 4. These geometries are the most commonly used layouts for collector roads. Pole spacing is characterized by the distance between poles on one side of the road.

Figure 4: Streetlight Layouts Typically Used



- **There is no ambient light** in the simulated environment that illuminates the collector roadway. RP-8 does not account for ambient light to adjust the recommended lighting design criteria; therefore NLPIP did not consider ambient light in the environment as it might influence pole spacing. Lighting practitioners that are interested in including ambient light from the environment in their calculations should look into the information provided by Rea et al. (2010).
- **The light loss factor is associated with a specific lighting technology.** The light loss factor takes into account luminaire dirt depreciation, lamp lumen depreciation (LLD), ballast factor, ambient temperature, and other operating conditions that affect light output. Assuming that the lighting layout criteria need to be met regardless of the lighting technology used to meet them, the light loss factor applied will influence pole spacing. See Appendix A for further information on how light loss factors were calculated. Table 2 shows the light loss factors for the streetlights used in the analyses.

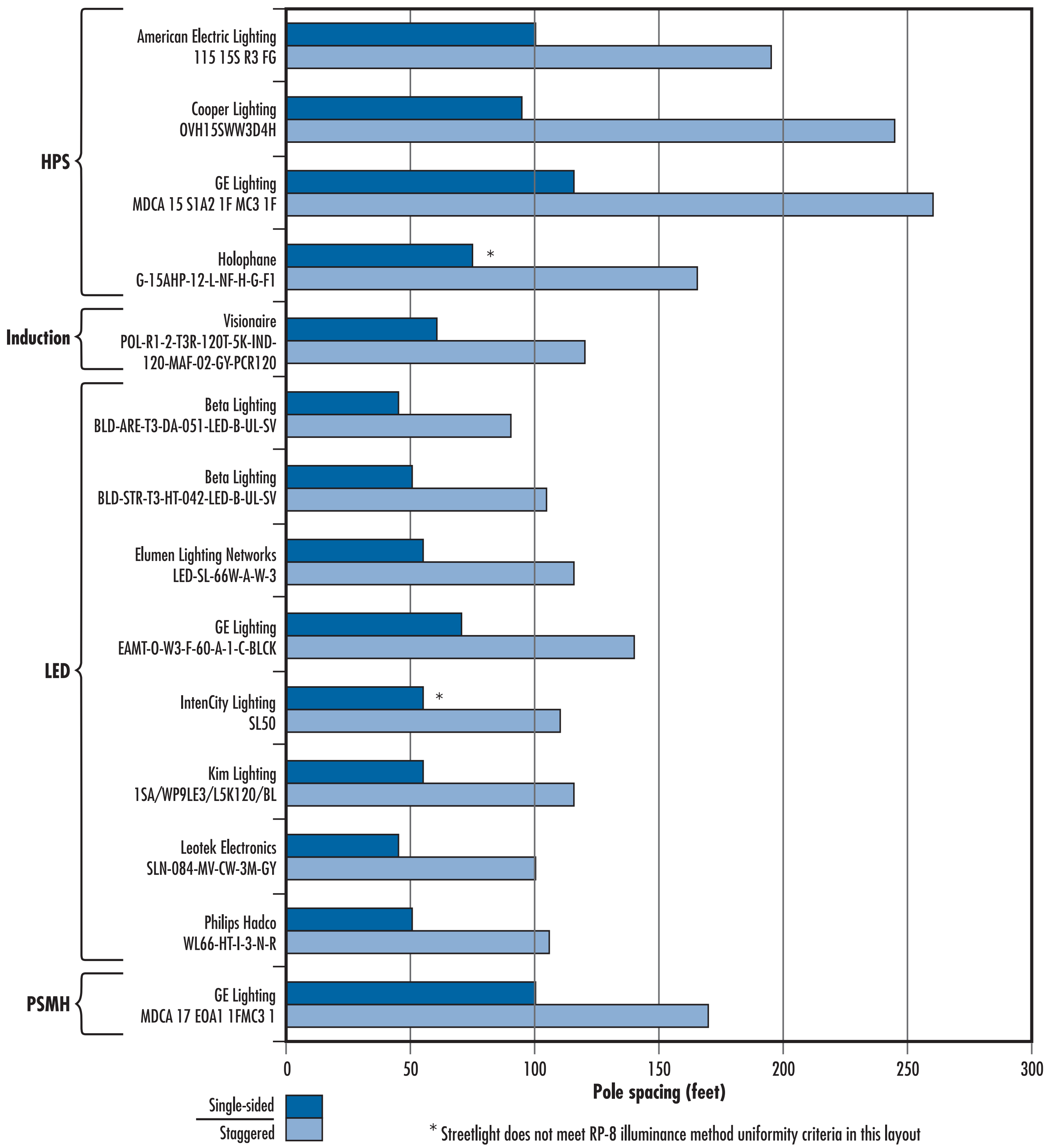
Table 2. Light Loss Factors

Streetlight Type	Lamp Lumen Depreciation	Luminaire Dirt Depreciation	Light Loss Factor
HPS	0.84	0.88	0.74
Induction	0.70	0.88	0.62
LED	0.79	0.88	0.70
PSMH	0.63	0.92	0.58

- **The streetlight mounting height was 27 ft (8.2 m).** As discussed on p. 8, NLPIP asked manufacturer representatives for equivalent streetlights based on a 25 ft (7.2 m) mounting height. After they were contacted, NLPIP consulted with a utility expert who indicated that a 27 ft (8.2 m) mounting height was a common mounting height for collector roads when overhead power distribution lines were present. NLPIP assumed that this small height difference had a negligible effect on the streetlight model that the manufacturers' representatives would have recommended.

NLPIP used the above parameters to determine pole spacing using the lighting software program AGi32 version 2.04 (Lighting Analysts, Inc.). The maximum pole spacings that met all of the RP-8 illuminance method criteria were determined using the assumptions above. The results are shown in Figure 5. Two streetlights, shown with an asterisk in Figure 5, did not meet the average-to-minimum uniformity ratio criterion in the single-sided layout at any pole spacing. For these streetlights, NLPIP calculated the pole spacing when the other two criteria were

Figure 5: Pole Spacing Needed to Meet RP-8 Illuminance Method



met (average illuminance was at or above 0.9 fc [9.7 lx] and the disability glare ratio was less than or equal to 0.4:1).

On average, the LED streetlights and the induction streetlight could be spaced only about one half the distance of the HPS streetlights and still meet RP-8 illuminance method criteria. The PSMH streetlight pole spacing was comparable to the HPS streetlight pole spacings.

Many LED manufacturers assert that LLD values of 0.90 – 0.95 are appropriate. Even when an LLD value of 0.95 was used (higher than the value 0.79 used to calculate the pole spacings shown in Fig. 5), the LED streetlights still required narrower pole spacing than the HPS streetlights, with one exception. In both single-sided and staggered layouts, the LED streetlight that provided the widest pole spacing (GE Lighting EAMT-0-W3-F-60-A-1-C-BLCK) was able to match the pole spacing of the HPS streetlight with the shortest pole spacing (Holophane G-15AHP-12-L-NF-H-G-F1).

Street-side Lumens

As shown in Figure 6, NLPIP found that downward street-side lumens (the portion of the lumens in the downward street-side quarter-sphere, hereinafter referred to as street-side lumens) had a strong correlation to pole spacing. The LED and induction streetlights needed to have much higher street-side lumens in order to provide equivalent pole spacing to the HPS and PSMH streetlights tested. The correlation between street-side lumens and pole spacing is good but not perfect because while street-side lumens correlate well with average horizontal illuminance, other criteria such as uniformity and limits on disability glare constrain pole spacing. For example, Point A in Figure 6 shows the pole spacing for the GE Lighting MDCA 15 S1A2 1F MC3 1F streetlight. This streetlight does not have the highest street-side lumens, but the pole spacing is the widest because of its horizontal illuminance uniformity. Point B shows the pole spacing for the Holophane G-15AHP-12-L-NF-H-G-F1 streetlight. While this streetlight produces the third highest street-side lumens of the 14 streetlights tested, it yields only the fifth widest pole spacing because the poles needed to be spaced closer together in order to control disability glare. Table 3 shows the average street-side lumens of the tested streetlights and the required street-side lumens needed by the LED and induction streetlights to obtain pole spacing equivalent to the HPS streetlights. Streetlights that provide a more uniform horizontal illuminance distribution and that control disability glare require street-side lumens that are closer to 8000 lumens (lm) than 9000 lm to provide pole spacing equivalent to the HPS streetlights.

The data sheets in Appendix B provide the street-side lumens for each streetlight tested. These data sheets also contain Luminaire Classification System graphs in which the forward light subzones (shown in green) represent the street-side lumens.

Figure 6: Correlation between Downward Street-side Lumens and Pole Spacing

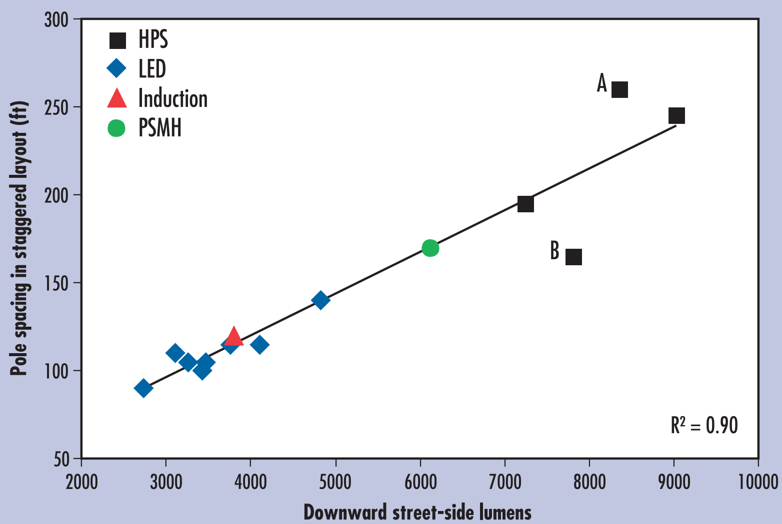


Table 3: Street-side Lumens Required to Provide Pole Spacing Equal to HPS Streetlights

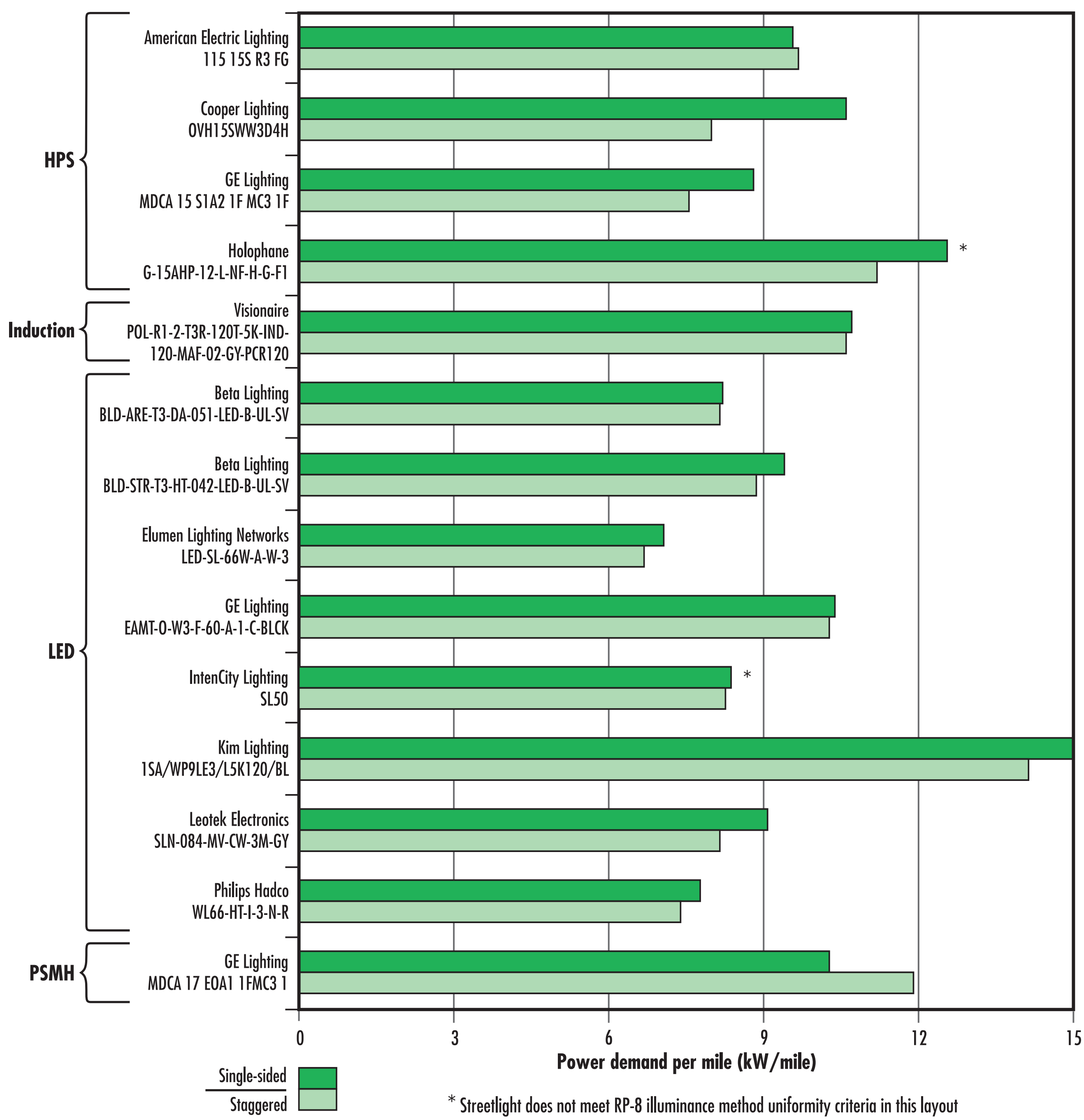
Streetlight Type	Measured Street-Side Lumens (lm)	Street-Side Lumens Needed To Obtain Same Pole Spacing as HPS (lm)
HPS	7,200 to 9,000 (average 8,000)	N/A
LED	2,700 to 4,800 (average 3,600)	8,000 to 9,000
Induction	3,800	9,000

The pole spacing determined using manufacturer-supplied photometric files was about the same as the spacing determined using the measured intensity distributions. NLPIP obtained photometric files for 12 of the 14 tested streetlights from manufacturers' websites and compared the pole spacing for a staggered layout using the method described above. The analysis of the manufacturer-supplied files resulted in pole spacings where 11 of the 12 manufacturer-supplied files were within 13% of NLPIP's results.

Power Demand

NLPIP used the pole spacing that met the RP-8 illuminance method criteria (shown in Figure 5) to lay out streetlights over one mile (1.6 km) of roadway in order to compare power demand for layouts using each of the tested streetlights. Results are shown in Figure 7. A lower power demand is better than a higher power demand.

Figure 7: Power Demand per Mile



The LED streetlight layouts, on average, resulted in a slightly lower power demand than the average HPS streetlight layouts. The LED layout with the lowest power demand (Elumen Lighting Networks LED-SL-66W-A-W-3) had 81% of the power demand of the HPS layout with the lowest power demand (GE Lighting MDCA 15 S1A2 1F MC3 1F). However, the power demand per mile for individual streetlight layouts varied significantly. When compared to the lowest power demand HPS streetlight layout, only two of the LED layouts had a lower power demand in the staggered layout and half had a lower power demand in the single-sided layout. The induction streetlight layout had a higher power demand than three of the four HPS streetlight layouts and seven of the eight LED streetlight layouts.

Specifiers interested in reducing lighting power (and associated light levels) by dimming or switching their streetlights can find more information about strategies and controls for dynamic outdoor lighting in NLPIP's *Lighting Answers: Dynamic Outdoor Lighting*.

Economics

NLPIP estimated the present value of the life cycle costs of each of the streetlight systems per 1.0 mile (1.6 kilometer [km]) of roadway over an assumed streetlight lifetime of 27 years, for both single-sided and staggered streetlight layouts. Life cycle costs included initial capital and installation costs as well as ongoing energy and maintenance costs. The results are shown in Figure 8.

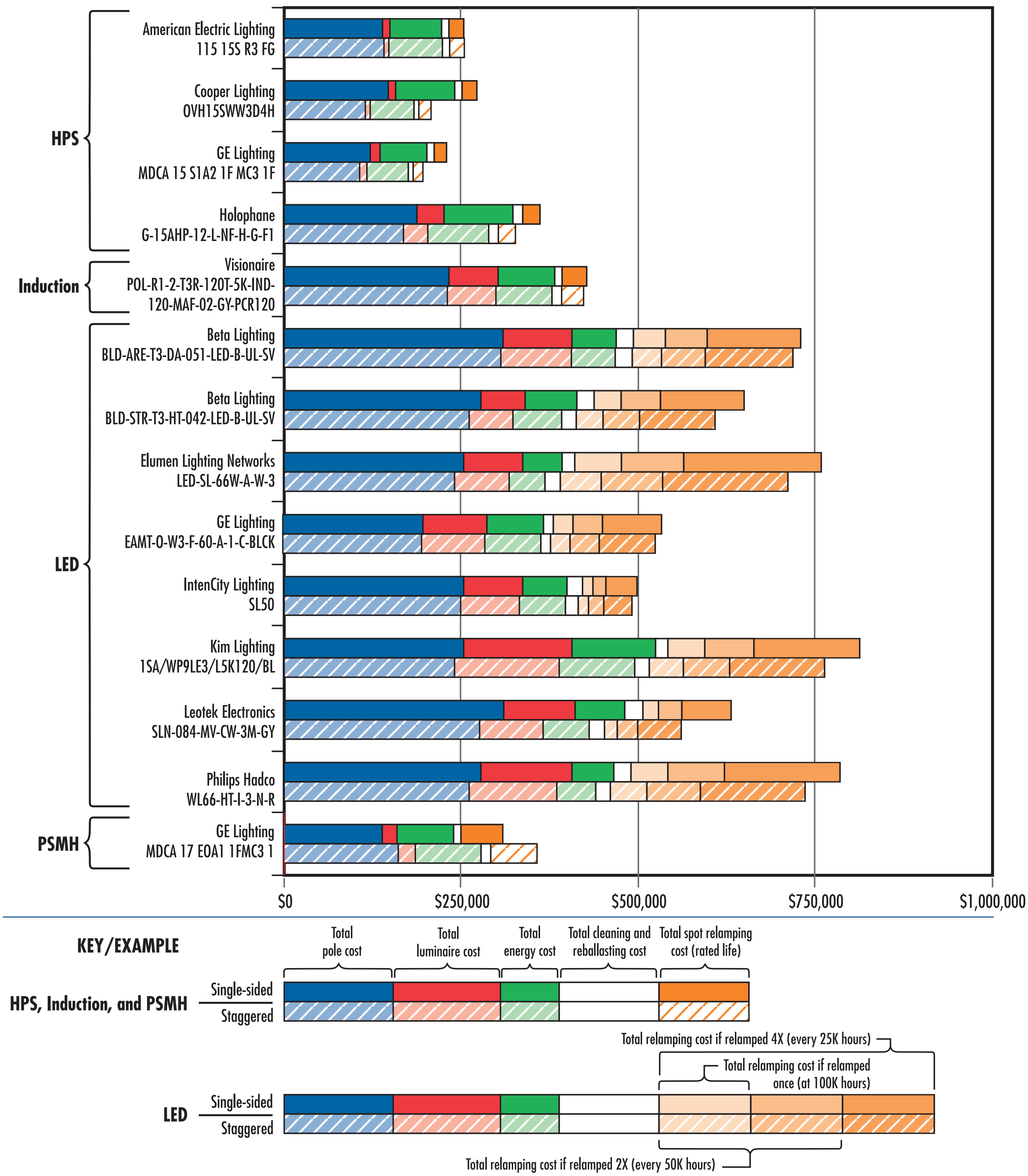
NLPIP used RS Means 2006 data (Chiang 2006) in its economic calculations. Thirty-foot (9.1 m) steel poles were used for the streetlights mounted at 27 ft (8.2 m) because this was the closest commercially-available pole for the mounting height required. RS Means estimated that material and labor costs for installing a 30 ft (9.1 m) steel pole with one arm bracket would be US$2,625, and the labor to install a streetlight on the pole would cost US$153. The purchase prices (shown in Appendix B) paid by NLPIP for each of the streetlights and lamps were used as the streetlights' capital costs. The total pole cost incorporated the number of streetlights per mile based on the results shown in Figure 5.

The life cycle cost analysis incorporated energy and maintenance costs including cleaning, reballasting (replacing the ballast or driver), and relamping the streetlights. NLPIP assumed 4,200 burn hours per year (11.5 hours per day on average) and an energy cost of US$0.10 per kWh (US DOE 2010). NLPIP also assumed that ballasts or drivers for all technologies would be replaced after 60,000 hours and that the streetlights would be cleaned every four years (except PSMH which is cleaned every 2.7 years at relamping) based on IES roadway lighting maintenance best practices (IESNA 2003). NLPIP included the cost for spot relamping the HPS lamps (non-cycling) every 30,000 hours, the PSMH lamp every 11,500 hours, and the induction lamp every 100,000 hours, which was the rated life of these lamps. There is more uncertainty in the lifetime estimation of LED streetlights than of the other, more mature, technologies, so NLPIP used a range of values as part of a sensitivity analysis for the LED relamping schedule. Results are shown in Figure 8 for the cases where the relamping is not needed (that is, the LEDs last the assumed 27 years, equal to 113,000 hours) and if relamping is needed every 100,000 hours, 50,000 hours, and 25,000 hours. See Appendix A for other economic assumptions that were used.

The analysis showed that HPS and PSMH sources had lower life cycle costs than the induction or LED sources. The life cycle costs of the latter technologies are heavily influenced by their initial capital costs, due mostly to the increased number of poles per mile.

One common claim made in manufacturer marketing materials about LED and induction streetlights is that their longevity and efficacy will lead to lower life cycle costs. This analysis shows that even if the tested LED streetlights never need to be replaced over their life, they will still be more expensive to own and operate than conventional HPS or PSMH streetlights. If the LEDs do need to be replaced, the life cycle cost can be up to twice that of HPS and PSMH streetlights. The life cycle cost of the induction streetlight was lower than the life cycle cost of four of the eight LED streetlights in a staggered layout (and five of the eight in a single-sided layout) if the LEDs never needed to be replaced. If the LEDs needed to be replaced even once, the life cycle cost of the induction streetlight was lower than seven of the eight LED streetlights, in either layout.

Figure 8. Life Cycle Cost per Mile over 27 Years



Labeling Problems

Identifying Catalog Numbers on Streetlights and Packaging

Seven of the 14 streetlights did not have their identifying catalog number on the streetlight or on the packaging. This information can be found on the data sheets in Appendix B. Poor labeling can lead to a number of problems, including difficulty in verifying that the correct streetlight was shipped, maintaining inventory, and performing maintenance. Poor labeling can be eliminated by purchasing streetlights that comply with ANSI C136.22, which requires the manufacturer to label the streetlight with the name and streetlight catalog number, as well as other relevant parameters.

NLPIP found that only one of the 14 streetlights tested (GE Lighting MDCA 17 E0A1 1FMC3 1) met the claim of having a Type III, medium, full cutoff distribution. Only five of the fourteen streetlights had a medium IES vertical classification and only six of the fourteen streetlights had a Type III IES lateral classification.

All 14 of the streetlights that NLPIP tested were claimed by the manufacturer to have full cutoff optics, but only seven (all of the HPS, the PSMH, the induction, and one of the LED streetlights) actually were full cutoff. A streetlight that emits no uplight may still not be classified as full cutoff if it does not limit the luminous intensity values in the 80° to 90° zone according to the IES cutoff classification criteria. Although the remaining seven LED streetlights were determined not to be full cutoff, the amount of direct uplight never exceeded 2%.

Small amounts of stray light during photometry measurements can greatly affect the cutoff classification of the streetlights. To help ensure that stray light did not affect the cutoff classification, NLPIP adjusted the measured intensity values by removing that portion that could reasonably be attributed to stray light. See Appendix A for more information on how NLPIP removed the stray light from the photometric files. More information about light pollution can be found in NLPIP's *Specifier Report: Parking Lot and Area Luminaires* publication and in *Outdoor site-lighting performance: A comprehensive and quantitative framework for assessing light pollution* (Brons et al. 2008).

Other Considerations

"White Light" Benefits

When light levels are extremely low, such as in starlight conditions, rod photoreceptors in the eye provide the only input signal to the visual system; this is known as scotopic vision. When light levels are higher, such as under daylight, vision is mediated by cones; this is known as photopic vision. In between photopic and scotopic vision falls a region called mesopic vision, when both rods and cones contribute to visual sensation. Light levels typical of most outdoor lighting installations are in the mesopic region.

The specifiers and general respondents polled by NLPIP indicated that spectral power distributions (SPD) should be considered in street lighting design in consideration of mesopic spectral sensitivity. At the time of this publication, there is no official system of photometry based on mesopic vision. However, two models of mesopic photometry which integrate the scotopic and photopic luminous efficiency functions into a complete system have been proposed: the unified system of photometry (Rea et al. 2004) and the Mesopic Optimisation of Visual Efficiency (MOVE) model of mesopic photometry (Eloholma and Halonen 2005). These models can be used to predict the fraction by which electric power could be reduced while still maintaining the same visual performance. In this study, the relatively high light levels recommended for collector roads (average luminance = 0.6 cd/m²) limited the mesopic visual efficacy benefits. The unified photometry model predicted a power reduction of less than 3%, whereas the MOVE model predicted a power reduction up to 19%. The power reduction varies based on the SPD and the lighting distribution of the particular streetlight. See Appendix A for additional information.

Discomfort Glare

Anecdotally, "white light" streetlights are perceived to cause more discomfort glare than HPS streetlights. NLPIP modeled the impact that short-wavelength (blue) light may have on discomfort glare using the discomfort glare model developed by Bullough (2009). When the SPDs were scaled to provide equal illuminance at the eye, the resulting calculations showed that the "white light" streetlights would induce up to 16% more discomfort glare due to the SPD than their HPS counterparts for the same photopic illuminance at the eye. NLPIP also analyzed the photometric files for discomfort glare using the Outdoor Site-Lighting Performance (OSP) method (Brons et al. 2008) in AGi32. Although ambient light was not accounted for in the pole spacing calculations because it is not part of RP-8, ambient light is considered in the discomfort glare equations in OSP. NLPIP reports the De Boer rating of discomfort glare for three ambient illuminance conditions (rural, suburban and urban) using the assumption of ambient illuminance level given by Brons et al. (2008): 0.02 lx (rural), 0.2 lx (suburban) and 2 lx (urban). When scaled to equal street-side lumens and equivalent (or wider) pole spacing as the HPS streetlights provided, the LED and induction streetlights produced about the same De Boer ratings on average as the HPS and PSMH streetlights (3.1 on the De Boer scale, in an urban ambient illuminance environment, rated as "disturbing") using the OSP method, even when the impact of SPD on discomfort glare from Bullough (2009) was included.

Conclusions

NLPIP evaluated four HPS, one induction, eight LED, and one PSMH streetlights, all purchased between July and October 2009. As part of this study, NLPIP conducted a survey of outdoor lighting specifiers and other professionals, and the results showed that safety was their most important consideration when evaluating streetlights. Therefore, NLPIP assumed the evaluated streetlights would be used in a system that meets the design criteria of RP-8, the *American National Standard Practice for Roadway Lighting*. This standard requires continuous roadway lighting, rather than lighting only areas of potential conflict, such as intersections. NLPIP determined the number of streetlights required per mile to meet the RP-8 standard and then used these findings to compare power demand and life cycle costs.

Pole Spacing

NLPIP found that none of the LED or induction streetlights tested matched the pole spacing provided by the HPS streetlights and still met the same recommended lighting criteria. The discrepancy in pole spacing between the lighting technologies was greater for staggered streetlight layouts than single-sided layouts. Street-side lumens were determined to be a good predictor of pole spacing.

If specifiers wish to replace a conventional streetlight system that just meets the RP-8 criteria set forth in this report with LED streetlights on a one-for-one basis, the LED streetlights will need to provide more street-side lumens than the LED products tested for this report in order to continue to meet RP-8.

Power Demand

The average power demand of the LED streetlight layouts was slightly lower than the average power demand of the HPS streetlight layouts. However, there was much variation between models. Compared to the HPS single-sided streetlight layout with the lowest power demand, half of the single-sided LED streetlight layouts had a higher power demand. In a staggered layout, three quarters of the LED streetlight layouts resulted in a higher power demand than the HPS streetlight layout with the lowest power demand. The lowest power demand LED streetlight layout had a 19% lower power demand per mile than the lowest power demand HPS streetlight layout, but the highest power demand LED streetlight layout required 187% of the lowest power demand HPS streetlight layout. On average, the PSMH and induction streetlight layouts had a higher power demand than the average HPS streetlight layouts.

Lighting Economics

Largely because of the narrower pole spacing needed, the life cycle costs of the LED and induction streetlights were greater than those of the HPS and PSMH streetlights. Because NLPIP had less certainty about the life of the LEDs than the life of the HPS, PSMH, or induction lamps, the economic comparisons employed a sensitivity analysis to evaluate the effect of the lifetime of the LEDs on life cycle costs. The results showed that even if the LED streetlights never needed relamping, all of the tested LED streetlights had a higher life cycle cost than any of the HPS or PSMH streetlights. The induction streetlight had a life cycle cost that was lower than many of the LED streetlights.

Labeling Problems

There was large variability between the tested streetlights' optical distribution and the manufacturers' claim of optical distribution. Only one of the 14 streetlights tested met the manufacturer's claim to provide Type III, medium, full cutoff performance. Furthermore, only seven of the streetlights were full cutoff, and only two of those streetlights were characterized as having Type III optics.

Other Considerations

"White light" benefits. Spectral effects of white light had small to moderate mesopic visual efficacy benefits for the collector roads analyzed in this report because of the relatively high light levels required by RP-8. Using the MOVE model, power reduction of up to 19% was possible. Local roads typically have lower illuminance levels than collector roads; therefore, "white light" should have greater visual benefits on these types of roads.

Discomfort glare. The average De Boer rating of all the streetlights when simulated in an urban illumination environment were classified as "disturbing."

Limitations

NLPIP purchased and tested only one sample of each streetlight model, and the results found here may differ from other samples. NLPIP purchased the streetlights tested in this report between July 2009 and October 2009. Manufacturers using newer-generation LED packages in their streetlights may be able to improve performance relative to the results shown here. Specifiers should ask manufacturers for current photometric data based on commercially-available products for emerging technology streetlights or, when possible, to obtain independent laboratory tests for streetlights under consideration.

Do LEDs and induction streetlights compare favorably with streetlights using conventional HPS and PSMH sources?

In general, HPS and PSMH streetlights provided better value based upon existing design criteria. As LED and induction streetlights become more common, initial costs may decrease, but unless street-side lumen output increases to allow equivalent pole spacing, the higher cost of poles will make any decrease in streetlight price irrelevant.

Appendix A: Testing and Calculation Methodology

This section provides a detailed explanation of how NLPIP tested the 14 sample products listed in this report.

Correlated Color Temperature, Color Rendering and Gamut Area Index

NLPIP evaluated CCT, color rendering index (CRI), and gamut area index (GAI) for this report. GAI describes the color gamut area of eight standard colors illuminated by a given lamp and normalizes the gamut area of an equal energy spectrum to 100. The measured CCT and CRI values for the LED and induction streetlights differed from the manufacturers' claims. The HPS and PSMH streetlights varied little in CCT from the lamp manufacturer's claims, but large discrepancies in CCT (from 80K lower to 3100K higher than claimed) were measured for nearly all the LED and induction streetlights. The LED streetlights, with a few exceptions, had higher CRI values than the manufacturers claimed, while the HPS and PSMH streetlights had lower CRI values than claimed. All of the LED and the induction streetlights had high GAI values (greater than 80). The HPS streetlights had low GAI values (less than 20). Choosing a streetlight with high CRI and high GAI values should provide drivers and pedestrians with better color rendering than high CRI values alone, including hue discrimination (Rea and Freyssinier 2010; Rea and Freyssinier 2008), which may be desirable in such places as downtown areas.

Economics

The organization maintaining the streetlights can choose to conduct spot or group relamping. The relamping method affects the pole spacing as well as the lighting system economics. In this report, NLPIP conservatively assumed group relamping for the light loss factor determination and spot relamping in the economic analyses. NLPIP conducted economic analyses using the following parameters:

- Discount rate: 3% (United States Department of Commerce, Technical Administration and National Institute of Standards and Technology 2008)
- Commercial electricity and end-use price: held constant at US$0.10 per kWh for the entire study period (US DOE 2010)
- Study period (and assumed life of each streetlight): 27 years
- Initial and replacement cost for streetlights and lamps: based on actual purchase price, distributor's quote, or manufacturer's representative quote (except for non-cycling HPS lamps, which cost US$33.88, based on the distributor's quote). Light sources for the LED and induction streetlights were included in the luminaire purchase price
- Steel pole and pole installation cost: based on RS means (Chiang 2006)
- Cleaning cost for all streetlights: based on US$30 per streetlight , a 2.7 year cleaning interval for PSMH streetlights (based on rated life), and a four year cleaning interval for all other streetlights
- Average spot relamping interval for HPS, PSMH, and induction lamps: based on the rated life. Relamping labor cost per streetlight: US$150 (Chiang 2006)
- Group replacement of ballasts and drivers: based on 60,000 hour life, a ballast or driver cost of US$100, and a labor cost of US$38 (except for the induction streetlights where the ballast is included in the lamp replacement costs)

Induction Streetlights and Relative Photometry

The IES recommends that relative photometry be used to measure the light output of outdoor fluorescent luminaires (IESNA 1996). This implies that induction streetlights should be tested using relative photometry because they are a type of fluorescent streetlight. However, NLPIP was unable to use relative photometry for the induction streetlight it tested. The induction system efficacy changed nonlinearly when the lamp was inside the streetlight (63 lm/W) compared to when it was measured at room temperature (59 lm/W). The lamp power was not constant, so the measured lamp lumens could not be scaled to equal the rated lamp lumens as required by relative photometry, and luminaire efficiency and rated luminaire lumens could not be calculated. Some induction lamp manufacturers have recognized this issue (which is due to amalgam tip temperature effects) and recommend special measurement procedures (OSRAM SYLVANIA 2004). Instead, NLPIP used the absolute photometric data for the induction streetlight in the analysis.

Light Loss Factors

Group relamping is a maintenance practice that replaces lamps all at the same time in order to decrease maintenance costs. The publication, *Design Guide for Roadway Lighting Maintenance* DG-4-03 (IESNA 2003), recommends using 66–75% of average rated life as the group relamping interval providing the lowest total costs, including maintenance, energy and installation costs. NLPIP used the middle of this range, 70% of rated lamp life, in order to determine the lamp lumen depreciation values for each source type. Published lumen maintenance curves from leading manufacturers for each lamp type were used to determine the lamp lumen depreciation values of each lamp type at 70% of rated life, with two exceptions. The lumen maintenance curve of a base-up 175W PSMH was used instead of the horizontal 175W PSMH lamp because NLPIP could not find published data for the horizontal lamp. An LLD value of 0.79 was used for the LED streetlights. This value was derived by applying the LLD value of 70% of rated life to the accepted LED definition of rated life (when the streetlight produces 70% of its initial light output). Linear depreciation of light output was assumed because the actual lumen maintenance curves were undetermined.

All streetlights were assumed to operate in clean roadway environments. For the light loss factor analysis, all streetlights except for the PSMH were assumed to be cleaned every four years, the maximum time recommended by DG-4-03 (IESNA 2003) between cleaning intervals. For the PSMH streetlight, a cleaning interval of two years was selected to coincide with the group relamping interval. Therefore, a luminaire dirt depreciation value of 0.88 was used for all streetlight types except for PSMH, for which NLPIP used a luminaire dirt depreciation of 0.92.

Ambient temperature in the field as well as other equipment factors will, to some extent, affect light output, but these effects were not examined in this report because the streetlights were tested only at an ambient temperature of 25°C, in accordance with *Approved Method: Electrical and Photometric Measurements of Solid-State Lighting Products,* LM-79-08 (IESNA 2008).

Lighting Metric Calculations

For the 14 streetlights tested, NLPIP evaluated the photometric files to determine the intensity distribution characteristics using the software program Photometric Toolbox Professional Edition version 1.73 (Lighting Analysts, Inc.).

NLPIP performed application-specific analyses using the photometric files in the Roadway Optimizer tool and created point calculation grids in the lighting software program AGi32 version 2.04 to determine the following: pavement illuminance, illuminance uniformity ratios, veiling luminance ratio (a measure of disability glare), pavement luminance, and vertical illuminance used for the calculation of discomfort glare.

The pole spacing calculations assumed a four-lane roadway, 12 ft (3.7 m) wide lines, and R3 pavement type, which is a road surface classification class given in RP-8. Streetlights were assigned a 6 ft (1.8 m) overhang length and had a height of 27 ft (8.2 m), common dimensions for streetlights with overhead electrical distribution.

Photometric measurements were taken with a calibrated mirror goniometer and were performed on PSMH and HPS lamps supplied by NLPIP after being seasoned for 100 hours. The induction streetlight was also seasoned for 100 hours prior to photometric testing. The LED streetlights were not seasoned, in accordance with LM-79-08 (IESNA 2008). All streetlights were tested at the rated voltage of 120 volts (V); streetlights with multi-tap ballasts were programmed at 120V.

Full 360° goniometric measurements were performed on all 14 streetlights. Vertical measurements were taken in 2.5° increments from 0° to 180° and horizontal measurements were taken in 5° increments, except in the portion of the beam where the candela values appeared to be changing rapidly; in this portion of the beam the horizontal measurements were taken in 2.5° increments. The horizontal information reported in the photometric file was averaged axially and the data reported were from 0° to 180°.

For streetlights with flat lenses, the goniometric center position was located at the center of the opening in the reflector. For streetlights with drop lenses or adjustable wings, the goniometric center was taken at the top of the lens closest to the housing.

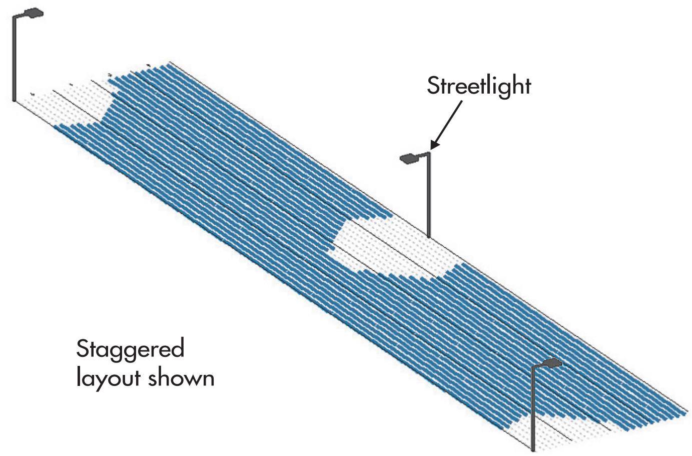
Luminaire System Application Efficacy

Luminaire system application efficacy (LSAE) has been used to evaluate the photometric performance of parking lot, freezer display case and under-cabinet luminaires. NLPIP modified the method used to calculate LSAE for parking lots (ASSIST 2009) to develop a method to calculate LSAE for roadways. An illuminance grid using 2 x 2 ft (0.6 x 0.6 m) point spacing was created in AGi32 to cover the roadway section of one of the streetlight cycles (section of the roadway between two streetlights on the same side of the road) that met all of the RP-8 illuminance method criteria for a staggered layout. Points that were lower than the RP-8 minimum (E_{min}) were not included. E_{min} is not given in RP-8, but is calculated using the following equation:

$$E_{min} = \frac{E_{avg}}{\left(\frac{E_{avg}}{E_{min}}\right)}$$

Starting with the illuminance values equal to or greater than E_{min}, NLPIP calculated the average illuminance (E_{avg}), until the average illuminance met the RP-8 criterion. In some cases the target average illuminance value was not met with more dense point spacing because the points closest to the curb were lower than the uniformity requirements in RP-8. The illuminance values contributing to the target average illuminance, but not exceeding it, were counted as "conforming cells" towards LSAE (see Figure A1). The lumens reaching each cell around the measured value were estimated by multiplying the illuminance value of the point by its area, where the area around each center value equals 4 ft^2 (1.2 m^2). LSAE was calculated by dividing the lumens in the conforming cells by two (because two streetlights contribute towards the lumens per streetlight cycle in a staggered layout) and then dividing by the input power of the tested streetlight. NLPIP found LSAE to be a good evaluation measure of energy efficiency because higher LSAE values were correlated with lower power demand values per mile.

Figure A1. LSAE Method Details



AGi32 illuminance values contributing to the target average illuminance used in LSAE are shown in the blue-shaded roadway area. Illuminance values exceeding the target average illuminance are shown in the light (white) roadway areas.

Stray Light Removal

Photometric measurements always include stray light artifacts because of reflections in the testing laboratory. One method of removing stray light for luminaires for which uplight is optically impossible (for example, streetlights with a flat lens and opaque housing) is to subtract from each intensity value the value measured directly above that luminaire. Instead, NLPIP used a more conservative approach. First, NLPIP determined the maximum amount of stray light found in the upper measurement hemisphere among all of the streetlights for which uplight is optically impossible, which occurred in one of the HPS streetlights. This maximum stray light value was scaled to each streetlight based on the ratio of the total lumens from that HPS streetlight to the total lumens from each streetlight. Finally, this scaled stray light value was subtracted from each measured intensity value, with any negative values set to zero. The maximum amount of stray light removed at any one angle for any streetlight was less than 7 cd.

Unified Photometry and MOVE Mesopic Photometry

To determine the spectral effect on visual efficacy, NLPIP used the unified photometry and the MOVE models. NLPIP used AGi32 to compute a point-by-point photopic pavement luminance grid using the standard roadway observer as defined by RP-8. Pavement luminance was calculated for each streetlight using the maximum pole spacing that met all of the RP-8 illuminance method criteria for staggered streetlight layouts. Each point in the grid was modified by the mesopic visual efficacy equations as defined in the unified photometry model (Rea et al. 2004) and in the MOVE publications. For the MOVE model, NLPIP based its calculations on a MOVE spreadsheet created by Eloholma and Halonen (2005). This spreadsheet is available online at: www.lightinglab.fi/CIETC1-58/files/MOVE_model.xls.

Appendix B: Data Sheets

The data sheets on the following pages provide information about the streetlights tested that were shown in previous tables as well as some extended information and results for each streetlight. The data sheets for each streetlight contain the following information:

- Streetlight manufacturer and catalog number
- Electrical characteristics, IES classification ratings (Rea 2000), and Backlight, Uplight and Glare (BUG) rating (IESNA 2007a)
- Downward street-side lumens, referred to as "street-side lumens"
- A photograph of the streetlight
- Streetlight efficacy
- Price (both streetlight and lamp, if applicable) is US dollars; N/A = not applicable
- SPD and related colorimetry metrics: CCT, CRI, GAI, and scotopic/photopic (S/P) ratio
- The intensity graph shown includes two intensity distribution curves. The red curve shows the horizontal cone drawn at the vertical angle where the maximum candela (max cd) value occurs. The blue curve shows the vertical plane drawn at the horizontal angle where the max cd occurs. These lines are drawn per the *Approved Guide for the Interpretation of Roadway Luminaire Photometric Reports,* LM-69-95 (IESNA 1995).
- Luminaire Classification System graph and associated zonal lumen values (IESNA 2007). Forward light solid angle subzones (which when summed equal the street-side lumens) are shown in green; backlight forward angle subzones are shown in purple; uplight solid angle subzones are shown in red.
- Application results including:
  - Pole spacing to meet RP-8 criteria (collector road, with medium pedestrian conflict, R3 pavement) for both single-sided and staggered layouts
  - Luminaire system application efficacy (LSAE) for the given mounting height
  - LSAE plot that shows LSAE values for a staggered layout with mounting heights between 15 ft (4.6 m) and 50 ft (15 m), with associated pole spacings
  - De Boer ratings in a staggered layout for three ambient lighting conditions (rural, suburban, and urban) when luminaire lumens are scaled to provide the same pole spacing as the average of the three widest spaced HPS streetlights
  - Iso-illuminance plots showing iso-footcandle lines of horizontal illuminance

Intensity distribution curves, Luminaire Classification System graphs, and iso-illuminance plots are adapted from Photometric Toolbox Professional Edition images. The light loss factor (LLF) assumptions described in the report are used in all of the calculations of the application-specific results shown on each data sheet.

Photometric values are rounded to three significant digits, except for values that are less than 100, which are rounded to the nearest integer.

De Boer Scale

9	just noticeable
8	
7	satisfactory
6	
5	just permissible
4	
3	disturbing
2	
1	unbearable

Luminaire Classification System

FL = forward low	FM = forward medium
FH = forward high	FVH = forward very high
BL = backward low	BM = backward medium
BH = backward high	BVH = backward very high
UL = upward low	UH = upward high

Data Sheet

American Electric Lighting
Catalog #115 15S R3 FG

The label on the received streetlight did not match the catalog number of the ordered model.

Lamp type: HPS
Power: 182.1W
Voltage: 120V
Luminaire lumens: 11300*
Street-side lumens: 7430*
Luminaire efficacy: 61.8* lm/W

Lateral class: II
Vertical class: Short
Cutoff class: Full Cutoff
BUG rating: B3-U1-G2*

Electrical
Power factor: 0.96

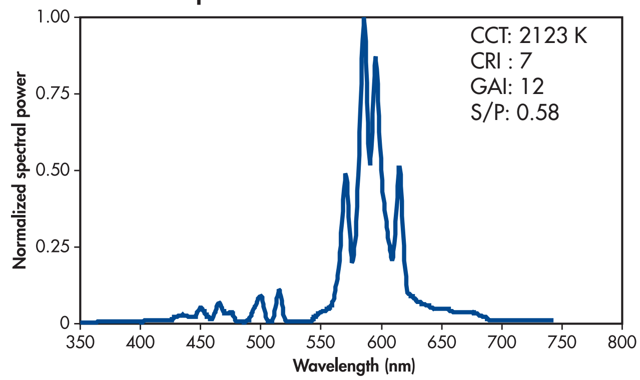
Pricing
Streetlight: $125.00
Lamp: $10.85
Module replacement: N/A

Application
LSAE (27 ft pole height): 16.7* lm/W
Pole spacing (single-sided): 100 ft
Pole spacing (staggered): 195 ft

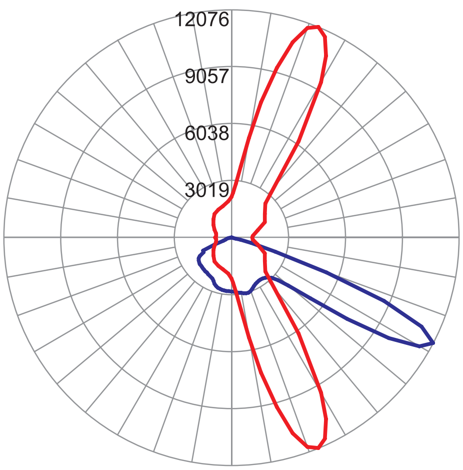
Discomfort Glare
De Boer rating (rural): 2.6
De Boer rating (suburban): 3.0
De Boer rating (urban): 3.4

* Indicates results based on relative photometry

Spectral Power Distribution

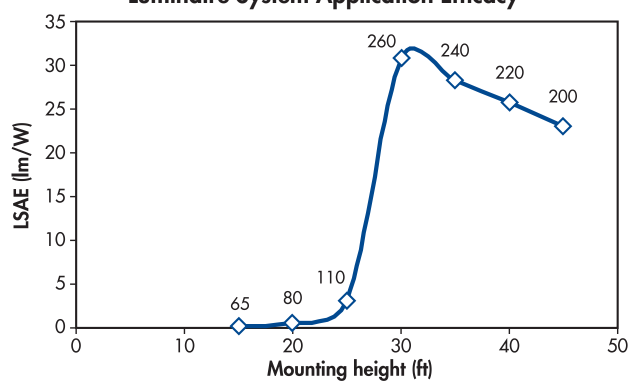


Intensity Distribution Curves



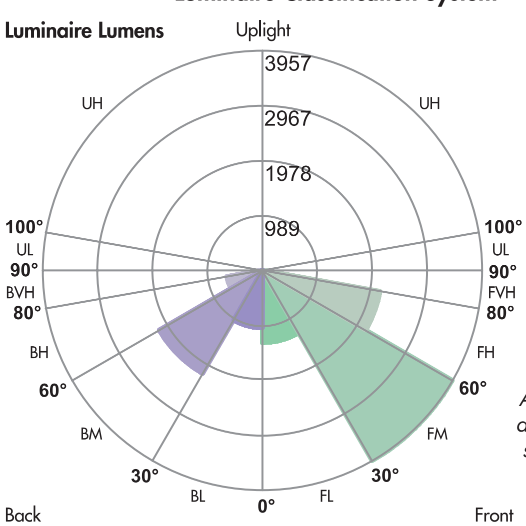
Red line - Horizontal cone through max cd vertical angle
Blue line - Vertical plane through max cd horizontal angle

Luminaire System Application Efficacy



Data labels indicate same-side pole spacing (ft) for staggered configuration

Luminaire Classification System

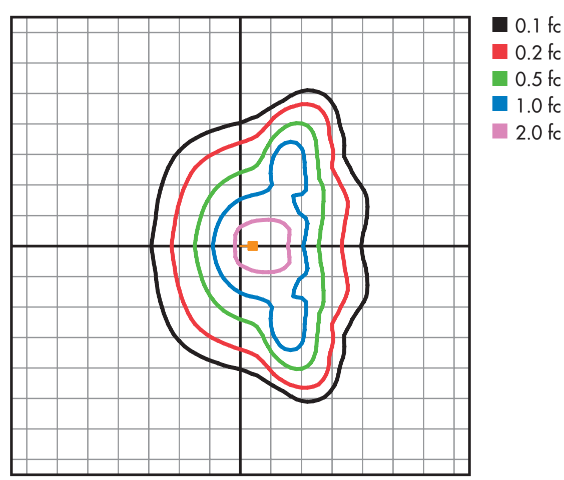


FL: 1300
FM: 3960
FH: 2150
FVH: 18
BL: 1030
BM: 2140
BH: 646
BVH: 11
UL: 0
UH: 0

Values in lumens

Areas FL, FM, FH, and FVH represent street-side lumens

Iso-Illuminance Plot



Template grid = 15 ft x 15 ft
Mounting height = 27 ft
Arm length = 6 ft
LLF= 0.74

Data Sheet

Cooper Lighting

Catalog #OVH15SWW3D4H

Lamp type: HPS
Power: 190.2W
Voltage: 120V
Luminaire lumens: 12100*
Street-side lumens: 9030*
Luminaire efficacy: 63.4* lm/W

Lateral class: II
Vertical class: Short
Cutoff class: Full Cutoff
BUG rating: B2-U1-G2*

Electrical
Power factor: 0.96

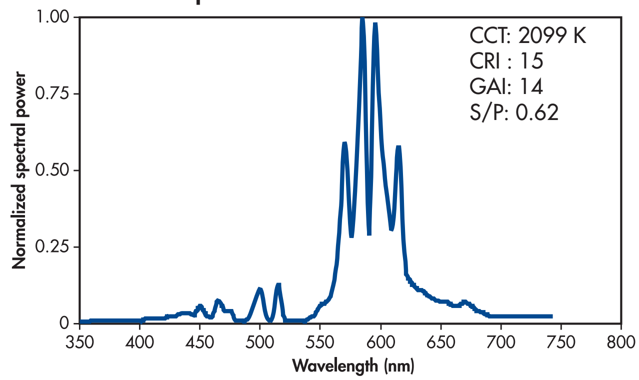
Pricing
Streetlight: $162.15
Lamp: $10.85
Module replacement: N/A

Application
LSAE (27 ft pole height): 23.7* lm/W
Pole spacing (single-sided): 95 ft
Pole spacing (staggered): 245 ft

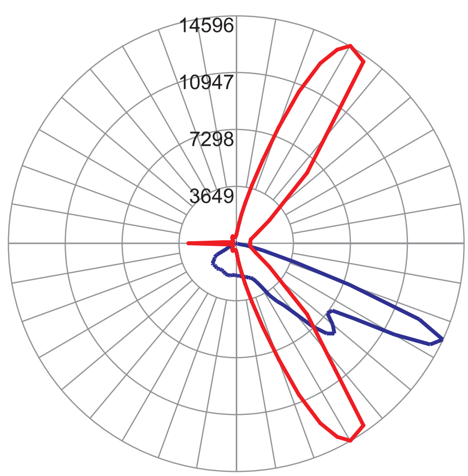
Discomfort Glare
De Boer rating (rural): 2.7
De Boer rating (suburban): 3.1
De Boer rating (urban): 3.5

* Indicates results based on relative photometry

Spectral Power Distribution

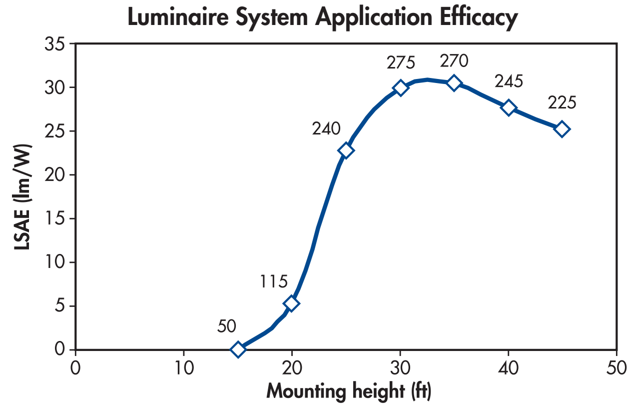


Intensity Distribution Curves



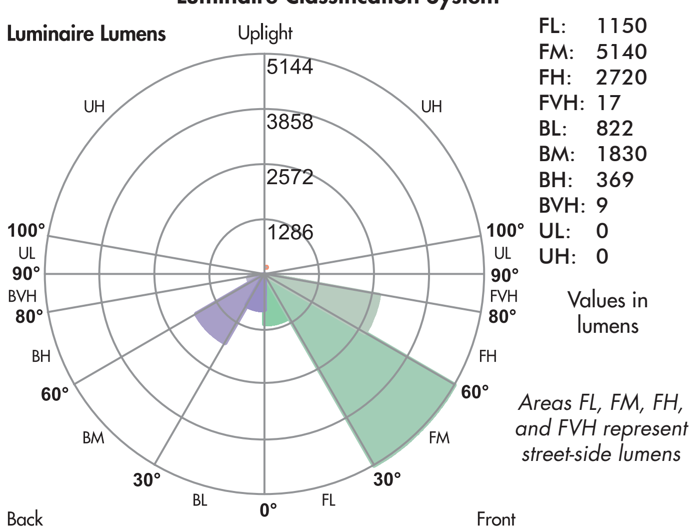
Red line - Horizontal cone through max cd vertical angle
Blue line - Vertical plane through max cd horizontal angle

Luminaire System Application Efficacy

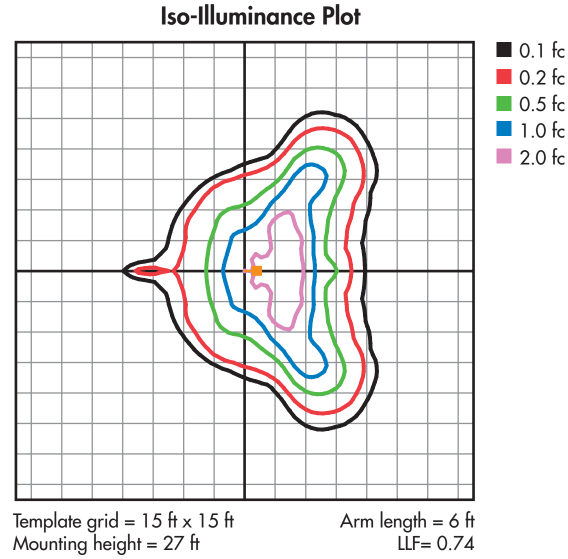


Data labels indicate same-side pole spacing (ft) for staggered configuration

Luminaire Classification System



Iso-Illuminance Plot



Template grid = 15 ft x 15 ft
Mounting height = 27 ft
Arm length = 6 ft
LLF= 0.74

Data Sheet

GE Lighting

Catalog #MDCA 15 S1A2 1F MC3 1F

The label on the received streetlight did not match the catalog number of the ordered model.

Lamp type: HPS
Power: 191.4W
Voltage: 120V
Luminaire lumens: 13400*
Street-side lumens: 8360*
Luminaire efficacy: 69.8* lm/W

Lateral class: II
Vertical class: Medium
Cutoff class: Full Cutoff
BUG rating: B3-U0-G2*

Electrical
Power factor: 0.97

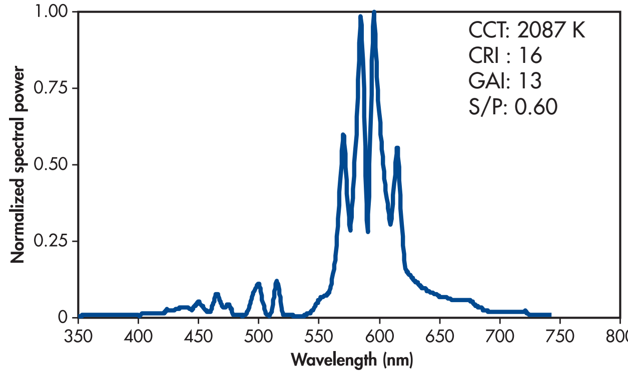
Pricing
Streetlight: $233.45
Lamp: $10.85
Module replacement: N/A

Application
LSAE (27 ft pole height): 25.8* lm/W
Pole spacing (single-sided): 115 ft
Pole spacing (staggered): 260 ft

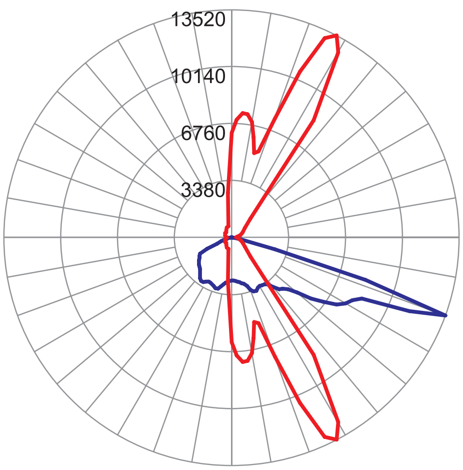
Discomfort Glare
De Boer rating (rural): 2.4
De Boer rating (suburban): 2.7
De Boer rating (urban): 3.0

* Indicates results based on relative photometry

Spectral Power Distribution

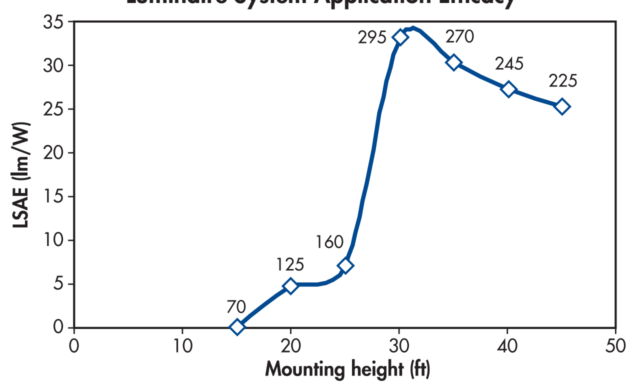


Intensity Distribution Curves



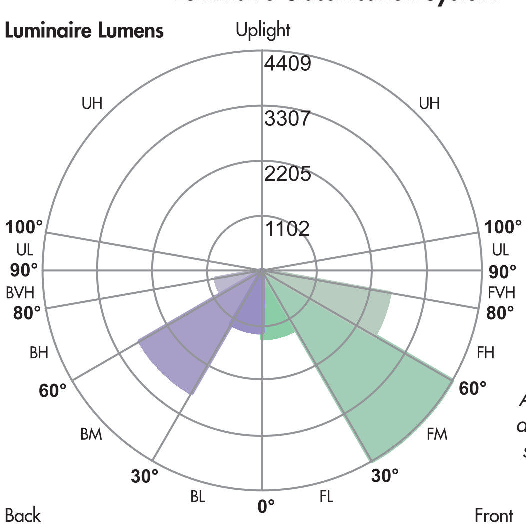
Red line - Horizontal cone through max cd vertical angle
Blue line - Vertical plane through max cd horizontal angle

Luminaire System Application Efficacy



Data labels indicate same-side pole spacing (ft) for staggered configuration

Luminaire Classification System

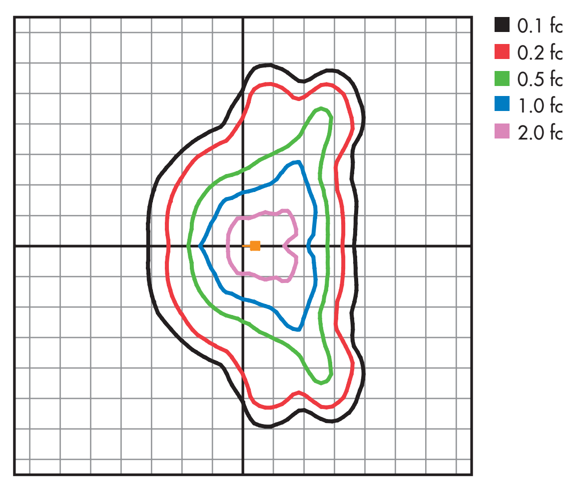


FL: 1350
FM: 4410
FH: 2590
FVH: 10
BL: 1230
BM: 2830
BH: 934
BVH: 7
UL: 0
UH: 0

Values in lumens

Areas FL, FM, FH, and FVH represent street-side lumens

Iso-Illuminance Plot



Template grid = 15 ft x 15 ft
Mounting height = 27 ft
Arm length = 6 ft
LLF= 0.74

Data Sheet

Holophane

Catalog #G-15AHP-12-L-NF-H-G-F1

Lamp type: HPS
Power: 178.4W
Voltage: 120V
Luminaire lumens: 12100*
Street-side lumens: 7810*
Luminaire efficacy: 67.9* lm/W

Lateral class: I
Vertical class: Medium
Cutoff class: Full Cutoff
BUG rating: B3-U1-G2*

Electrical
Power factor: 0.98

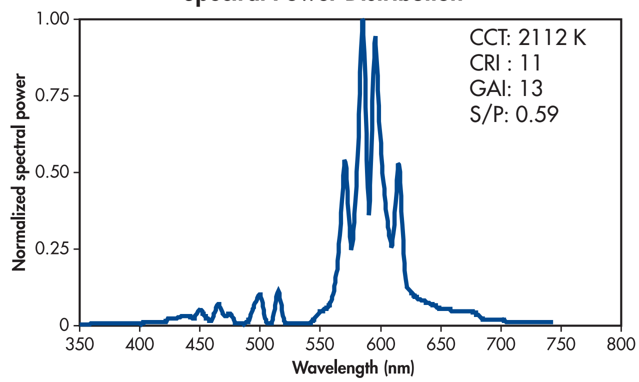
Pricing
Streetlight: $525.00
Lamp: $10.85
Module replacement: N/A

Application
LSAE (27 ft pole height): 7.0* lm/W
Pole spacing (single-sided): 75 ft
Pole spacing (staggered): 165 ft

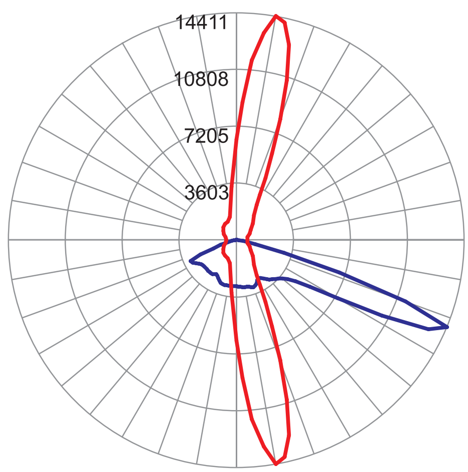
Discomfort Glare
De Boer rating (rural): 2.7
De Boer rating (suburban): 3.1
De Boer rating (urban): 3.5

* Indicates results based on relative photometry

Spectral Power Distribution

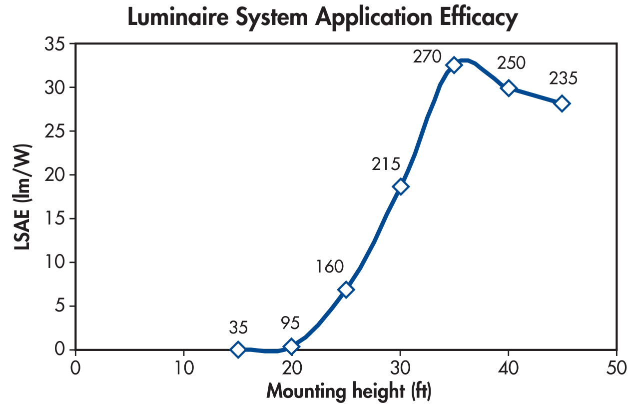


Intensity Distribution Curves



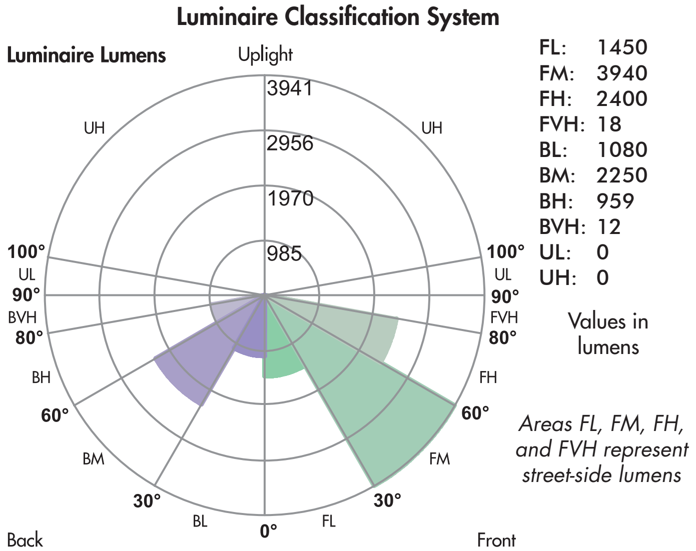
Red line - Horizontal cone through max cd vertical angle
Blue line - Vertical plane through max cd horizontal angle

Luminaire System Application Efficacy

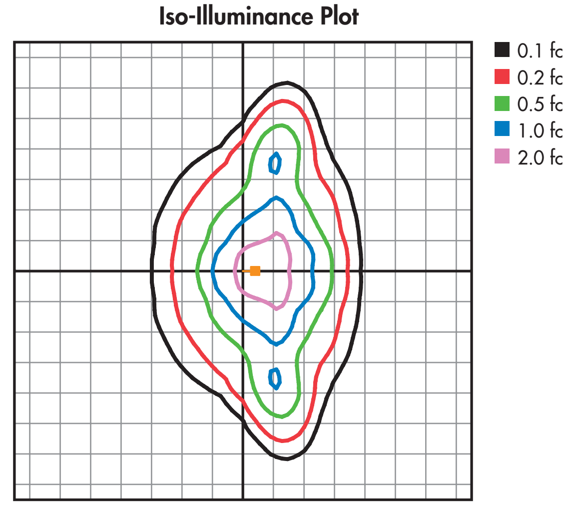


Data labels indicate same-side pole spacing (ft) for staggered configuration

Luminaire Classification System



Iso-Illuminance Plot



Template grid = 15 ft x 15 ft
Mounting height = 27 ft
Arm length = 6 ft
LLF= 0.74

Data Sheet

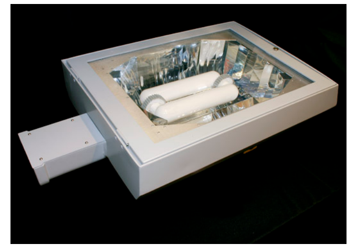
Visionaire

Catalog #POL-R1-2-T3R-120T-5K-IND-120-MAF-02-GY-PCR120

The label on the received streetlight did not match the catalog number of the ordered model.

Lamp type: Induction
Power: 121.7W
Voltage: 120V
Luminaire lumens: 6960
Street-side lumens: 3800
Luminaire efficacy: 57.2 lm/W

Lateral class: III
Vertical class: Very Short
Cutoff class: Full Cutoff
BUG rating: B2-U1-G2



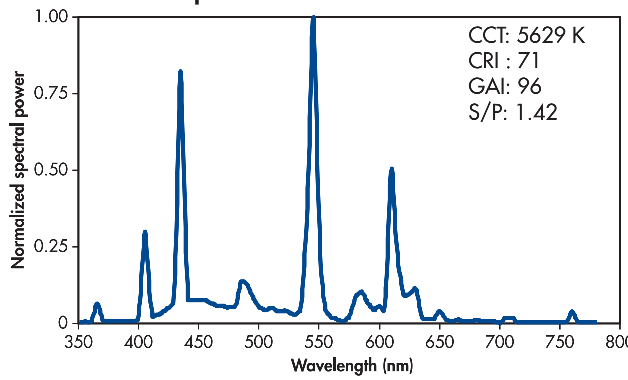
Electrical
Power factor: 1

Pricing
Streetlight: $786.65
Lamp: N/A
Module replacement: $585.00

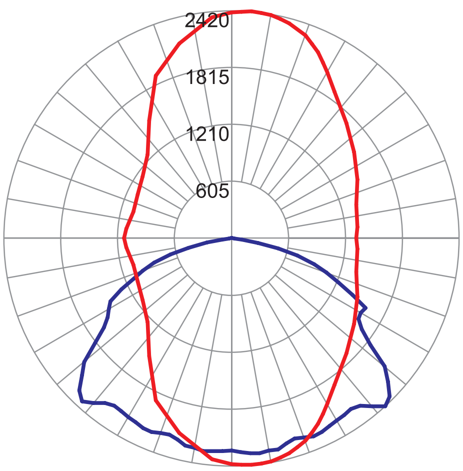
Application
LSAE (27 ft pole height): 21 lm/W
Pole spacing (single-sided): 60 ft
Pole spacing (staggered): 120 ft

Discomfort Glare
De Boer rating (rural): 2.4
De Boer rating (suburban): 2.7
De Boer rating (urban): 3.1

Spectral Power Distribution

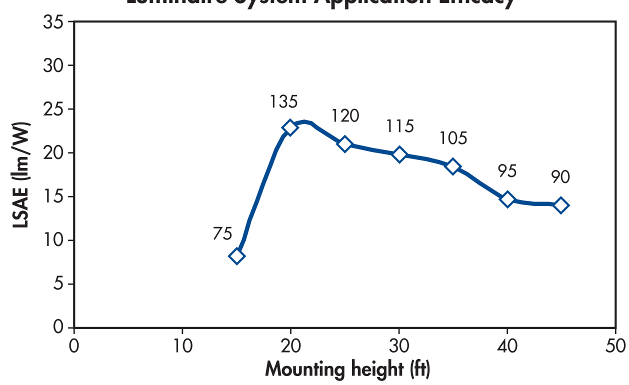


Intensity Distribution Curves



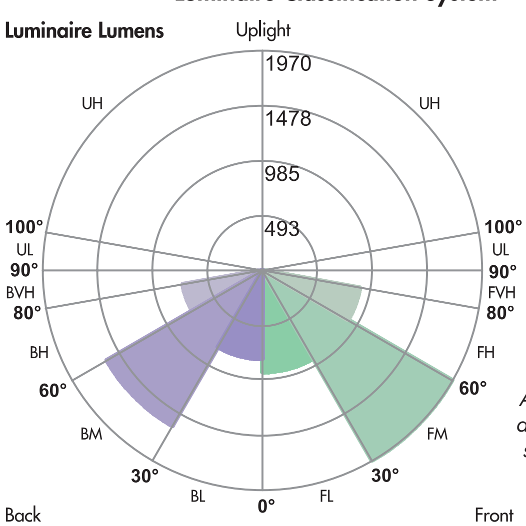
Red line - Horizontal cone through max cd vertical angle
Blue line - Vertical plane through max cd horizontal angle

Luminaire System Application Efficacy



Data labels indicate same-side pole spacing (ft) for staggered configuration

Luminaire Classification System

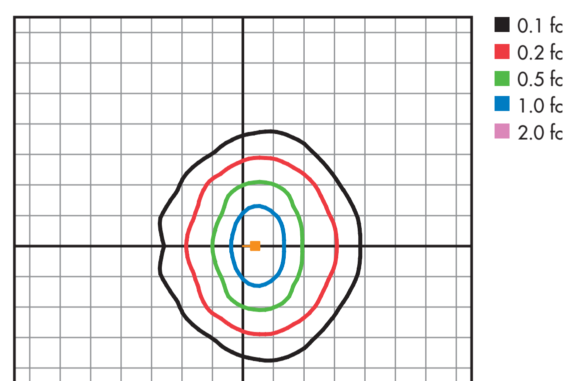


FL: 913
FM: 1970
FH: 889
FVH: 32
BL: 793
BM: 1610
BH: 724
BVH: 23
UL: 0
UH: 0

Values in lumens

Areas FL, FM, FH, and FVH represent street-side lumens

Iso-Illuminance Plot



Template grid = 15 ft x 15 ft
Mounting height = 27 ft

Arm length = 6 ft
LLF= 0.62

Data Sheet

Beta Lighting

Catalog #BLD-ARE-T3-DA-051-LED-B-UL-SV

The label on the received streetlight did not match the catalog number of the ordered model.

Lamp type: LED
Power: 70.3W
Voltage: 120V
Luminaire lumens: 4820
Street-side lumens: 2730
Luminaire efficacy: 68.6 lm/W

Lateral class: III
Vertical class: Short
Cutoff class: Cutoff
BUG rating: B2-U1-G1

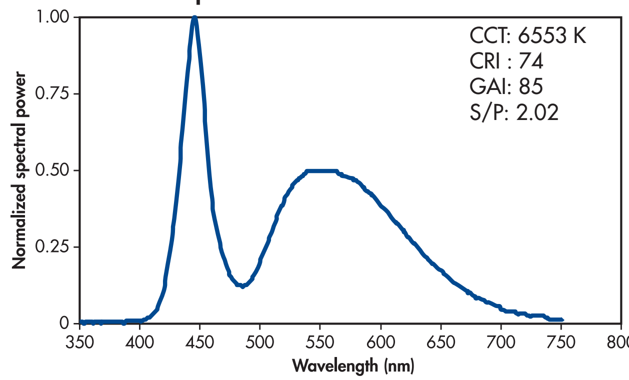
Electrical
Power factor: 0.99

Pricing
Streetlight: $833.75
Lamp: N/A
Module replacement: $600.00

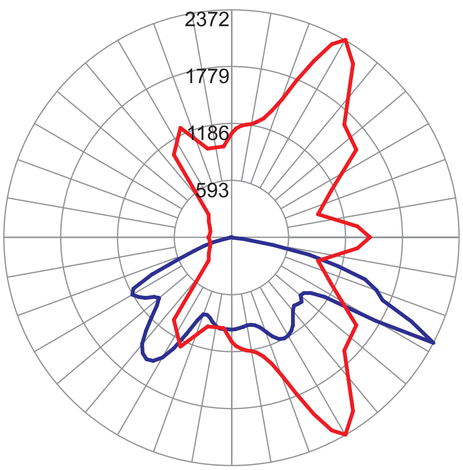
Application
LSAE (27 ft pole height): 27.3 lm/W
Pole spacing (single-sided): 45 ft
Pole spacing (staggered): 90 ft

Discomfort Glare
De Boer rating (rural): 2.2
De Boer rating (suburban): 2.5
De Boer rating (urban): 2.9

Spectral Power Distribution

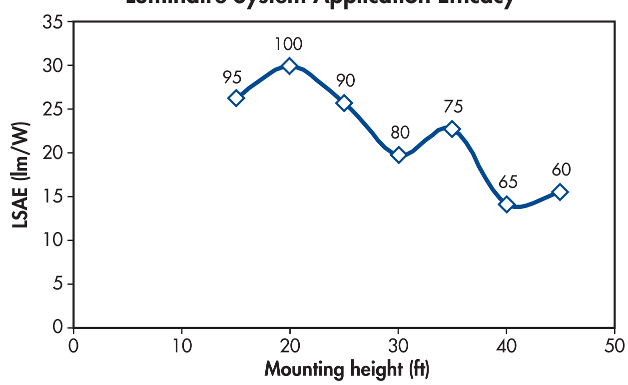


Intensity Distribution Curves



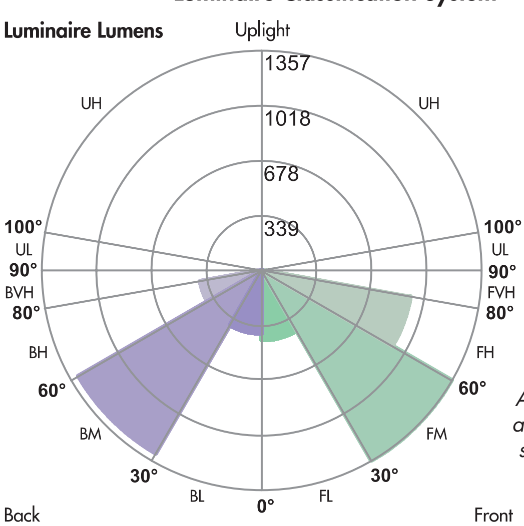
Red line - Horizontal cone through max cd vertical angle
Blue line - Vertical plane through max cd horizontal angle

Luminaire System Application Efficacy



Data labels indicate same-side pole spacing (ft) for staggered configuration

Luminaire Classification System

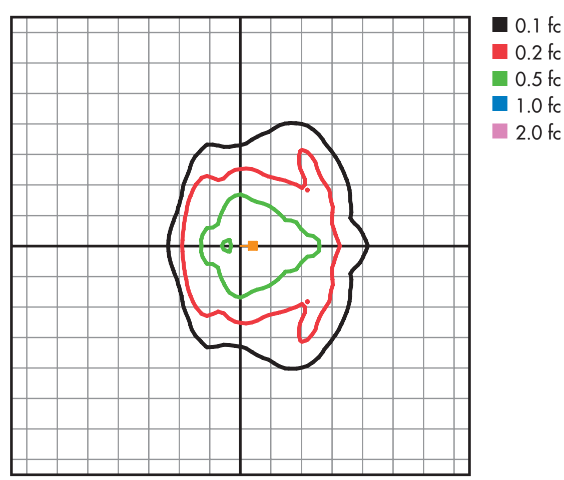


FL: 431
FM: 1360
FH: 934
FVH: 13
BL: 390
BM: 1300
BH: 384
BVH: 8
UL: 0
UH: 0

Values in lumens

Areas FL, FM, FH, and FVH represent street-side lumens

Iso-Illuminance Plot



Template grid = 15 ft x 15 ft
Mounting height = 27 ft
Arm length = 6 ft
LLF= 0.7

Data Sheet

Beta Lighting

Catalog #BLD-STR-T3-HT-042-LED-B-UL-SV

The label on the received streetlight did not match the catalog number of the ordered model.

Lamp type: LED
Power: 88.9W
Voltage: 120V
Luminaire lumens: 5730
Street-side lumens: 3250
Luminaire efficacy: 64.5 lm/W

Lateral class: III
Vertical class: Short
Cutoff class: Semi-Cutoff
BUG rating: B2-U1-G2

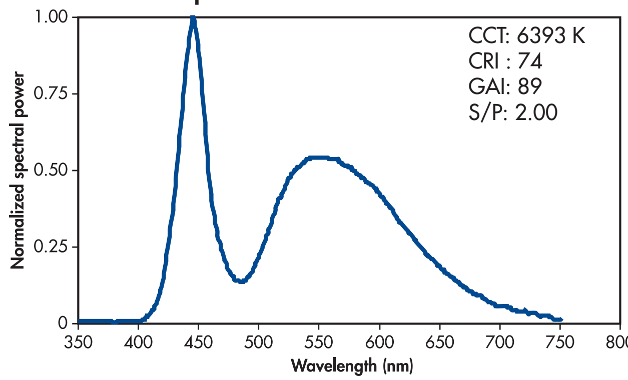
Electrical
Power factor: 0.99

Pricing
Streetlight: $607.20
Lamp: N/A
Module replacement: $600.00

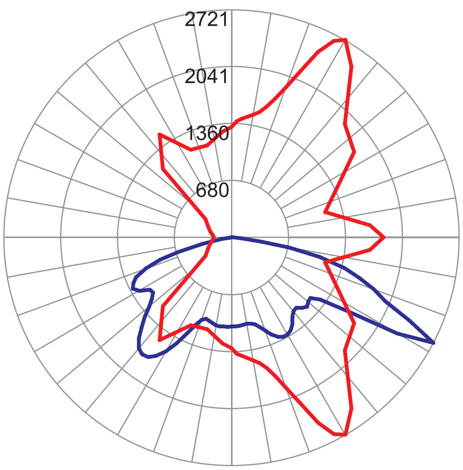
Application
LSAE (27 ft pole height): 24.8 lm/W
Pole spacing (single-sided): 50 ft
Pole spacing (staggered): 105 ft

Discomfort Glare
De Boer rating (rural): 2.3
De Boer rating (suburban): 2.6
De Boer rating (urban): 2.9

Spectral Power Distribution

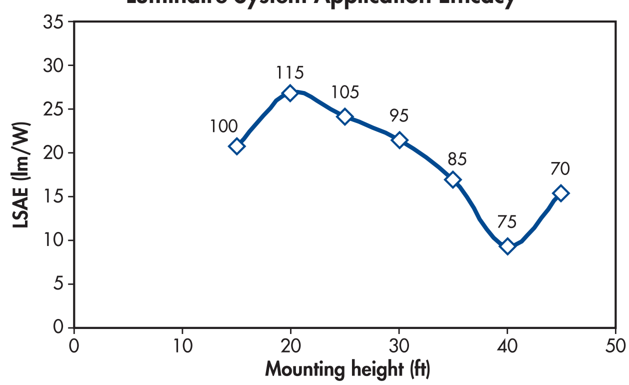


Intensity Distribution Curves



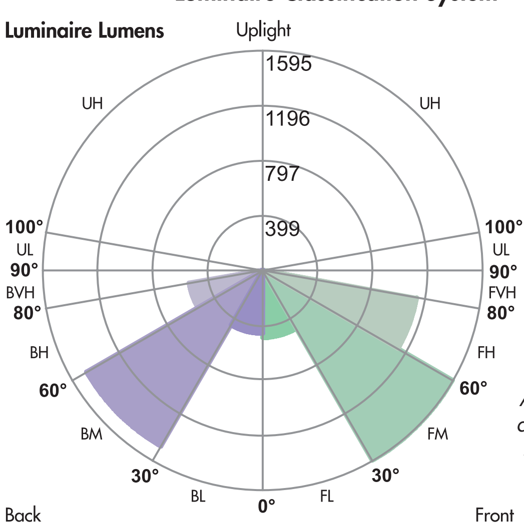
Red line - Horizontal cone through max cd vertical angle
Blue line - Vertical plane through max cd horizontal angle

Luminaire System Application Efficacy



Data labels indicate same-side pole spacing (ft) for staggered configuration

Luminaire Classification System

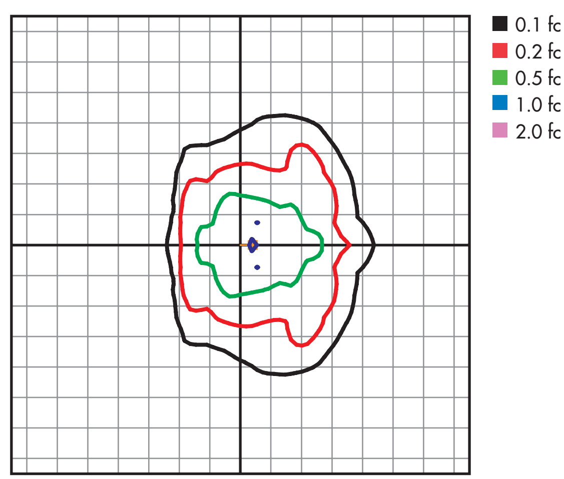


FL: 488
FM: 1590
FH: 1140
FVH: 34
BL: 458
BM: 1480
BH: 541
BVH: 8
UL: 0
UH: 0

Values in lumens

Areas FL, FM, FH, and FVH represent street-side lumens

Iso-Illuminance Plot



Template grid = 15 ft x 15 ft
Mounting height = 27 ft
Arm length = 6 ft
LLF= 0.7

Data Sheet

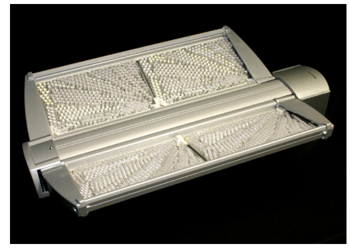
Elumen Lighting Networks

Catalog #LED-SL-66W-A-W-3

The label on the received streetlight did not match the catalog number of the ordered model.

Lamp type: LED
Power: 73.4W
Voltage: 120V
Luminaire lumens: 4760
Street-side lumens: 3750
Luminaire efficacy: 64.9 lm/W

Lateral class: II
Vertical class: Short
Cutoff class: Non-Cutoff
BUG rating: B1-U2-G1



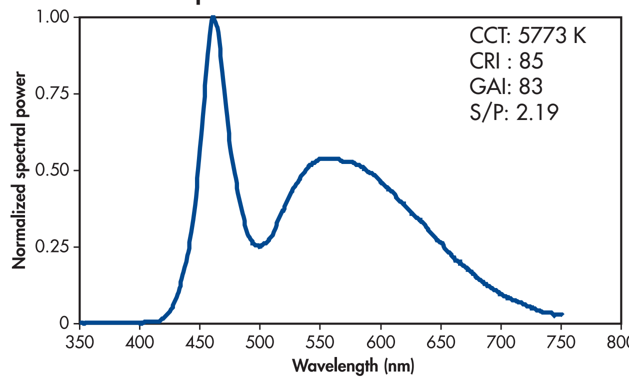
Electrical
Power factor: 0.99

Pricing
Streetlight: $895.00
Lamp: N/A
Module replacement: $1,200.00

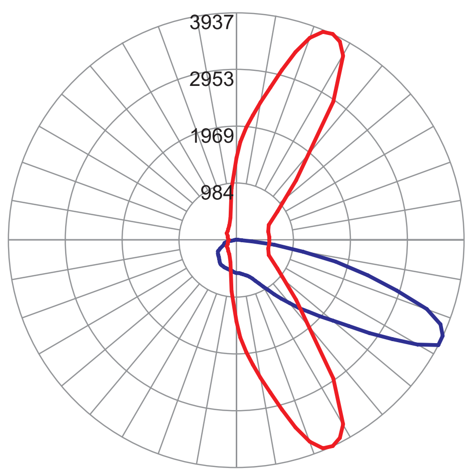
Application
LSAE (27 ft pole height): 33.3 lm/W
Pole spacing (single-sided): 55 ft
Pole spacing (staggered): 115 ft

Discomfort Glare
De Boer rating (rural): 2.9
De Boer rating (suburban): 3.3
De Boer rating (urban): 3.8

Spectral Power Distribution

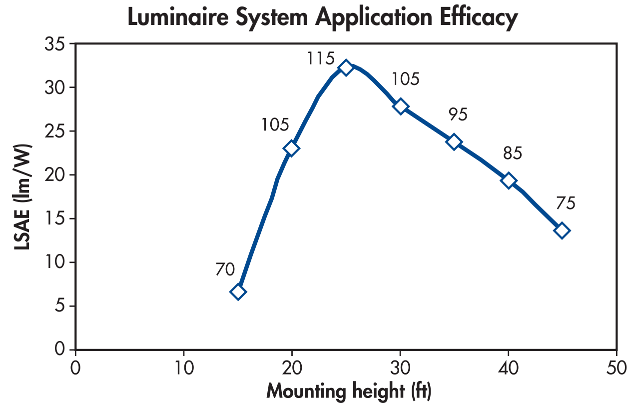


Intensity Distribution Curves



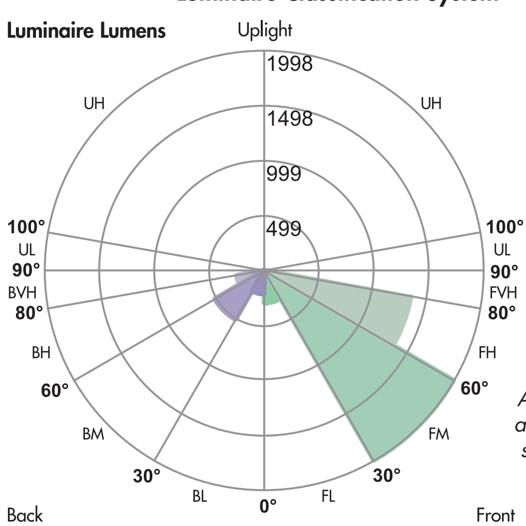
Red line - Horizontal cone through max cd vertical angle
Blue line - Vertical plane through max cd horizontal angle

Luminaire System Application Efficacy



Data labels indicate same-side pole spacing (ft) for staggered configuration

Luminaire Classification System

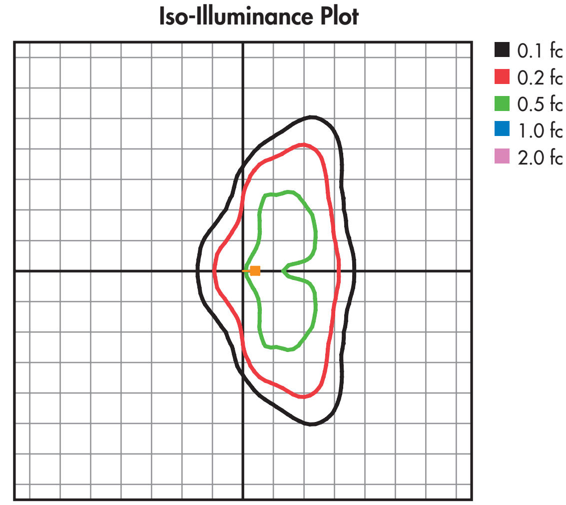


FL: 296
FM: 2000
FH: 1360
FVH: 97
BL: 214
BM: 516
BH: 253
BVH: 27
UL: 3
UH: 0

Values in lumens

Areas FL, FM, FH, and FVH represent street-side lumens

Iso-Illuminance Plot



Template grid = 15 ft x 15 ft
Mounting height = 27 ft
Arm length = 6 ft
LLF= 0.7

Data Sheet

GE Lighting

Catalog #EAMT-0-W3-F-60-A-1-C-BLCK

Lamp type: LED
Power: 138.2W
Voltage: 120V
Luminaire lumens: 7120
Street-side lumens: 4830
Luminaire efficacy: 51.5 lm/W

Lateral class: IV
Vertical class: Short
Cutoff class: Full Cutoff
BUG rating: B3-U1-G3

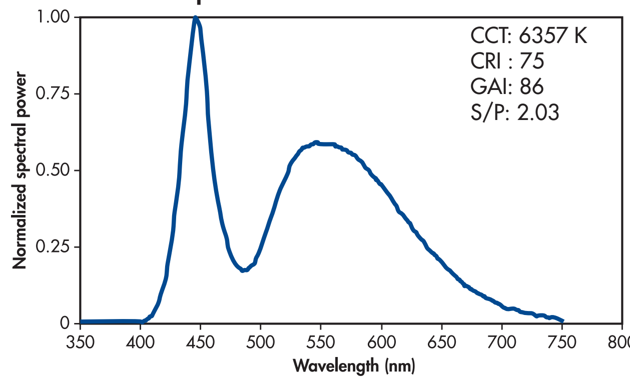
Electrical
Power factor: 0.99

Pricing
Streetlight: $1,176.49
Lamp: N/A
Module replacement: $600.00

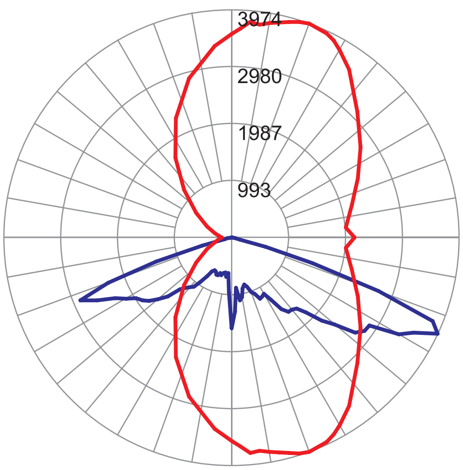
Application
LSAE (27 ft pole height): 21.7 lm/W
Pole spacing (single-sided): 70 ft
Pole spacing (staggered): 140 ft

Discomfort Glare
De Boer rating (rural): 2.9
De Boer rating (suburban): 3.3
De Boer rating (urban): 3.7

Spectral Power Distribution

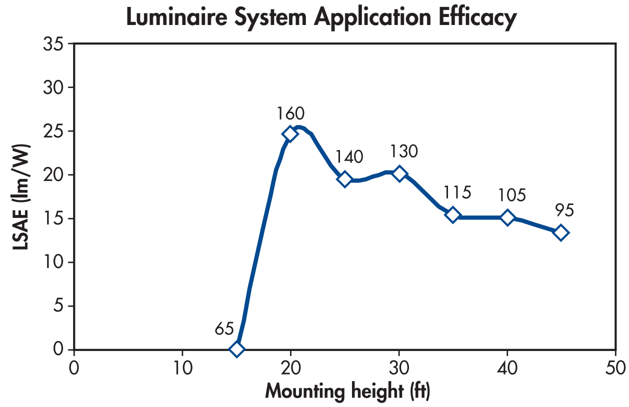


Intensity Distribution Curves



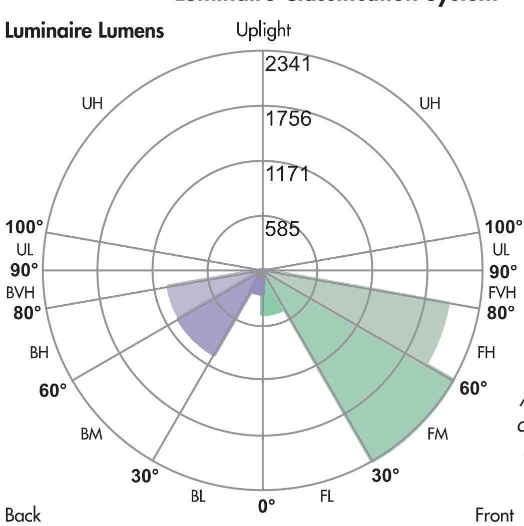
Red line - Horizontal cone through max cd vertical angle
Blue line - Vertical plane through max cd horizontal angle

Luminaire System Application Efficacy



Data labels indicate same-side pole spacing (ft) for staggered configuration

Luminaire Classification System

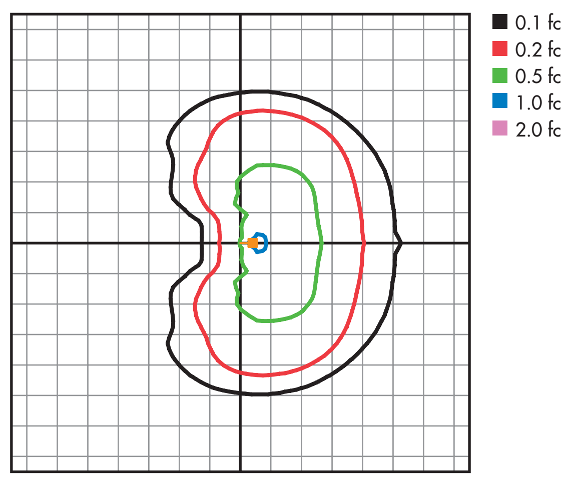


FL: 461
FM: 2340
FH: 2000
FVH: 26
BL: 241
BM: 1030
BH: 1010
BVH: 9
UL: 0
UH: 0

Values in lumens

Areas FL, FM, FH, and FVH represent street-side lumens

Iso-Illuminance Plot



Template grid = 15 ft x 15 ft
Mounting height = 27 ft
Arm length = 6 ft
LLF= 0.7

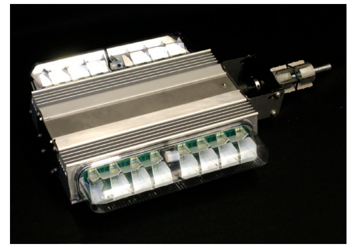
Data Sheet

IntenCity Lighting

Catalog #SL50

Lamp type: LED
Power: 87W
Voltage: 120V
Luminaire lumens: 4340
Street-side lumens: 3100
Luminaire efficacy: 49.9 lm/W

Lateral class: II
Vertical class: Short
Cutoff class: Semi-Cutoff
BUG rating: B1-U2-G1



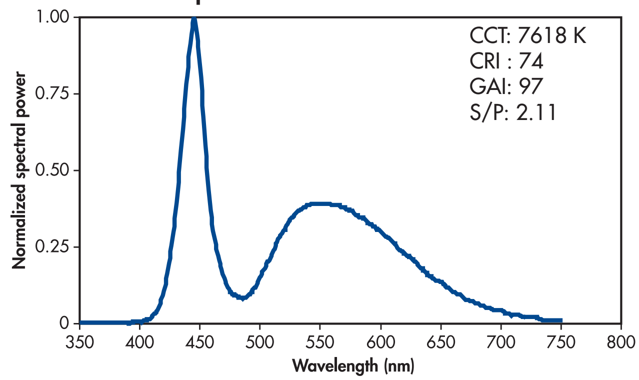
Electrical
Power factor: 0.98

Pricing
Streetlight: $890.00
Lamp: N/A
Module replacement: $150.00

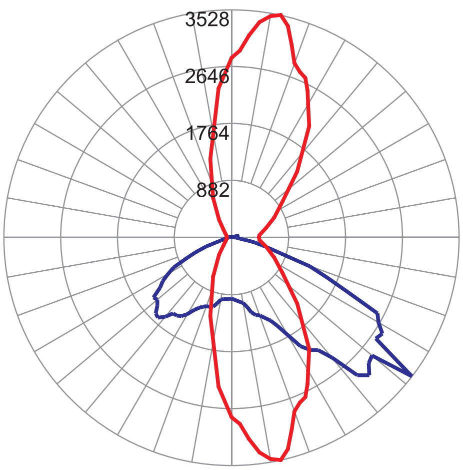
Application
LSAE (27 ft pole height): 27.3 lm/W
Pole spacing (single-sided): 55 ft
Pole spacing (staggered): 110 ft

Discomfort Glare
De Boer rating (rural): 3.2
De Boer rating (suburban): 3.6
De Boer rating (urban): 4.1

Spectral Power Distribution

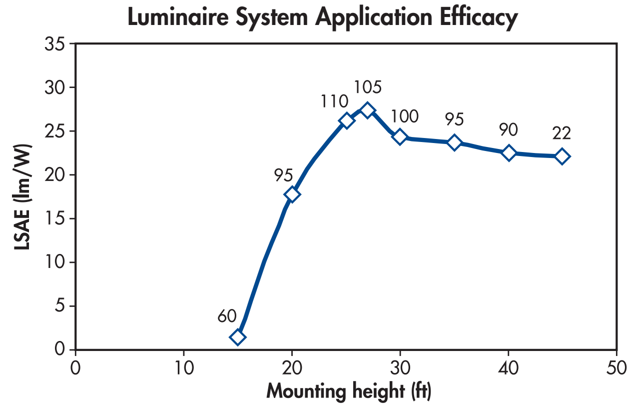


Intensity Distribution Curves



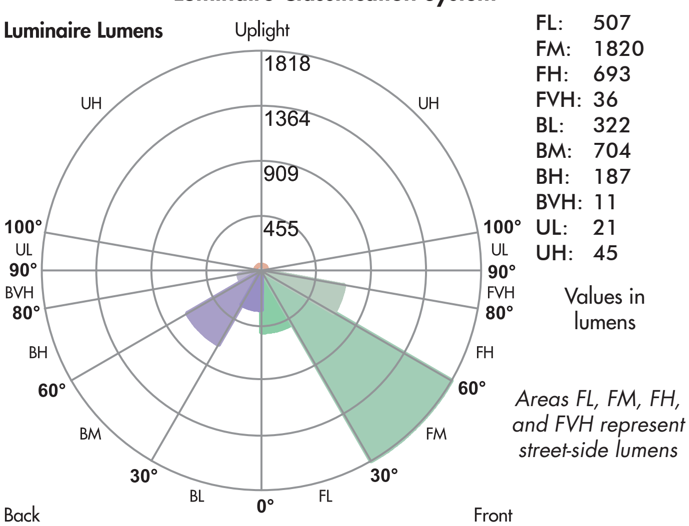
Red line - Horizontal cone through max cd vertical angle
Blue line - Vertical plane through max cd horizontal angle

Luminaire System Application Efficacy

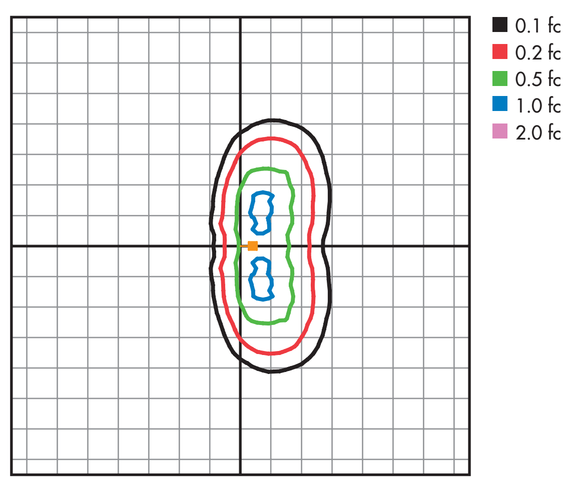


Data labels indicate same-side pole spacing (ft) for staggered configuration

Luminaire Classification System



Iso-Illuminance Plot



Template grid = 15 ft x 15 ft
Mounting height = 27 ft
Arm length = 6 ft
LLF= 0.7

Data Sheet

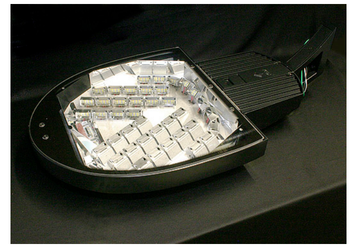
Kim Lighting

Catalog #1SA/WP9LE3/
L5K120/BL

The label on the received streetlight did not match the catalog number of the ordered model.

Lamp type: LED
Power: 194.8W
Voltage: 120V
Luminaire lumens: 5260
Street-side lumens: 4100
Luminaire efficacy: 27.0 lm/W

Lateral class: IV
Vertical class: Short
Cutoff class: Semi-Cutoff
BUG rating: B1-U1-G2



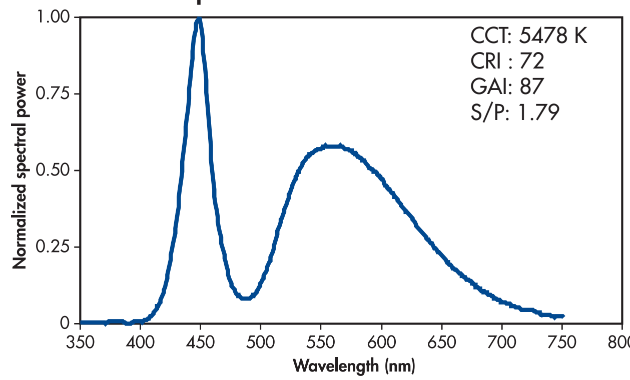
Electrical
Power factor: 0.99

Pricing
Streetlight: $1,620.00
Lamp: N/A
Module replacement: $900.00

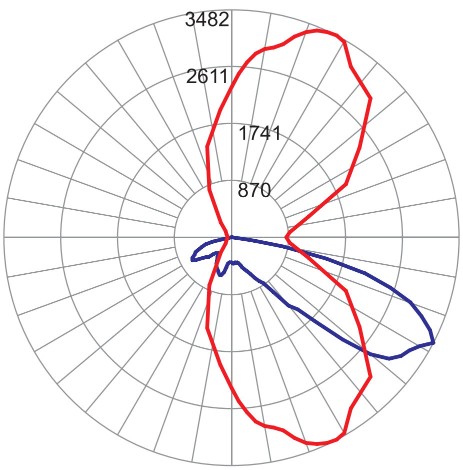
Application
LSAE (27 ft pole height): 15.4 lm/W
Pole spacing (single-sided): 55 ft
Pole spacing (staggered): 115 ft

Discomfort Glare
De Boer rating (rural): 3.0
De Boer rating (suburban): 3.4
De Boer rating (urban): 3.9

Spectral Power Distribution

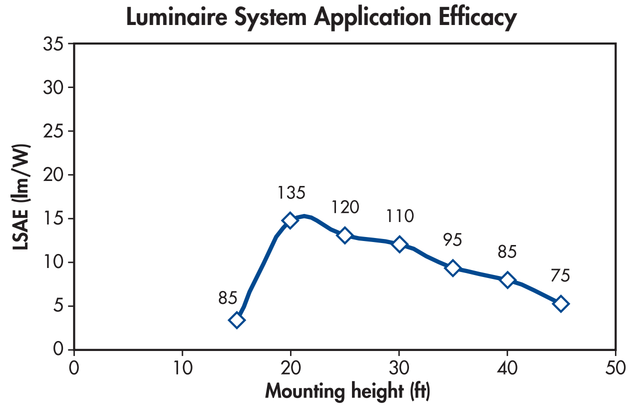


Intensity Distribution Curves



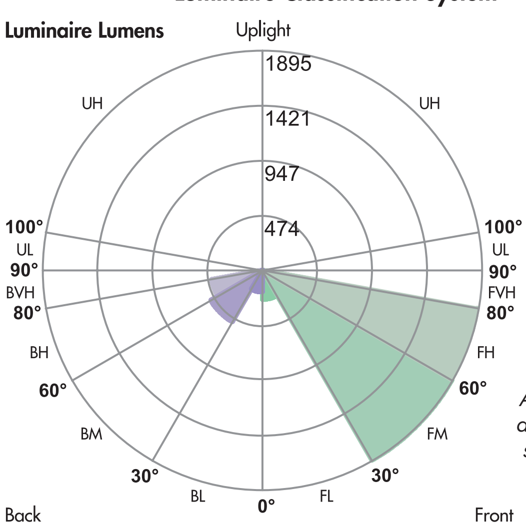
Red line - Horizontal cone through max cd vertical angle
Blue line - Vertical plane through max cd horizontal angle

Luminaire System Application Efficacy



Data labels indicate same-side pole spacing (ft) for staggered configuration

Luminaire Classification System

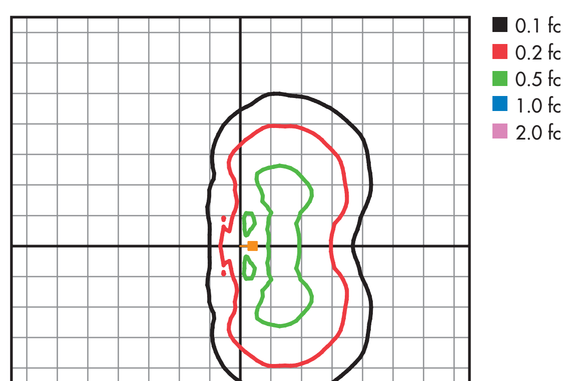


FL: 250
FM: 1890
FH: 1890
FVH: 71
BL: 187
BM: 513
BH: 443
BVH: 16
UL: 0
UH: 0

Values in lumens

Areas FL, FM, FH, and FVH represent street-side lumens

Iso-Illuminance Plot



Template grid = 15 ft x 15 ft
Mounting height = 27 ft
Arm length = 6 ft
LLF= 0.7

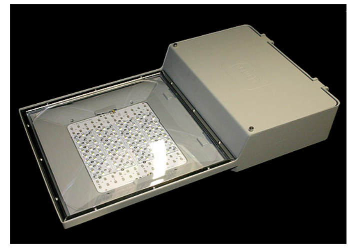
Data Sheet

Leotek Electronics

Catalog #SLN-084-MV-CW-3M-GY

Lamp type: LED
Power: 77.8W
Voltage: 120V
Luminaire lumens: 5840
Street-side lumens: 3420
Luminaire efficacy: 75.1 lm/W

Lateral class: III
Vertical class: Medium
Cutoff class: Cutoff
BUG rating: B2-U1-G2



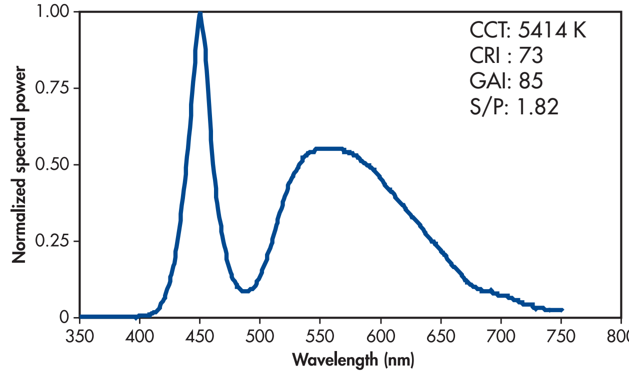
Electrical
Power factor: 0.99

Pricing
Streetlight: $877.50
Lamp: N/A
Module replacement: $250.00

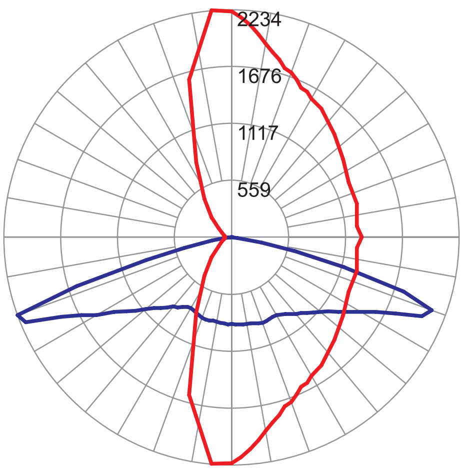
Application
LSAE (27 ft pole height): 27.2 lm/W
Pole spacing (single-sided): 45 ft
Pole spacing (staggered): 100 ft

Discomfort Glare
De Boer rating (rural): 2.3
De Boer rating (suburban): 2.6
De Boer rating (urban): 3.0

Spectral Power Distribution

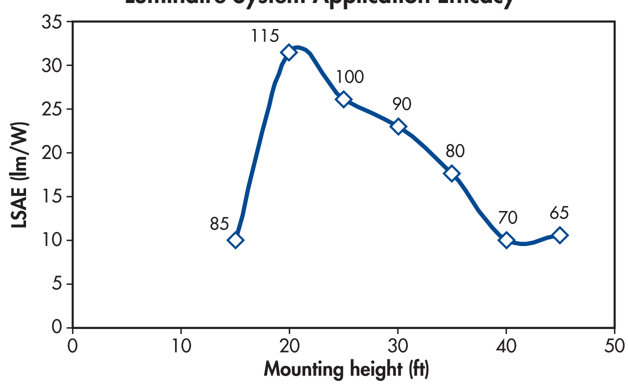


Intensity Distribution Curves



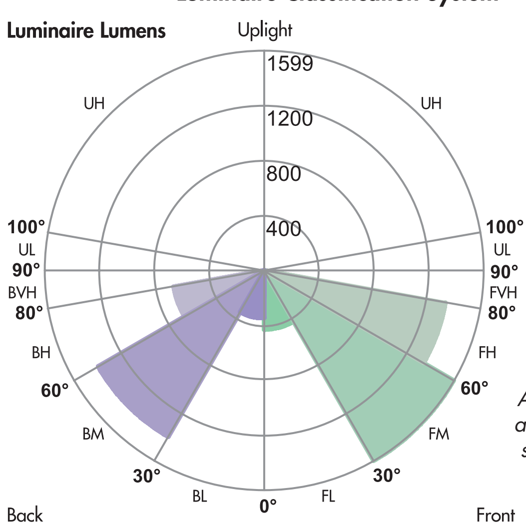
Red line - Horizontal cone through max cd vertical angle
Blue line - Vertical plane through max cd horizontal angle

Luminaire System Application Efficacy



Data labels indicate same-side pole spacing (ft) for staggered configuration

Luminaire Classification System

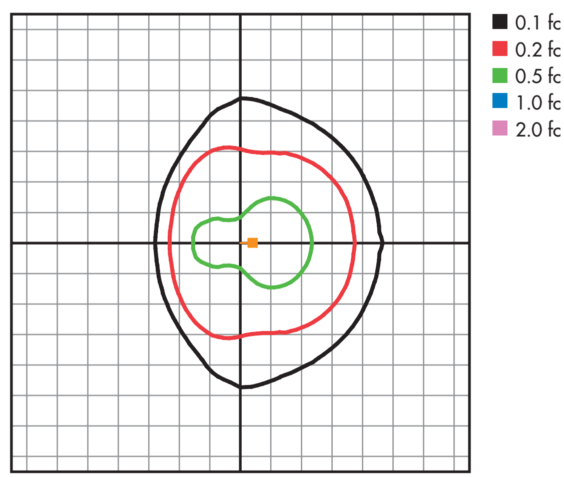


FL: 428
FM: 1600
FH: 1340
FVH: 48
BL: 346
BM: 1398
BH: 669
BVH: 8
UL: 3
UH: 0

Values in lumens

Areas FL, FM, FH, and FVH represent street-side lumens

Iso-Illuminance Plot



Template grid = 15 ft x 15 ft
Mounting height = 27 ft
Arm length = 6 ft
LLF= 0.7

Data Sheet

Philips Hadco

Catalog #WL66-HT-I-3-N-R

Lamp type: LED
Power: 74.1W
Voltage: 120V
Luminaire lumens: 4410
Street-side lumens: 3460
Luminaire efficacy: 59.5 lm/W

Lateral class: III
Vertical class: Medium
Cutoff class: Non-Cutoff
BUG rating: B1-U2-G1

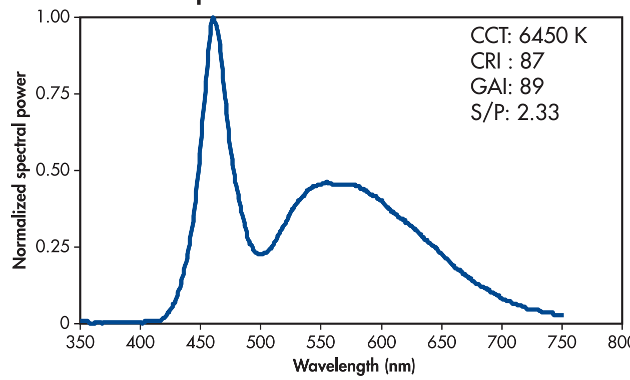
Electrical
Power factor: 0.99

Pricing
Streetlight: $1,218.00
Lamp: N/A
Module replacement: $900.00

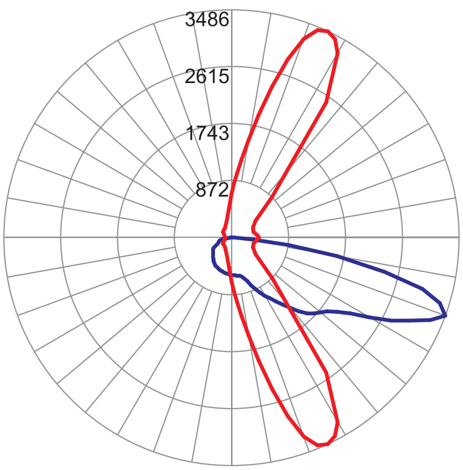
Application
LSAE (27 ft pole height): 29.6 lm/W
Pole spacing (single-sided): 50 ft
Pole spacing (staggered): 105 ft

Discomfort Glare
De Boer rating (rural): 2.9
De Boer rating (suburban): 3.2
De Boer rating (urban): 3.7

Spectral Power Distribution

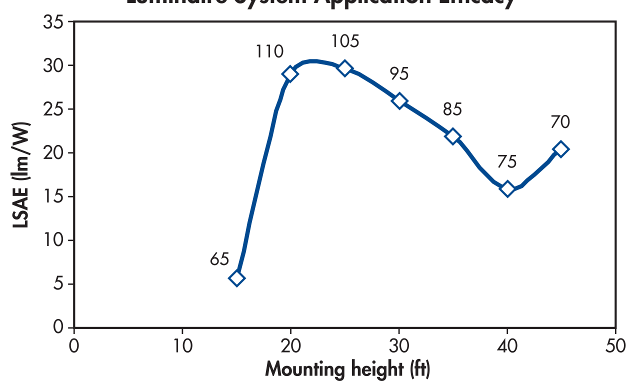


Intensity Distribution Curves



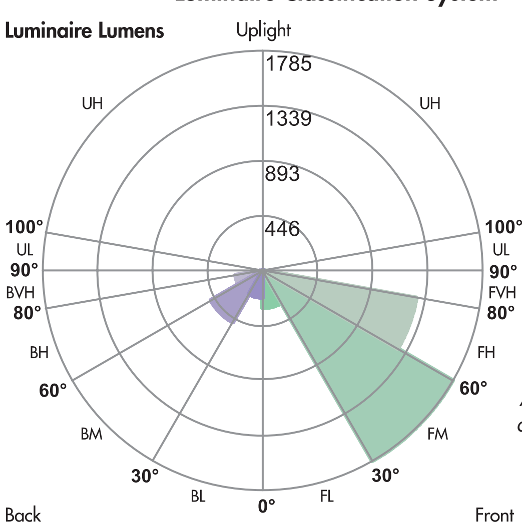
Red line - Horizontal cone through max cd vertical angle
Blue line - Vertical plane through max cd horizontal angle

Luminaire System Application Efficacy



Data labels indicate same-side pole spacing (ft) for staggered configuration

Luminaire Classification System

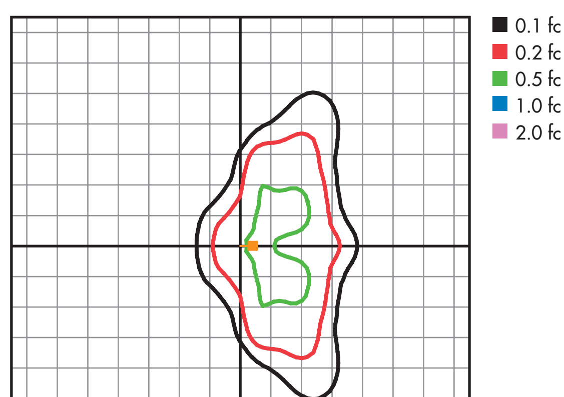


FL: 301
FM: 1790
FH: 1270
FVH: 108
BL: 216
BM: 482
BH: 220
BVH: 25
UL: 3
UH: 0

Values in lumens

Areas FL, FM, FH, and FVH represent street-side lumens

Iso-Illuminance Plot



Template grid = 15 ft x 15 ft
Mounting height = 27 ft
Arm length = 6 ft
LLF= 0.7

Data Sheet

GE Lighting

Catalog #MDCA 17 E0A1 1FMC3 1

Lamp type: PSMH
Power: 194.8W
Voltage: 120V
Luminaire lumens: 10300*
Street-side lumens: 6120*
Luminaire efficacy: 52.9 lm/W

Lateral class: III
Vertical class: Medium
Cutoff class: Full Cutoff
BUG rating: B2-U1-G2*

Electrical
Power factor: 0.98

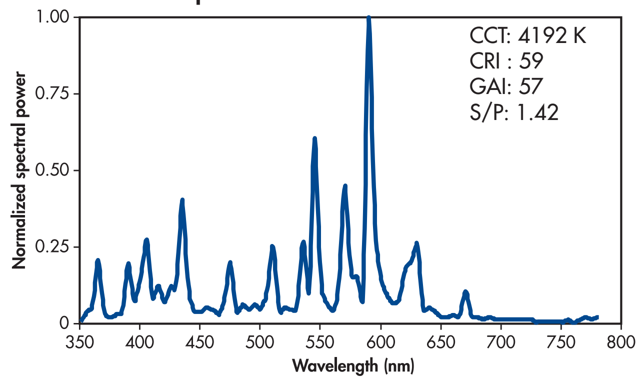
Pricing
Streetlight: $346.50
Lamp: $50.02
Module replacement: N/A

Application
LSAE (27 ft pole height): 18.8* lm/W
Pole spacing (single-sided): 100 ft
Pole spacing (staggered): 170 ft

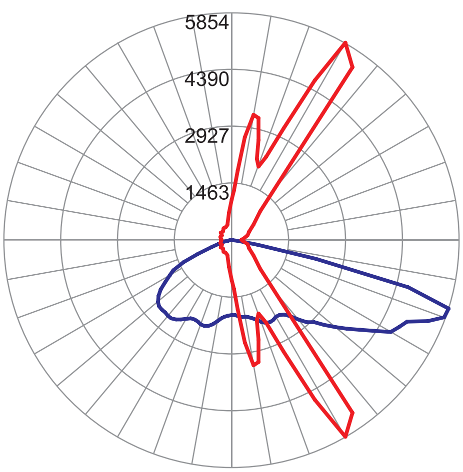
Discomfort Glare
De Boer rating (rural): 2.4
De Boer rating (suburban): 2.8
De Boer rating (urban): 3.1

* Indicates results based on relative photometry

Spectral Power Distribution

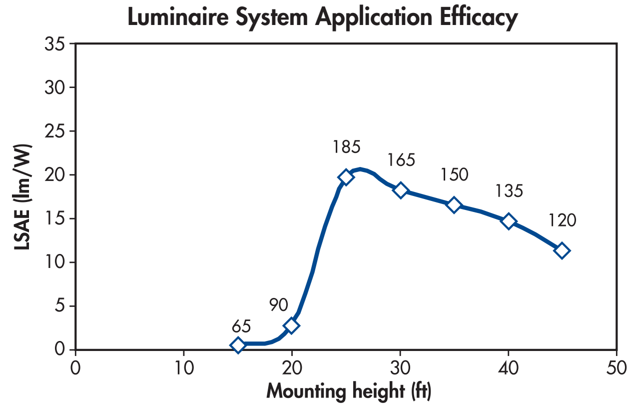


Intensity Distribution Curves



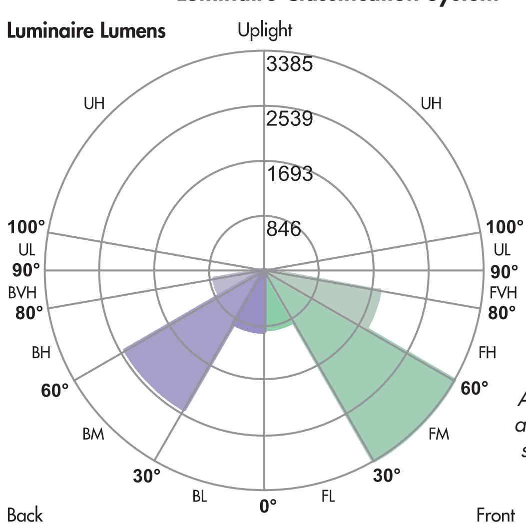
Red line - Horizontal cone through max cd vertical angle
Blue line - Vertical plane through max cd horizontal angle

Luminaire System Application Efficacy



Data labels indicate same-side pole spacing (ft) for staggered configuration

Luminaire Classification System

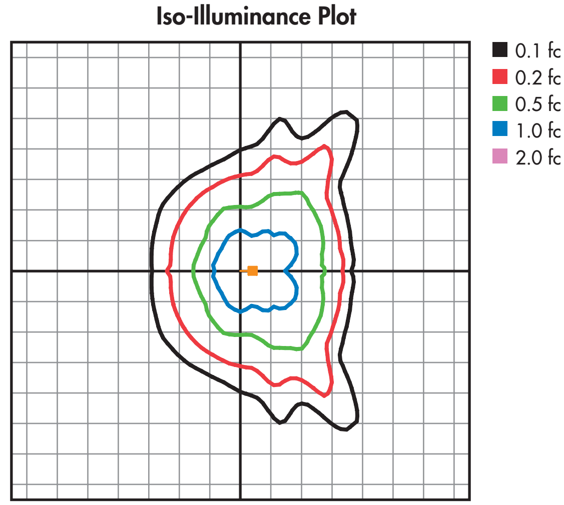


FL: 901
FM: 3390
FH: 1800
FVH: 28
BL: 938
BM: 2460
BH: 773
BVH: 14
UL: 0
UH: 0

Values in lumens

Areas FL, FM, FH, and FVH represent street-side lumens

Iso-Illuminance Plot



Template grid = 15 ft x 15 ft
Mounting height = 27 ft
Arm length = 6 ft
LLF= 0.58

Further Information

NLPIP Publications

- **Cobra head, arm-mounted and post-top streetlights.** For more information, refer to *Specifier Reports: Parking Lot and Area Luminaires*, available online at: www.lrc.rpi.edu/nlpip/publicationDetails.asp?id=900&type=1.
- **Color rendering.** For more information, refer to *Lighting Answers: Light Sources and Color,* available online at www.lrc.rpi.edu/nlpip/publicationDetails.asp?id=901&type=2.
- **Light pollution.** For more information, refer to *Lighting Answers: Light Pollution*, available online at: www.lrc.rpi.edu/nlpip/publicationDetails.asp?id=884&type=2.
- **Outdoor lighting controls.** For more information, refer to *Lighting Answers: Dynamic Outdoor Lighting*, available online at: www.lrc.rpi.edu/nlpip/publicationDetails.asp?id=928&type=2.

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NLPIP
NATIONAL LIGHTING PRODUCT INFORMATION PROGRAM

Specifier Reports

Volume 13 Number 1 November 2010

Streetlights for Collector Roads

Addendum: Analysis of the costs of LED streetlights that meet IES RP-8 roadway lighting criteria for collector roads at the same pole spacing as HPS streetlights

Abstract

In the accompanying main report, the National Lighting Product Information Program (NLPIP) describes an evaluation of light-emitting diode (LED), high pressure sodium (HPS), pulse start metal halide (PSMH), and induction streetlights. The streetlights selected for evaluation were recommended in 2009 by nine different manufacturer representatives as equivalent to the incumbent 150W HPS streetlight. The report concluded that the LED streetlights recommended as replacements for the incumbent streetlight would cost more than twice as much to own and operate over the life of the streetlights, primarily because the LED streetlights required narrower pole spacings, and the cost of the poles per mile dominated the life cycle costs.

NLPIP produced this Addendum to provide specifiers with estimates of life cycle costs for LED streetlights that could replace the incumbent technology using the same pole spacing as required for typical 150W HPS streetlights. Since poles dominate the total life cycle costs of roadway lighting systems, the pole spacing was held constant for this analysis. Here NLPIP provides both the *total* (including poles) and the *relative* (excluding poles) life cycle costs associated with LED and HPS streetlights. Current (October–November 2010) LED streetlight prices and manufacturer-provided photometric data were used in this analysis.

This analysis showed that the relative life cycle costs per mile of the evaluated LED streetlights were most affected by the initial streetlight price, the LED module replacement price, and the life of the LED modules. These LED streetlights would reduce energy use by an average of 7% relative to the incumbent 150W HPS streetlights. If the LED modules were to require replacement after 25,000 hours of operation, the average relative life cycle cost for the LED streetlights would be 2.3 times the average life cycle cost of the 150W HPS streetlights. An LED module life of 50,000 hours would result in the LED streetlights having an average relative life cycle cost 1.7 times that of the 150W HPS streetlights.

Introduction

In the accompanying main report, the National Lighting Product Information Program (NLPIP) evaluated a variety of new and conventional streetlights using the same procedure often followed by typical lighting specifiers, and the methodology was documented so that readers could follow each step of the process. NLPIP determined the specification for the streetlight most commonly used to light collector roads in the United States: 150W high pressure sodium (HPS) with a Type III medium full cutoff distribution. NLPIP then asked manufacturer representatives to identify models of HPS, light-emitting diode (LED), induction, and pulse start metal halide (PSMH) streetlights that were equivalent to that specification, a selection process used by many lighting specifiers. In July through October 2009, NLPIP purchased 14 streetlights identified by nine different manufacturer representatives, measured their photometric performance, and calculated the pole spacing that would be needed to meet the criteria published in IES RP-8 for illuminating collector roads. Based on this pole spacing and a range of LED module replacement periods, NLPIP calculated the power demand per mile of roadway and the life cycle costs per mile of roadway. The report concluded that the LED streetlights recommended as replacements for the incumbent 150W HPS streetlights could save, on average (mean), 1% for staggered pole layouts and 10% for single-sided layouts of the energy required by the incumbent technology, but would cost approximately 2.6 and 2.4 times more, respectively, to own and operate. The primary reason that they would be more than twice as expensive was that the LED streetlights required narrower pole spacings, and the cost of the poles per mile dominated the life cycle costs.

NLPIP prepared this Addendum to provide specifiers with both the *total* (including poles) and the *relative* (excluding poles) life cycle costs associated with LED streetlights. In the analysis conducted in the main report, poles dominated the total life cycle costs. For this Addendum's analysis, NLPIP selected LED streetlights that could replace the incumbent streetlights at the incumbent streetlights' pole spacing and still meet RP-8 roadway lighting criteria, thereby holding pole costs constant. Total life cycle costs refers to the present value life cycle cost of owning and operating streetlights for one mile of roadway, including poles. Relative life cycle cost excludes the cost of the poles.

Analysis Method

NLPIP selected streetlights for the present analysis from manufacturers' websites. LED streetlights were identified from the websites of the seven manufacturers of LED streetlights evaluated in the main report, and HPS streetlights were identified from the websites of the four manufacturers of HPS streetlights evaluated in the main report. All LED streetlights that had photometric files available for download, were described as Type III, and either had more LEDs and higher light output or were newer models than those evaluated in the main report were considered. All HPS streetlights that had power demands of 100 or 150W, Type III distributions, and photometric files available for download were considered. Using this method, 20 LED and 14 HPS streetlights were identified in October and November 2010. All 20 LED streetlight models were different than those evaluated in the main report, while the HPS streetlights included both new and previously tested models. Neither induction nor metal halide streetlights were evaluated in this Addendum.

As in the main report, NLPIP simulated the illumination of a collector road using the Roadway Optimizer tool in AGi32 (version 2.14). The same road geometry, mounting height, and light loss factors (LLFs) were assumed. Unlike in the main report, only a staggered layout was considered because, on average, a staggered layout results in lower total life cycle costs than a single-sided layout. The pole spacing was held constant at 220 feet, the median pole spacing provided by the 150W HPS streetlights in the main report.[1] Also unlike the analysis in the main report, NLPIP relied on the manufacturers' luminaire photometric data, even for the HPS streetlights that NLPIP had previously tested. (A note of caution is offered to specifiers here, as it was in the main report: NLPIP found that some of the photometric data reported by manufacturers were inconsistent with those measured for the tested luminaires.)

Using this method, five of the 20 LED streetlights identified met either the illuminance or luminance roadway lighting criteria in RP-8 without over-lighting the roadway. None of the 100W HPS but most of the 150W HPS streetlights met the RP-8 collector road illuminance criteria at a 220-foot pole spacing. For a given manufacturer, there was very little functional difference in the light distribution or in the electric power to meet the 220-foot pole spacing. Therefore, NLPIP selected a representative 150W HPS model from each of the four most-specified manufacturers identified in the main report.

Power Demand

These nine streetlights (five LED and four HPS) were then analyzed for power demand per mile of the simulated collector roadway. For the five LED streetlights, NLPIP used the system power provided by the manufacturers. For the four HPS streetlights, NLPIP used the tested power from the main report because the system power demand was not reported by manufacturers for all of the streetlights considered here. The difference between the tested power and the reported system power was less than 6%.

The results of the simulation showed that the power demand for these five LED streetlights ranged from 16% lower to 8% higher (7% lower on average) than the average power demand of the four HPS streetlights. This result is similar to the energy savings of the tested LED streetlights in the main report, as would be expected since they all met the roadway lighting requirements of RP-8.

Economics

For the five LED streetlights, NLPIP obtained single-unit prices both for streetlights and LED replacement modules from manufacturer representatives in the Albany, N.Y., area in October and November 2010.[2] NLPIP calculated the life cycle costs (analyzed per mile of roadway) for the five LED streetlights using these prices and the economic methods shown on page 21 of the main report. For the four HPS streetlights and their lamps, NLPIP used the same prices that were used in the main report. Again, all life cycle costs were calculated using the staggered pole layout.

One factor that influences life cycle costs is the life of the LED modules over the 27-year (113,000 operating hours) life of the streetlight. As in the main report, NLPIP used a range of values as part of a sensitivity analysis for the LED module replacement schedule. Results are shown for the cases where replacement is needed every 100,000 hours (LED modules replaced once), 50,000 hours (replaced twice), and 25,000 hours (replaced four times). The HPS streetlight is assumed to be relamped every 30,000 hours. For all technologies, the ballast or driver is replaced once at 60,000 hours and the streetlight is cleaned every four years.

[1] The median pole spacing was more representative of the central tendency than the average because there was an outlier among the small group of samples examined in the main report. NLPIP believes that 220 feet is a reasonable pole spacing for this Addendum analysis because it is in the middle of the range required by a sample of municipal codes identified by NLPIP (via the Internet) that prescribe pole spacing for 150W HPS streetlights for collector roads.

[2] The prices for the GE Lighting LED module and the BetaLED STR-LWY streetlight and replacement modules were not available from the manufacturer representatives. For the GE Lighting LED streetlight, NLPIP used the same LED replacement module price as in the main report; for the BetaLED STR-LWY, the prices of a BetaLED STR-LWY 100 LED streetlight and replacement modules were used.

The range of the life cycle costs for the five LED streetlights is shown in Figure 1 and Table 1. For example, the total (including poles) life cycle costs of these LED streetlights purchased in 2010 and having a 25,000-hour rated life range from $313,000 to $475,000. This compares with an average total life cycle cost of $239,000 for the 150W HPS streetlights. As shown in Table 1, if the LED streetlight modules last 25,000 hours, the average relative (excluding poles) life cycle cost for the LED streetlights is 2.3 times the average relative life cycle cost of the 150W HPS streetlights. The analysis shows that the relative life cycle costs are dependent on the luminaire price, replacement price, and relamping period. When using LED instead of HPS streetlights, the average reduction in energy use is 2% to 4% of the relative life cycle costs (and 2% of the total life cycle costs) at this time.

Figure 1: Estimated present value life cycle costs per mile of roadway over 27 years for five LED streetlights and the average of four HPS streetlights in a staggered arrangement that meet RP-8 roadway lighting criteria. Pole spacing for all streetlights is 220 feet between streetlights on the same side.

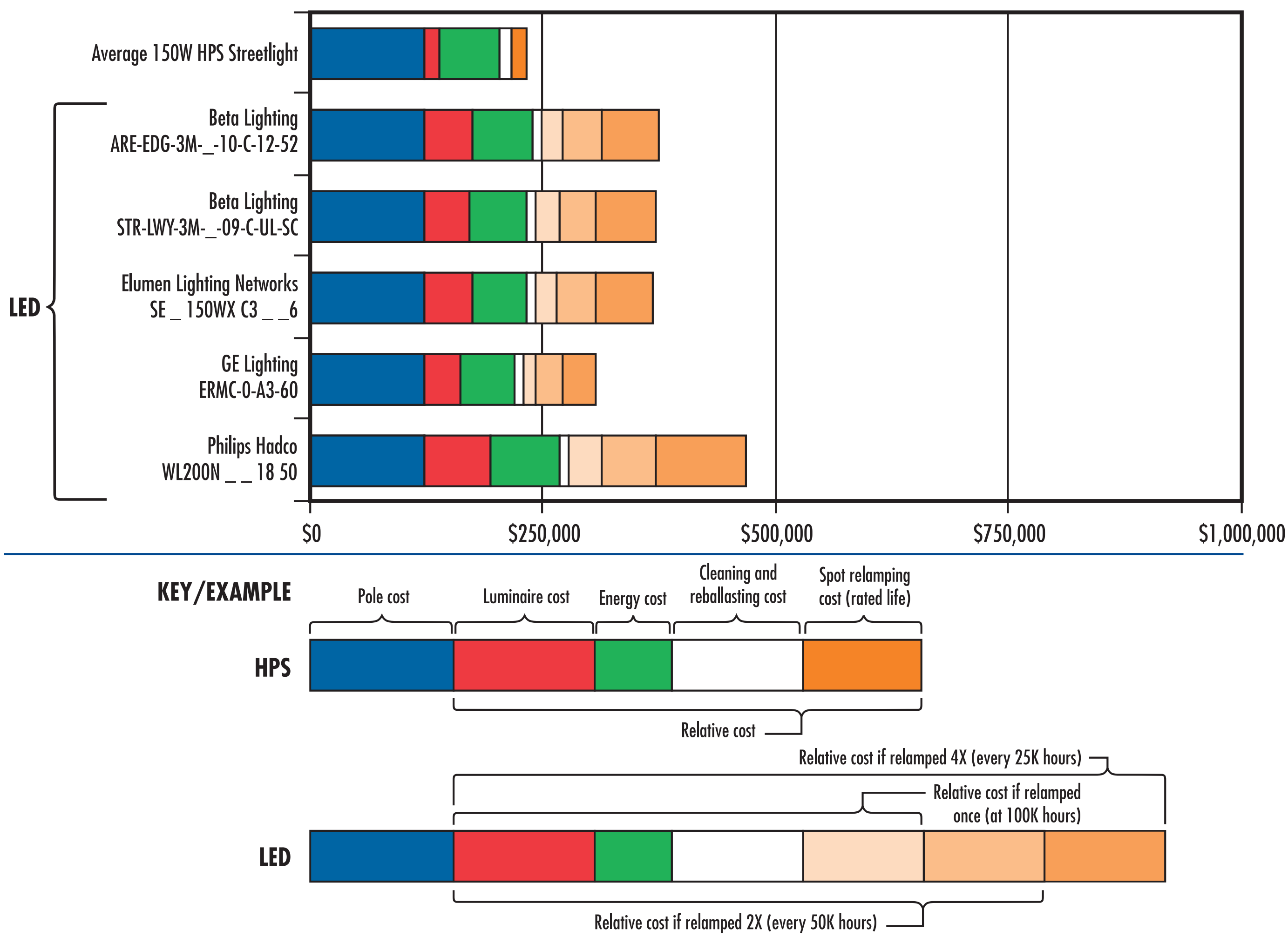

Table 1: Total and relative average life cycle costs per mile of roadway for five LED and four HPS streetlights.

Streetlight type	Relamping interval (h/yr)	Total life cycle costs (including poles) ($/mile)			Relative life cycle costs (excluding poles) ($/mile)		
		Range	Average	Fraction by which average LED life cycle costs are higher than HPS average (%)	Range	Average	Fraction by which average LED life cycle costs are higher than HPS average (%)
HPS	30,000/7	$234,000–253,000	$239,000	—	$111,000–129,000	$116,000	—
LED	25,000/6	$313,000–475,000	$384,000	61%	$189,000–351,000	$260,000	125%
	50,000/12	$277,000–378,000	$320,000	34%	$154,000–254,000	$197,000	70%
	100,000/24	$250,000–320,000	$279,000	17%	$126,000–197,000	$155,000	35%

Conclusion

This Addendum considered five LED and four HPS streetlights selected in October and November 2010 that might be used to illuminate a collector road meeting RP-8 roadway lighting criteria. The *total* (including poles) and *relative* (excluding poles) life cycle costs per mile of roadway were determined using a fixed, 220-foot pole staggered-spacing layout for all the simulated streetlights.

The accompanying main report showed that the LED streetlights had an average total life cycle cost 2.6 times the incumbent HPS streetlights if the LED modules were to last 25,000 hours. The analysis in this Addendum, in which NLPIP selected the streetlights to meet RP-8 at a fixed pole spacing of 220 feet, showed that the average relative (excluding poles) life cycle costs of the LED streetlights were 2.3 times the HPS streetlights if the LED modules were to last 25,000 hours. Although the LED modules may last longer than 25,000 hours (the manufacturers of the LED streetlights included in this report claim LED streetlight lifetimes of 50,000 to 100,000 hours), the LED streetlights included in this study come with warranties of five years (approximately 20,000 operating hours), so streetlight system owners should be aware that they may face module replacement costs well before the manufacturers' claimed lifetimes. An LED module life of 50,000 hours would result in the LED streetlights having an average relative life cycle cost 1.7 times the average relative life cycle cost of the 150W HPS streetlights. An LED module life of 100,000 hours would result in the LED streetlights having an average relative life cycle cost 1.4 times the average relative life cycle cost of the 150W HPS streetlights.

The present analysis showed that relative life cycle costs per mile of roadway were dominated by the streetlights' initial prices and the LED module replacement costs, but not the costs of energy, even though the LED streetlights evaluated can reduce power demand by about 7%.

Streetlights for Collector Roads

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National Lighting Product Information Program Publications

Guide to Fluorescent Lamp-Ballast Compatibility, 1996
Guide to Specifying High-Frequency Electronic Ballasts, 1996
Guide to Selecting Frequently Switched T8 Fluorescent Lamp-Ballast Systems, 1998

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