NLPIP
NATIONAL LIGHTING PRODUCT INFORMATION PROGRAM

Specifier Reports

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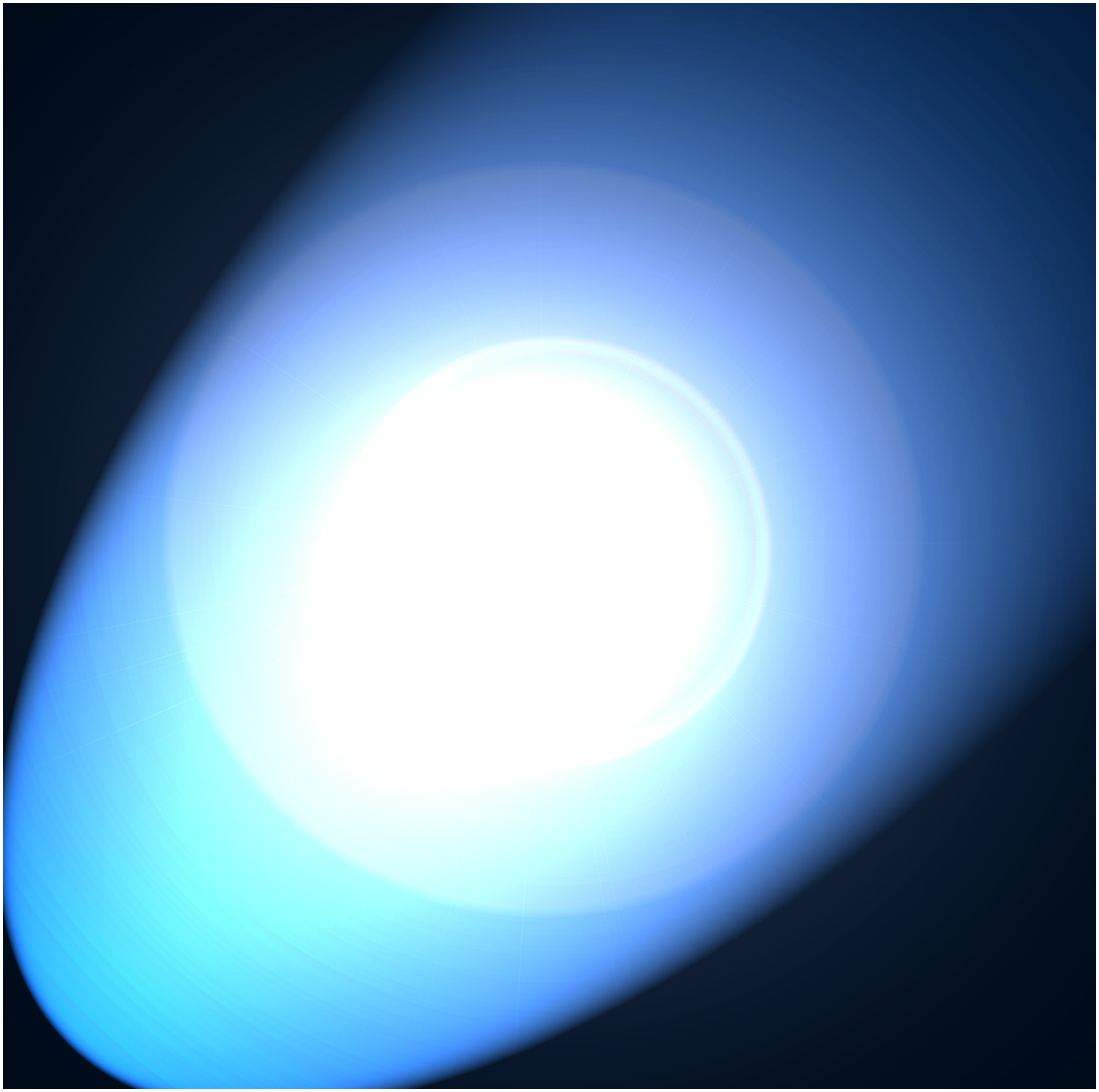
Streetlights for Local Roads

Volume 14 Number 1, February 2011



NLPIP
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NLPIP's mission is to help lighting specifiers and other lighting decision-makers 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*.

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ISSN 1067-2451

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Contents

Abstract

Between February and March 2010, the National Lighting Product Information Program (NLPIP) at Rensselaer Polytechnic Institute's Lighting Research Center purchased six streetlights identified by manufacturer representatives as equivalent to a 100-watt (W) high pressure sodium (HPS), Type II, medium, full cutoff cobra head. One used an HPS lamp (the base case model), one used an induction lamp, and four used light-emitting diode (LED) modules. NLPIP determined how many of each type of streetlight were needed to illuminate one mile (1.6 kilometer) of a local road in an urban residential area to meet the roadway lighting design criteria specified in the American National Standards Institute (ANSI)/ Illuminating Engineering Society of North America (IESNA) RP-8-00, *American National Standard Practice for Roadway Lighting* (referred to as RP-8 below). NLPIP then calculated power demand and life-cycle costs per mile for each streetlight. For a more complete understanding of this application, additional analyses were conducted related to white light benefits, discomfort glare, absolute photometry, manufacturer-supplied photometric data, higher light output streetlights, higher mounting heights, wider roads, and volume discount pricing.

Using a GE Lighting 100 W HPS streetlight as the tested base case, NLPIP found that:

- The tested LED streetlights required 3% to 92% (average 40%) more poles per mile than the base case to meet the RP-8 design criteria. The tested GE Lighting induction streetlight required 64% more poles per mile than the base case to meet the RP-8 criteria. One tested LED streetlight, the Beta Lighting STR-LWY-2M-HT-04-C-UL-SV, was able to provide pole spacing similar to the base case.

- The tested LED streetlights required 41% less to 15% more power per mile than the base case (average 6% less per mile for a staggered layout and 24% less per mile for a single-sided layout) to meet the RP-8 criteria. The tested induction streetlight required 51% and 41% more power per mile than the base case in staggered and single-sided layouts, respectively, to meet the RP-8 criteria.

- The life-cycle costs per mile for all of the tested streetlights were dominated by the capital and installation cost of the poles and streetlights. The life-cycle costs per mile of the tested LED streetlights ranged from 0.98 to 2.84 times as much as the base case because of the pole spacing required by the tested LED and induction streetlights to meet RP-8. For an assumed LED module replacement interval of 25,000 hours, the average tested LED streetlight life-cycle cost per mile was 1.9 times that of the base case. For an assumed LED module replacement interval of 50,000 hours, the average tested LED streetlight life-cycle cost per mile was 1.6 times that of the base case. The average life-cycle cost per mile of the tested induction streetlight was 1.8 times that of the base case.

- NLPIP identified one tested LED streetlight that met RP-8 and could have a lower life-cycle cost per mile than the base case in one scenario largely because its pole spacing was close to that of the base case, and therefore, had a similar pole cost. With a volume discount of 50% for the streetlights and replacement modules (and lamps for the base case), the tested Beta Lighting STR-LWY-2M-HT-04-C-UL-SV streetlight in a single-sided layout would have a lower life-cycle cost per mile than the base case if it were to have a life of 50,000 hours (12 years) or longer (or at single-unit pricing, 113,000 hours [27 years] or longer).

- Some streetlight system owners may be able to obtain financial incentives for installing LED and induction streetlights. In order for the tested LED

(with a life of 25,000 hours or longer) or induction streetlight systems to have a lower life-cycle cost per mile than the base case, the required incentives would have to range from $250 to $1,550 per streetlight, in addition to a volume pricing discount.

- At the RP-8 local road illuminance levels, additional power reductions of up to 15% were possible for the LED and induction streetlights under the CIE model of mesopic photometry. These power reductions would not change the rank ordering of the streetlights based on the life-cycle cost results.
- In addition to the streetlights tested for this study, NLPIP analyzed streetlights with higher light output offered on the manufacturers' websites in November 2010 to determine if they could have the same pole spacing provided by the base case and meet RP-8 criteria. Since the LED streetlights with higher light output were limited by RP-8's uniformity and disability glare ratio criteria, none of these streetlights were able to have the same pole spacing as the base case at a 25-foot (7.6-meter) mounting height.

These results are for the streetlights evaluated in this study, for the roadway and mounting height geometries used in the analyses, and for streetlight systems that meet the RP-8 lighting design criteria. Surveys of municipality and utility representatives, and outdoor lighting specifiers and manufacturers, by Mara et al. (2005) showed that, on average, only 25% of local roads are continuously lit as recommended by RP-8. Although 75% of streetlight system owners do not light their local roads to RP-8 recommendations, NLPIP followed the RP-8 performance criteria because no other national lighting standard exists, and because there is high variability in the pole spacings prescribed by municipalities. The low adoption rate of RP-8 nationally could indicate that this national standard is not meeting the needs of streetlight system owners.

Introduction

Streetlights with light-emitting diode (LED) modules and with induction lamps are being marketed as effective replacements for high pressure sodium (HPS) streetlights for new construction and retrofit applications. LED and induction streetlights are sometimes claimed to provide greater energy savings, better lighting uniformity and distribution, and lower maintenance costs than 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).

A previous report from the National Lighting Product Information Program (NLPIP), *Specifier Reports: Streetlights for Collector Roads* (NLPIP 2010a), describes the evaluation process and results from HPS, induction, LED and pulse-start metal halide streetlights tested by NLPIP for use along collector roads. The present report for streetlights designed for local roads uses the same methodologies described in *Specifier Reports: Streetlights for Collector Roads*, with exceptions noted, so readers should refer to that publication for additional details.

Municipalities use a variety of methods to determine streetlight pole spacing, such as prescribing a maximum pole spacing, requiring the streetlight system to meet a national standard, or lighting conflict points such as intersections. NLPIP surveyed municipal codes via the Internet and found prescribed maximum pole spacings for 100 W HPS streetlights for local roads ranging from 100 feet (ft, 30.5 meters [m]) to 400 ft (122 m). Because there was no consensus on maximum pole spacing among these codes, NLPIP turned to a national roadway lighting standard, the American National Standards Institute (ANSI)/Illuminating Engineering Society of North America (IESNA) RP-8-00 (IESNA 2000, R2005), *American National Standard Practice for Roadway Lighting* (referred to as RP-8 below), to determine pole spacing, even though not all streetlight systems are designed to this standard.

As discussed in *Specifier Reports: Streetlights for Collector Roads*, a survey of lighting professionals showed that they identified driver and pedestrian safety as the most important metric of streetlight installations. A national roadway lighting standard, such as RP-8, is intended to provide good visibility and presumably to safeguard vehicular and pedestrian traffic. In addition to the safety benefits, designing a streetlight system to a national lighting standard should also reduce legal liability (NLPIP 2010b). NLPIP used the RP-8 roadway lighting design criteria in both the previous and present roadway lighting studies because, as of yet, no other standard exists that better links driver and pedestrian safety with improved visibility provided by fixed lighting.

NLPIP purchased and performed photometric evaluations of six streetlights, one that used an HPS lamp, one that used an induction lamp, and four that used LED modules. Using mounting heights and geometries typical of local roads in urban residential areas, NLPIP analyzed these streetlights for light output and distribution, energy use, spectral effects according to the CIE system of mesopic photometry, discomfort glare, and life-cycle costs based on the pole spacing determined using the RP-8 roadway lighting design criteria for local roads.

Streetlight Selection

As in *Specifier Reports: Streetlights for Collector Roads,* NLPIP used:

- surveys of lighting specifiers to identify the brands to purchase,
- a typical road geometry for simulation (in this case, a local road), and
- the services of manufacturer representatives to identify streetlights with performance equivalent to a base case specification.

Identifying the Base Case Criteria

Previous survey results (Mara et al. 2005) indicated that 100-watt (W) HPS, full cutoff streetlights were those most frequently installed to illuminate local roads. NLPIP used a streetlight mounting height of 25 ft (7.6 m) because this is a typical mounting height for residential areas based on an Internet search of municipal codes. Using the AASHTO (2004) design policy, NLPIP determined that the most appropriate optical distribution for local roads in residential areas using this mounting height is an IES Type II, medium distribution. Although the IESNA has phased out the cutoff classification system for all luminaires and currently uses the Luminaire Classification System (LCS) metric (IESNA 2009) instead, most of the municipal codes that limited vertical light distribution gave a cutoff classification requirement rather than an LCS requirement; therefore, NLPIP included cutoff in its base case specification. For this analysis, NLPIP used a 100 W HPS, Type II, medium, full cutoff cobra head as the base case streetlight.

Identifying Brands to Purchase

Subsequent to the two surveys conducted for *Specifier Reports: Streetlights for Collector Roads*, a third online survey of specifiers was conducted in December 2009 to determine which brands of HPS streetlights are commonly specified and which brands of LED and induction streetlights are commonly specified or are being evaluated for local roads. The survey yielded responses from 28 specifiers. Each specifier was asked to report up to three models of each streetlight type: HPS, LED and induction. Figure 1 shows the 42 mentions of HPS streetlights, and Figure 2 shows the 33 mentions of LED streetlights by the respondents. Of the induction streetlights identified, two specifiers mentioned Global Induction Lighting, one mentioned GE Lighting, and one mentioned US Lighting Tech.

Figure 1. Most specified HPS streetlights, listed by manufacturer

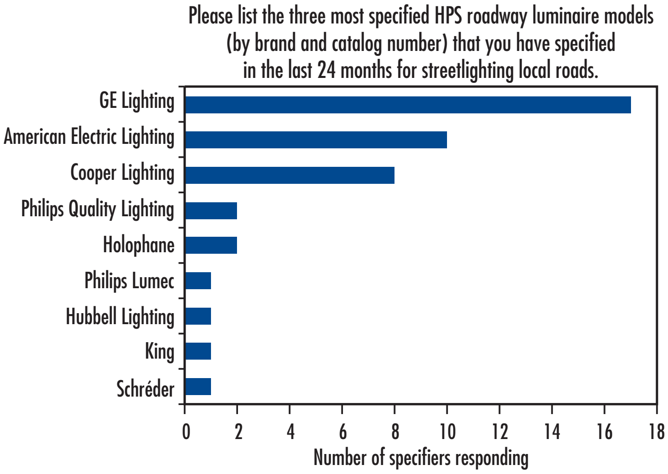
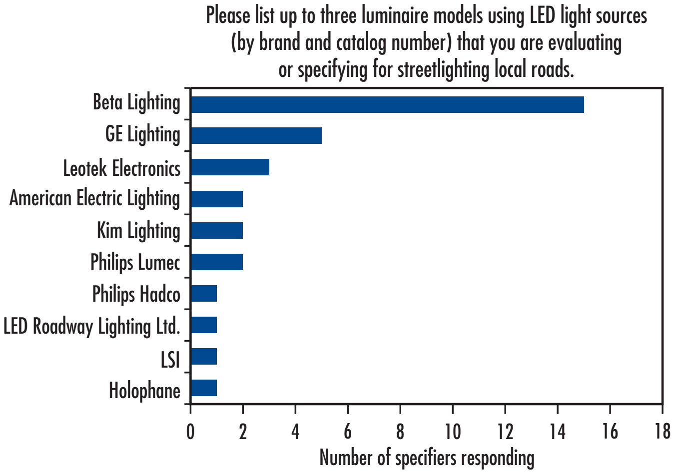


Figure 2. Most evaluated or specified LED streetlights, listed by manufacturer



Identifying Streetlight Models to Purchase

For this report, NLPIP evaluated six streetlights: one HPS, one induction, and four LED. NLPIP purchased one HPS streetlight from GE Lighting because it was the HPS streetlight manufacturer most often mentioned in the survey. NLPIP purchased one induction streetlight from GE Lighting as well because it was the sole listed manufacturer of an induction cobra head-style streetlight with a representative sales force. NLPIP purchased four LED streetlights from those listed in the December 2009 survey. Beta and Leotek LED streetlights were selected because they were frequently mentioned in the survey. Despite being the second most-often-mentioned brand of LED streetlight in the survey, GE Lighting was not selected because two GE Lighting products had already been selected, and NLPIP thought it valuable to have a variety of manufacturers represented in this study. The next three LED streetlights were equally represented in the survey results. Of these three, NLPIP purchased streetlights from American Electric Lighting and Philips Lumec. Kim Lighting was not selected because its sole LED streetlight model available at the time had already been evaluated in *Specifier Reports: Streetlights for Collector Roads*, and it was claimed by a manufacturer representative to be equivalent to a 150 W HPS streetlight rather than the 100 W HPS base case used in this report.

NLPIP contacted manufacturer representatives of the identified brands in the Albany, N.Y., area and asked them to identify streetlight models that were equivalent to a “100 W HPS Type II medium full cutoff cobra head with a 25 ft (7.6 m) mounting height.” Representatives provided the catalog number and product pricing to local distributors, and NLPIP purchased the streetlights between February and March 2010. Photometric testing was conducted from March to April 2010 at Luminaire Testing Laboratory in Allen town, Pa., under contract with NLPIP. Detailed results of these tests and the prices NLPIP paid for the streetlights are presented in Appendix A.

Pole Spacing

NLPIP determined pole spacing using the same methodology detailed in *Specifier Reports: Streetlights for Collector Roads* with these exceptions:

- The simulated road was a local road (a road that provides direct access to residential, commercial or industrial properties) with low pedestrian conflict, such as would be found in residential areas. NLPIP simulated a 26 ft (7.9 m) wide road with two lanes, per AASHTO (2004) geometric design policy.
- NLPIP used the recommended roadway lighting design criteria for local roads with low pedestrian conflict given in RP-8, shown in Table 1. (Another national lighting standard, AASHTO Roadway Lighting Design Guide GL-6 [2005], is derived from RP-8. Its recommended illuminance and luminance criteria for local roads in residential areas are the same as those shown in Table 1).

Table 1. RP-8 recommended illuminance and luminance roadway design criteria for local roads with low pedestrian conflict

Illuminance method criteria	Average pavement illuminance	0.4 footcandle (fc) (4.3 lux [lx])
	Average to minimum pavement illuminance ratio	6.0:1
	Maximum veiling luminance to average pavement luminance ratio	0.4:1
Luminance method criteria	Average pavement luminance	0.3 cd/m²
	Average to minimum pavement luminance ratio	6.0:1
	Maximum to minimum pavement luminance ratio	10.0:1
	Maximum veiling luminance to average pavement luminance ratio	0.4:1

- The luminance method criteria in RP-8 were used for this roadway geometry to determine pole spacing because they produced longer pole spacings than the illuminance method criteria for the majority of streetlights.
- The streetlight mounting height was 25 ft (7.6 m).

As in *Specifier Reports: Streetlights for Collector Roads*:

- The light loss factor is associated with a specific technology, as shown in Table 2.

Table 2. Light Loss Factors

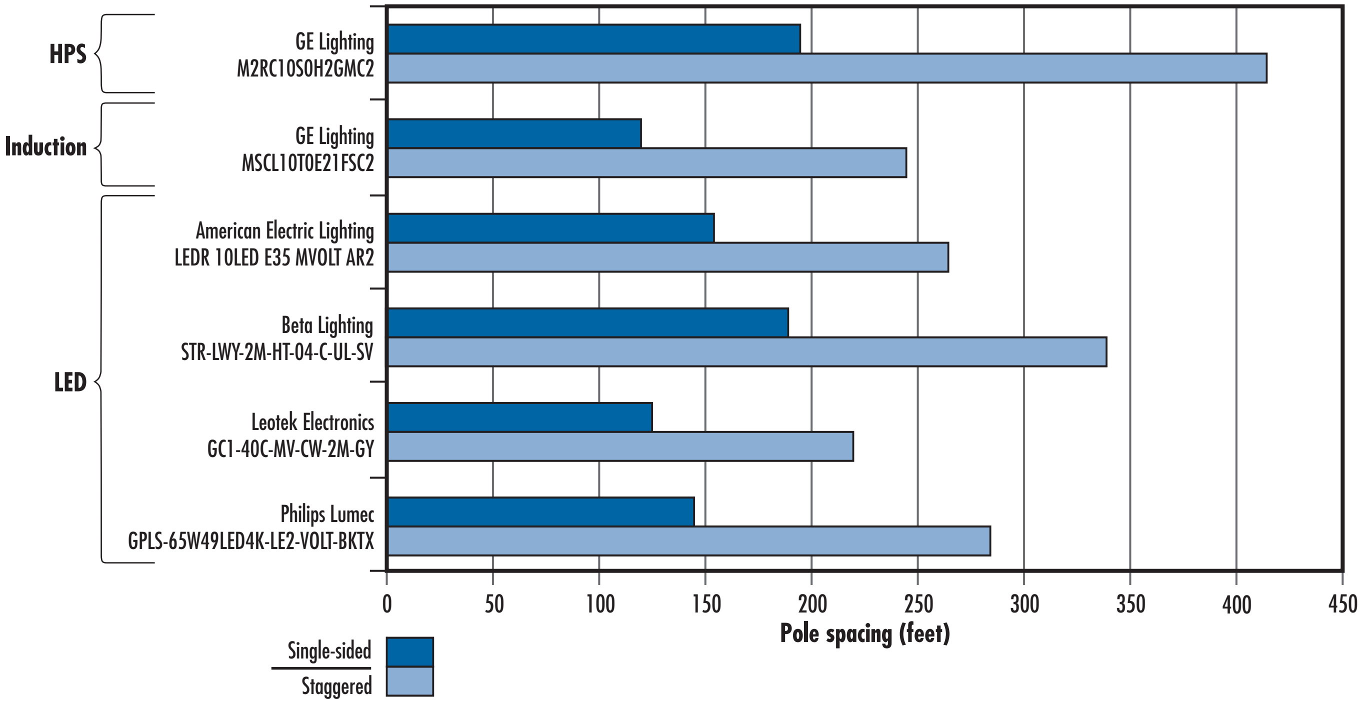
Streetlight Type	Lamp Lumen Depreciation	Luminaire Dirt Depreciation	Light Loss Factor
HPS	0.84	0.88	0.74
Induction	0.70	0.88	0.62
LED	0.79	0.88	0.70

- The pole spacing calculations assumed an R3 pavement type, which is a road surface classification given in RP-8.
- Streetlights were assigned a 6 ft (1.8 m) overhang length based on information from a utility lighting expert.

Maximum Pole Spacing Results from NLPIP Testing

NLPIP used the photometric files from the tested streetlights and the above criteria in the Roadway Optimizer tool in AGi32 version 2.14 to determine the maximum pole spacing for each streetlight because this would yield the lowest life-cycle costs. This type of analysis would be most applicable to new construction (i.e., no existing poles). The results are shown in Figure 3. Results for established pole spacing, such as for roads with existing poles, are presented in the "Additional Analyses" section below.

Figure 3. Pole spacing needed to meet RP-8 luminance method criteria for a 26 ft (7.9 m) wide road. Greater pole spacing means fewer poles are required.



The tested LED streetlights required shorter distances between poles to meet RP-8, on average 79% for single-sided layouts and 67% for staggered layouts of the distance for the tested GE Lighting 100 W HPS streetlight, the base case. This means that 27% (single) and 52% (staggered) more poles per mile than the base case would be required (average 40% with a range of 3% to 92% more poles per mile). One LED streetlight, the Beta Lighting STR-LWY-2M-HT-04-C-UL-SV, was able to be spaced almost as far apart as the base case (96% of the distance) in the single-sided layout, and was able to be spaced 82% of the base case distance in a staggered layout. The tested GE Lighting induction streetlight could be spaced 62% and 59% of the distance the base case achieved in single-sided and staggered layouts, respectively, and required 64% more poles per mile, on average, than the base case to meet the RP-8 criteria. All of the streetlight pole spacings were limited by the uniformity ratios and disability glare ratio requirements (rather than the luminance requirement) in RP-8, except for the Beta Lighting STR-LWY-2M-HT-04-C-UL-SV, which was limited by both the luminance and glare ratio criteria.

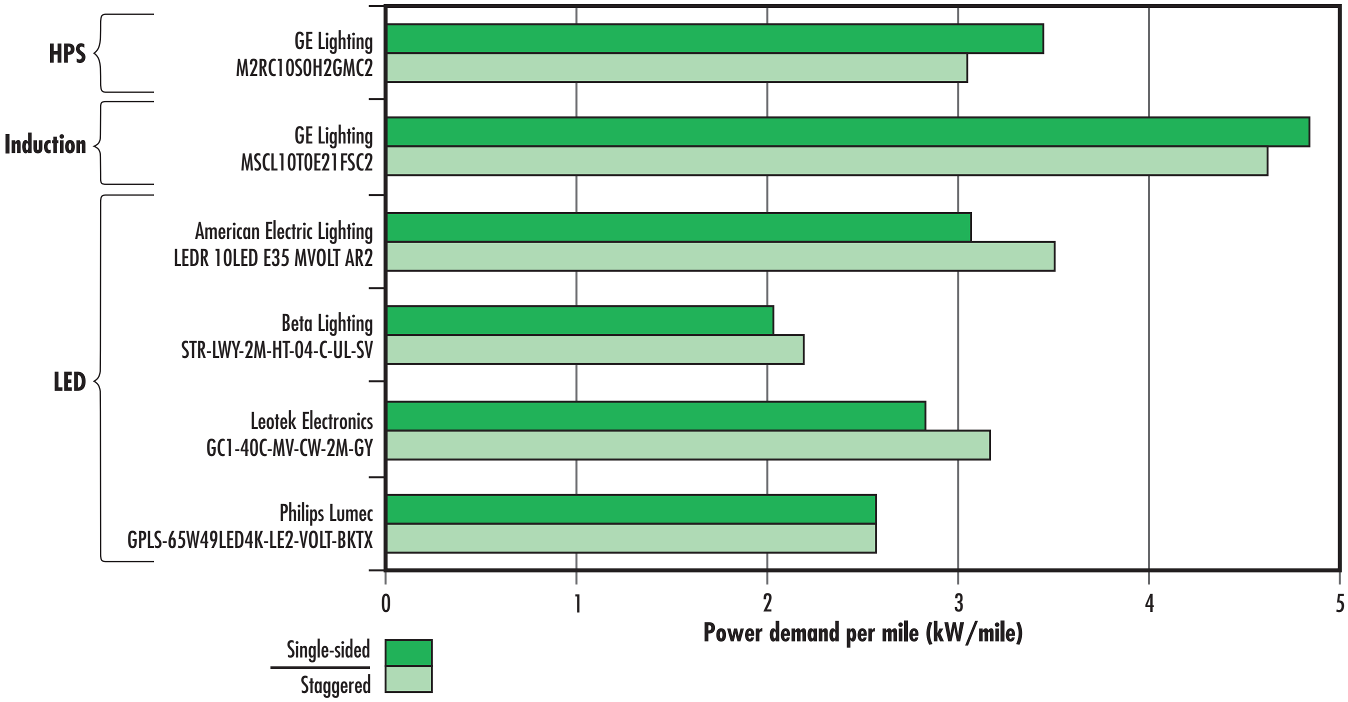
Power Demand

NLPIP used the pole spacings shown in Figure 3, which met the RP-8 luminance criteria, to determine the power demand of each streetlight over one mile (1.6 kilometer [km]) of road. The results are shown in Figure 4 in kilowatts per mile (kW/mi).

The tested LED streetlights required 41% less to 15% more power per mile than the base case (average 6% less per mile for a staggered layout and 24% less per mile for a single-sided layout) to meet the RP-8 criteria. In a single-sided layout, all of the LED streetlights had a lower power demand per mile than the base case. In a staggered layout, two of the four LED streetlights had a lower power demand per mile than the base case.

The tested induction streetlight required 51% and 41% more power per mile than the base case in staggered and single-sided layouts, respectively. The induction streetlight also had a higher power demand per mile than all four LED streetlights in both staggered and single-sided layouts.

Figure 4. Power demand per mile for 26 ft (7.9 m) wide road. Lower power demand is better.



Economics

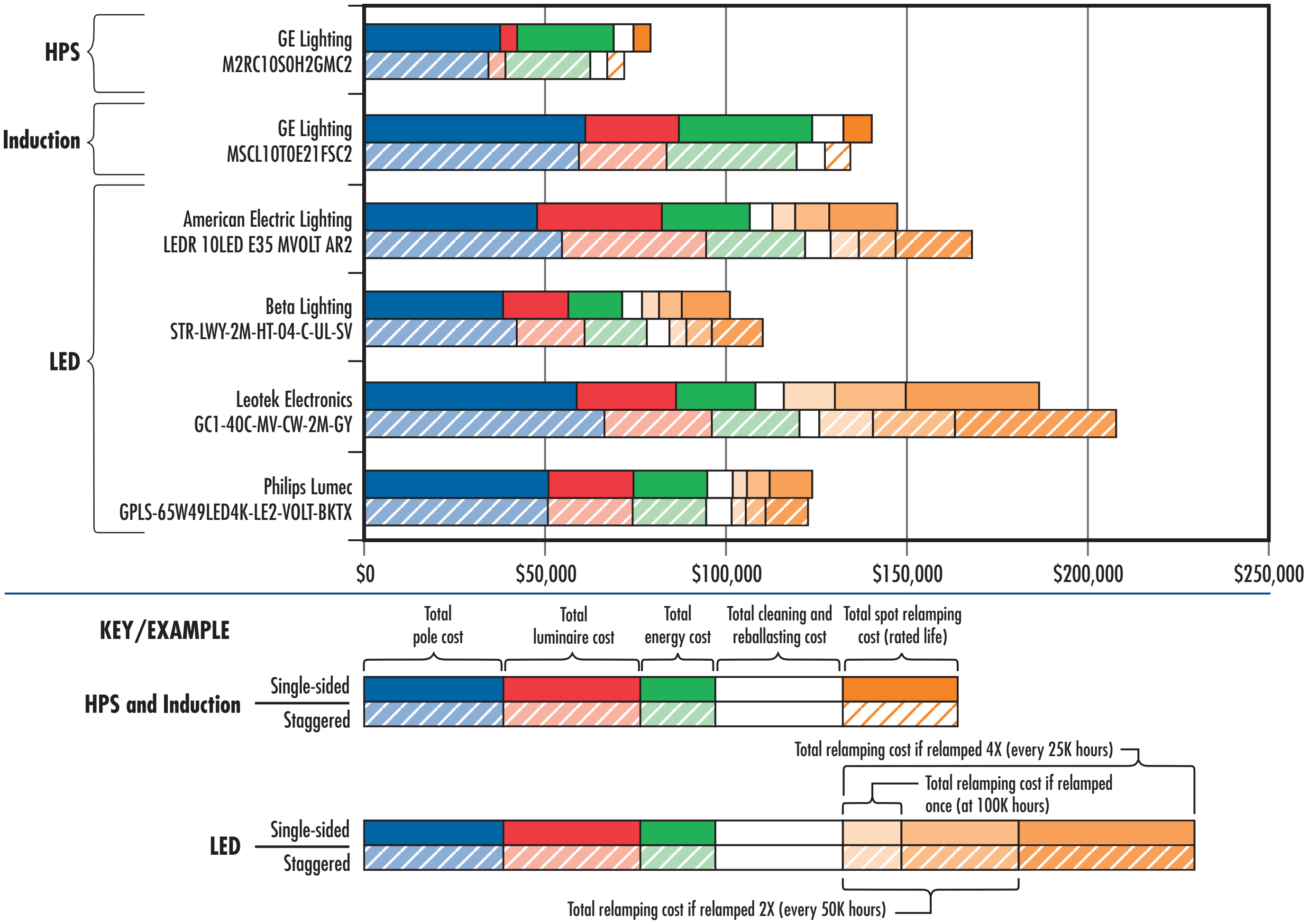
NLPIP estimated the present value life-cycle cost of each of the streetlight systems per mile of road over an assumed streetlight lifetime of 27 years (113,000 operating hours), for both single-sided and staggered layouts. Twenty-seven years is the median streetlight service life used to calculate depreciation periods that NLPIP found in the 40 most recent electric utility annual reports to the Federal Energy Regulatory Commission (FERC). Life-cycle costs included initial capital and installation costs, as well as ongoing energy and maintenance costs. The results are shown in Figure 5.

NLPIP used the same methodology and assumptions described in *Specifier Reports: Streetlights for Collector Roads*, except for the following:

- RS Means 2010 data (Chiang 2009) were used in the economic calculations.
- Wood poles 30 ft (9.1 m) long were used for the streetlights mounted at 25 ft (7.6 m). RS Means estimates that the material and labor costs for installing a 30 ft (9.1 m) wood pole with one 6 ft (2 m) arm bracket is US$1,405, and the labor to install a streetlight on the pole is US$178.
- A non-cycling 100 W HPS lamp was used in the economic calculations because this type of lamp represents best practice according to a utility expert with whom NLPIP consulted. A 100 W HPS lamp from Sylvania (LU100/PLUS/ECO) with a rated life of 40,000 hours was used in the economic calculations. (Therefore, the economic analysis assumed two relamping occurrences during the 113,000 hour life of the streetlight.) The distributor's quoted price for the lamp was $13.50.

As in *Specifier Reports: Streetlights for Collector Roads*, NLPIP used the LED module replacement prices, shown in Appendix A, for the economic analyses and the streetlight price for the Leotek Electronics GC1-40C-MV-CW-2M-GY because the manufacturer representative indicated that replacement modules were not available for this model. 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. Results are shown in Figure 5 for the

Figure 5. Life-cycle cost per mile over 27 years for 26 ft (7.9 m) wide road. Lower life-cycle cost is better.



cases where relamping is not needed (that is, the LEDs have a life of 27 years, or 113,000 hours) and if relamping is needed every 100,000 hours, 50,000 hours, and 25,000 hours. The accepted definition of LED rated life is when the streetlight produces 70% of its initial light output (IESNA 2008).

The base case had a lower life-cycle cost per mile than all of the tested LED and induction streetlights except for one scenario. The Beta Lighting STR-LWY-2M-HT-04-C-UL-SV, in a single-sided layout, had a life-cycle cost per mile 2% lower than the base case if the LED modules were to have a life of 113,000 hours. The induction streetlight had a life-cycle cost near the middle of the range of the LED streetlights' life-cycle costs.

These analyses showed that even if the tested LED streetlights never needed to be replaced or relamped during their 113,000-hour lifetime, they would still be more expensive to own and operate than the base case, with the one exception mentioned above. If the LED modules were to have a life of 100,000 hours, the life-cycle costs per mile of the LED streetlights would be 1.03 to 1.96 times more than the life-cycle cost of the base case. If the LED modules were to have a life of 50,000 hours, the life-cycle costs per mile would be 1.11 to 2.25 times more than the life-cycle cost of the base case. If the LED modules were to have a life of 25,000 hours, the life-cycle costs per mile would be 1.26 to 2.84 times more than the life-cycle cost of the base case.

The average life-cycle cost per mile of the tested induction streetlight was 1.8 times that of the base case.

As previously noted, the life-cycle costs per mile are largely dominated by the number of poles because of pole costs and the greater number of streetlights needed to be purchased and maintained. Streetlights designed to provide longer pole spacings that satisfy the RP-8 criteria have the greatest potential to decrease life-cycle costs.

NLPIP also calculated the base case life-cycle cost per mile using a standard (cycling) 100 W HPS lamp instead of the non-cycling lamp used in the above analysis. This lamp was less expensive (distributor's quoted price: $12.00) but had a shorter rated life (24,000 hours). NLPIP found that the LED and induction streetlights still had higher life-cycle costs per mile compared with the base case using this lamp, except for one scenario: the tested Beta Lighting STR-LWY-2M-HT-04-C-UL-SV streetlight in a single-sided layout if the LED modules were to last 100,000 hours or longer. By changing the HPS lamp used in the base case from a 40,000-hour HPS lamp to a 24,000-hour HPS lamp, the base case life-cycle cost increased by 4%, but this did not change the rank order of the results.

Labeling Problems

All six of the tested streetlights were claimed to have a Type II, medium, full cutoff distribution, but only one of them, the Leotek Electronics GC1-40C-MV-CW-2M-GY, actually did. Five of the six streetlights had a Type II IES lateral classification, but only three of the six streetlights had a medium IES vertical classification.

Although the IES now uses the Luminaire Classification System (LCS) instead of the cutoff classification system, the cutoff classification system continues to be commonly used in municipal codes and some LED streetlight marketing materials, so NLPIP provides information using both classification systems in Appendix A. For LED streetlights, the cutoff classification calculation uses luminaire lumens because this is the only data available for LED streetlights, even though the cutoff classification is based on lamp lumens by definition.

Only the GE Lighting induction streetlight and the Leotek Electronics GC1-40C-MV-CW-2M-GY LED streetlight had a full cutoff distribution, even though all the streetlights tested were claimed by manufacturer representatives to be equal to a full cutoff specification. Although the remaining five streetlights were determined not to qualify as a full cutoff distribution, they emitted no uplight. (A streetlight that emits no uplight is classified as a full cutoff distribution only if it limits the lamp luminous intensity values in the 80° to 90° zone according to the IES cutoff classification criteria [Rea 2000].) Specifiers wishing to avoid direct uplight from their streetlights can require in their performance specifications that the streetlight shall emit no light in the LCS uplight zones.

Additional Analyses

Additional analyses were conducted considering white light benefits, discomfort glare, absolute photometry, manufacturer-supplied photometric data, higher light output streetlights, higher mounting heights, wider roads, and volume discount pricing.

White Light Benefits

As discussed in *Specifier Reports: Streetlights for Collector Roads*, specifiers believe that spectral power distributions (SPD) should be considered in street lighting design. Recently, a recommended system for mesopic photometry based on visual performance was published by the CIE (2010). NLPIP used this photometric system to estimate the life-cycle cost reduction possible by dimming the streetlights using the fixed pole spacing shown in Figure 3 while still meeting the RP-8 luminance criteria. The five "white light" streetlights (four LED and induction) could be dimmed from 3% to 15% and still meet the RP-8 roadway lighting design criteria. This power reduction would result in life-cycle costs per mile decreasing by 1% to 3% as a result of reduced energy use. This life-cycle cost reduction does not account for additional labor costs that may be associated with actually dimming the streetlights before or during installation.

Increasing pole spacing is a more effective method to reduce life-cycle cost per mile than dimming the streetlights. Using the CIE mesopic photometry system, two of the "white light" streetlights (American Electric Lighting LEDR 10LED E35 MVOLT AR2 and Leotek Electronics GC1-40C-MV-CW-2M-GY) could be spaced up to 12% farther apart, resulting in life-cycle costs per mile reductions of 6% to 10%. However, these reduced life-cycle costs would not change the rank ordering of the streetlights shown in Figure 5. The other three "white light" streetlights could not be spaced farther apart because their pole spacings were limited by the disability glare ratio criterion, which is not affected by mesopic photometry since it is based on foveal vision (Fry 1954).

Discomfort Glare

NLPIP predicted discomfort glare for the six streetlights tested using the Outdoor Site-Lighting Performance (OSP) method (Brons et al. 2008, Bullough et al. 2008). Because the OSP method does not include spectral effects, NLPIP adjusted the results to take spectrum into account by using the discomfort glare model developed by Bullough (2009), as described in *Specifier Reports: Streetlights for Collector Roads*. The LED and induction streetlight lumens were scaled to provide equal street-side lumens and equivalent pole spacing to the base case layout (195 ft [59.4 m] using a single-sided layout). In doing so, the RP-8 criteria for uniformity and/or disability glare ratios were not met, even though the average luminance criterion was met. The predicted discomfort glare is rated using the De Boer scale, where a higher rating is associated with less discomfort glare. In a simulated urban environment, such as in a residential urban neighborhood, the models predicted that the LED streetlights tested would produce higher De Boer ratings (i.e., less discomfort glare) than the base case. The LED streetlights had predicted De Boer ratings that were between "just permissible and "disturbing" compared with the "disturbing" rating predicted for the base case. Both the GE Lighting induction and the base case were predicted to have lower De Boer ratings (rated as "disturbing").

Absolute Photometry

The pole spacing results given in this report are based on relative photometry for the GE Lighting HPS and induction streetlights and absolute photometry for the LED streetlights, as is the current practice. The absolute lumens (both lamp and resulting luminaire lumens) from the HPS streetlight were 9% lower than the rated lumens, and the absolute lumens from the induction streetlight were 8% lower than the rated lumens. Using absolute photometry in the AGi32 calculations, instead of relative photometry, did not change the pole spacing for the base case, and decreased the pole spacing for the induction streetlight by 5 ft (2 m) (4%) because the pole spacing was limited by the uniformity ratio criterion for these luminaires. For the induction streetlight, the 4% decrease in pole spacing would increase the induction streetlight's life-cycle cost by 4%.

Manufacturer-supplied Photometric Data

On average, the pole spacing determined using manufacturer-supplied photometry was about the same as the spacing determined using the measured intensity distributions. NLPIP obtained photometric files for all of the tested streetlights from manufacturers' websites or from the local manufacturer representatives in November 2010. The photometric data provided on the websites for the base case and induction streetlights were based on relative photometry. The manufacturers' photometric data resulted in pole spacings 15% shorter to 12% longer than that provided by the tested intensity distributions, with an average of 1% shorter.

Established Pole Spacing Results Using Higher Light Output Streetlights

Municipalities may consider replacing existing streetlights using the existing poles. To determine an appropriate pole spacing for analysis, NLPIP identified municipal codes via the Internet that prescribe pole spacing for 100 W HPS streetlights for local roads and found that the median pole spacing was 220 ft (67.1 m) between poles. In many cases, the local codes were unclear about whether the spacing given was for single-sided or staggered layouts and which lighting design criteria the given pole spacings were designed to meet. As shown in the "Pole Spacing" section above, none of the streetlights tested for this study would be able to meet the RP-8 luminance or illuminance criteria assuming a 26 ft (7.9 m) road width and an established 220 ft (67.1 m) pole spacing in a single-sided layout (and 440 ft [134 m] spacing between streetlights on the same side for a staggered layout).

To investigate whether higher light output streetlights could meet the RP-8 roadway lighting design criteria at 220 ft (67.1 m), NLPIP identified streetlights from the same manufacturers that were newer or provided more light output. NLPIP identified LED streetlights from the websites of the four manufacturers tested in this report and HPS streetlights from GE Lighting's website. No additional Type II induction streetlights were available from GE Lighting's website. NLPIP used the manufacturers' photometric data for this analysis. All identified streetlights had photometric files available for download or available from the manufacturer representatives, were described as Type II, and either had more LEDs and higher light output or were newer models than those tested in this report. HPS streetlights with power demands up to 150 W were included. Using this method, NLPIP identified 14 additional LED streetlights and four additional HPS streetlights from the manufacturers' websites in November 2010. NLPIP used both the tested GE Lighting 100 W HPS streetlight and additional HPS streetlights from GE Lighting for this analysis. NLPIP did not find GE Lighting HPS streetlight photometric data using a 100 W HPS lamp, so therefore proportionally scaled the lamp lumens from the GE Lighting 150 W HPS photometric data in AGi32 for use in the lighting simulations. The tested GE Lighting 100 W HPS streetlight (the base case) provided a 15% longer pole spacing than that provided by the proportionally scaled manufacturer photometric data for the same GE Lighting HPS streetlight model.

The results showed that none of these higher light output streetlights could meet the RP-8 illuminance or luminance criteria at 220 ft single-sided pole spacings, including the additional HPS streetlights. NLPIP then used the pole spacing achieved by the base case, 195 ft (59.4 m) between streetlights in a single-sided layout, as the established pole spacing criterion, but again none of the 14 LED streetlights nor the four additional HPS streetlights analyzed could meet the RP-8 illuminance or luminance criteria at this pole spacing. The streetlights could not meet the uniformity or disability glare ratio requirements in the RP-8 criteria, although they were able to meet the average luminance level requirements.

Higher Mounting Heights

In this study, NLPIP assumed a 25 ft (7.6 m) mounting height because, as already noted, this is typical for residential areas. As shown in the Luminaire System Application Efficacy charts in Appendix A, the most efficacious mounting height for many of these streetlights is higher than 25 ft (7.6 m), so NLPIP investigated the effect of mounting height on pole spacing because, again, pole costs dominate life-cycle costs.

For three of the four tested LED streetlights (American Electric Lighting LEDR 10LED E35 MVOLT AR2, Leotek Electronics GC1-40C-MV-CW-2M-GY, and Philips Lumec GPLS-65W49LED4K-LE2-VOLT-BKTX) and for the base case, increasing the mounting heights yielded longer pole spacings. For these three LED streetlights, the mounting height that resulted in the longest pole spacing (a height of 30 ft [9.1 m] to 40 ft [12 m]) increased the pole spacing in the range of 20% to 65%. At these mounting heights, the pole spacings were constrained by the RP-8 average luminance criterion, not the failure to meet the uniformity or disability glare ratio requirements. The GE Lighting induction streetlight yielded shorter pole spacings at increased mounting heights.

Increasing the mounting height up to 40 ft (12 m) would increase the pole spacing of four of the tested streetlights and would change the rank order of one tested LED streetlight. At a 40 ft (12 m) mounting height, the American Electric Lighting LEDR 10LED E35 MVOLT AR2 streetlight would provide the longest pole spacing (24% longer than that achieved by the base case) and a life-cycle cost 1% to 17% lower than the base case.

Although it is uncommon for poles of this height to be used in residential neighborhoods, these mounting heights may be used for other local roads, such as in industrial areas, but these roads are typically wider with more travel lanes and aluminum poles are used instead of wood poles. Results based on an industrial road scenario are discussed in the “Wider Roads” section below.

The effects of mesopic photometry were examined using a mounting height of 40 ft (12 m) because this height produced the most uniform lighting distribution. As discussed above, at a 25 ft (7.6 m) mounting height, only two of the five tested streetlights producing “white light” could be spaced farther apart using mesopic photometry. At a 40 ft (12 m) mounting height, four of the five tested “white light” streetlights could be spaced farther apart using mesopic photometry, with an incremental increase in pole spacing of 4% to 10% above what could be achieved using photopic photometry at this height.

Wider Roads

Local roads in urban residential areas are discussed throughout this report, but local roads are also found in industrial areas. Typically, industrial local roads are wider because they have more lanes and they use higher light output streetlights with higher mounting heights. NLPIP examined cases with a 48 ft (15 m) wide road, mounting heights of 35 ft (11 m) and 40 ft (12 m) (which would employ aluminum rather than wood poles), and 150 W and 250 W Type II HPS streetlights as the base cases.

NLPIP identified streetlights from manufacturer websites using a similar procedure as described in the “Higher Light Output Streetlights” section. NLPIP found some LED streetlights that could meet RP-8’s roadway lighting design criteria at the pole spacing provided by the 150 W HPS streetlights, but these streetlights had a 3% higher power demand on average than the 150 W HPS streetlights. NLPIP could not identify any LED streetlights that could meet RP-8’s criteria at the pole spacing that a 250 W HPS streetlight provided.

Economic Effects of Volume Pricing

The economic analysis above is based on the single-unit prices that NLPIP paid for the streetlights. Utilities and municipalities purchase streetlights in high volumes and receive a discounted price, so NLPIP conducted an additional life-cycle cost analysis for the tested streetlights assuming a volume discount of 50% for all the tested streetlights and replacement lamps and modules. The rank order of the streetlight life-cycle costs did not change, but the difference in price between the HPS and LED streetlights was reduced. Also, with a volume discount, the tested Beta Lighting STR-LWY-2M-HT-04-C-UL-SV streetlight in a single-sided layout would have a lower life-cycle cost per mile than the base case if it were to have a life of 50,000 hours (12 years) or longer, compared with 113,000 hours (27 years) at single-unit pricing.

Some streetlight system owners may be able to obtain financial incentives for installing LED and induction streetlights. In order for the tested LED (with a life of 25,000 hours or longer) or induction streetlight systems to have a lower life-cycle cost per mile than the base case, the required incentives would have to range from $250 to $1,550 per streetlight, in addition to the volume pricing discount.

Limitations

NLPIP purchased and tested only one sample of each streetlight model and only one HPS brand, and the results found here may differ from other samples and brands. NLPIP purchased the streetlights tested in this report between February 2010 and March 2010. Manufacturers using newer-generation LED packages and different optics 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, obtain independent laboratory tests for streetlights under consideration.

NLPIP used the RP-8 roadway lighting design criteria in its analyses. Specifiers using different lighting performance criteria may reach different conclusions about these technologies. Surveys of municipality and utility representatives, and outdoor lighting specifiers and manufacturers, by Mara et al. (2005) showed that, on average, only 25% of local roads are continuously lit as recommended by RP-8. Although 75% of streetlight system owners do not light their local roads to RP-8 recommendations, NLPIP followed the RP-8 performance criteria because no other national lighting standard exists, and because there was high variability among municipalities in their prescribed pole spacings. The low adoption rate of RP-8 nationally could indicate that this national standard is not meeting the needs of streetlight system owners. A new national standard—one based on recent crash statistics, visual performance metrics, understandings of mesopic vision, and streetlight control capabilities—might better serve the needs of streetlight system owners.

Conclusions

NLPIP simulated streetlight systems meeting RP-8 for a typical local road in a residential area. The simulations showed that in a single-sided layout, the four LED streetlights tested would have a lower power demand per mile than the tested GE Lighting HPS streetlight, which served as the base case, but in a staggered layout two of the four LED streetlights would have a higher power demand per mile than the base case. In both layouts, the GE Lighting induction streetlight NLPIP tested would have a higher power demand per mile than the base case. The tested LED and induction streetlights would have higher life-cycle costs per mile than the base case, except for one of the LED streetlights in one scenario that assumed at least a 27-year module life. To have a lower life-cycle cost than the base case, the tested LED and induction streetlights, other than the one scenario mentioned, would need to provide longer pole spacings.

NLPIP also considered a number of other factors that could affect streetlight layout and power demand. These considerations include mesopic photometry, mounting height, road width, established pole spacing, and higher light output streetlights. In most cases, the HPS streetlight(s) provided longer pole spacings than the LED and induction streetlights, with a few exceptions. NLPIP also examined the effect of volume pricing on life-cycle cost per mile and found that it would not change the rank ordering of the streetlights tested for most of the scenarios examined.

Appendix A: Data Sheets

The data sheets on the following pages provide information about the streetlights tested. 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 2009)
- 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 2009). 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 (local road, with low pedestrian conflict, R3 pavement) for both single-sided and staggered layouts
  - Luminaire system application efficacy (LSAE) for the given mounting height (NLPIP 2010a)
  - LSAE plot that shows LSAE values for a single-sided layout with mounting heights between 15 ft (4.6 m) and 50 ft (15 m), with associated pole spacings
  - De Boer ratings in a single-sided layout for three ambient lighting conditions (rural, suburban, and urban) when luminaire lumens are scaled to provide the same pole spacing as the HPS streetlight
  - 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

GE Lighting

Catalog #M2RC-
10S0H2GMC2

Lamp type: HPS
Power: 127.4W
Voltage: 120V
Luminaire lumens: 7300*
Street side lumens: 4300*
Luminaire efficacy: 57.3* lm/W

Lateral class: II
Vertical class: Short
Cutoff class: Semi-Cutoff
Bug rating: B2-U1-G2*

Electrical

Power factor: 0.97

Pricing

Luminaire: $157.15
Lamp: $13.50
Module replacement: N/A

Application

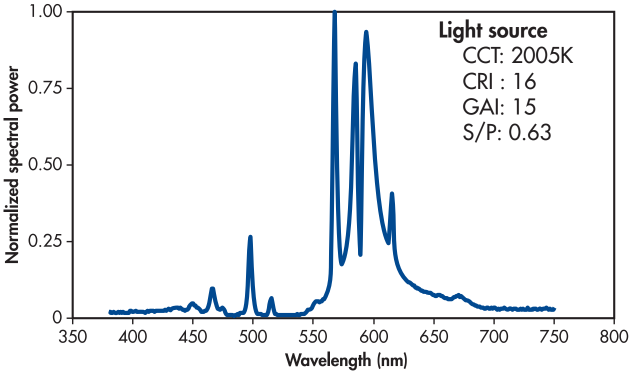
LSAE (25 ft height): 14.9 lm/W
Pole spacing (single side): 195 ft
Pole spacing (staggered): 415 ft

Discomfort Glare

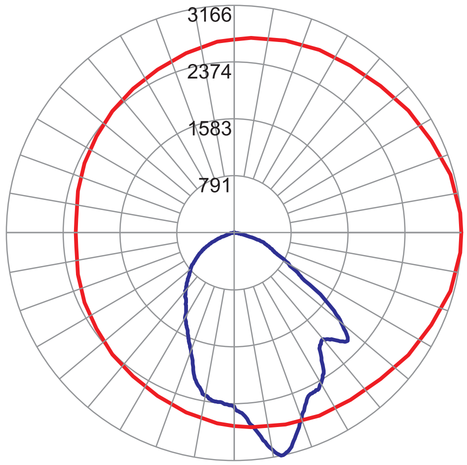
De Boer rating (rural): 3.0
De Boer rating (suburban): 3.4
De Boer rating (urban): 3.9

* Indicates results based on relative photometry

Spectral Power Distribution

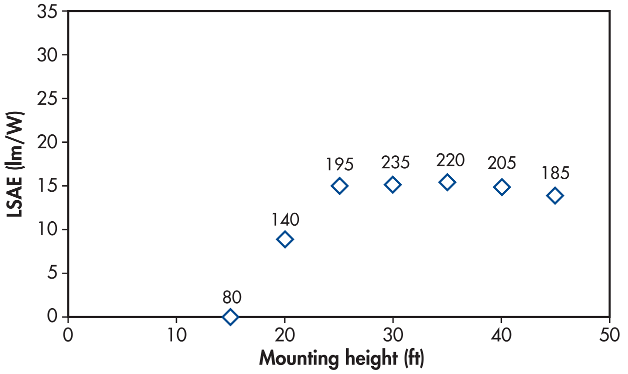


Intensity Distribution Curve



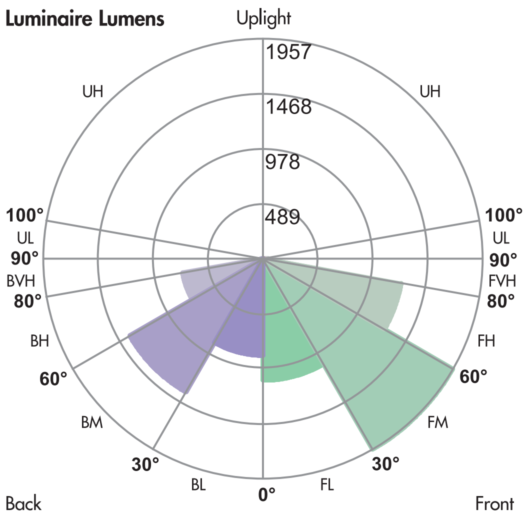
Red line - Horizontal plane through max cd vertical angle
Blue line - Vertical plane through max cd horizontal angle

Luminaire System Application Efficacy



Data labels indicate pole spacing (ft) for single-sided configuration

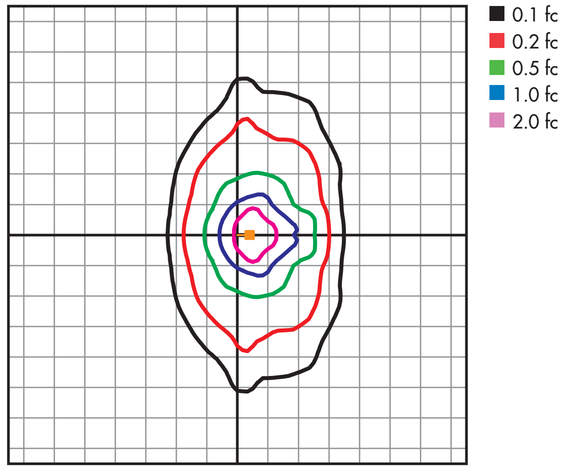
Luminaire Classification System



FL: 1100
FM: 2000
FH: 1300
FVH: 49
BL: 900
BM: 1400
BH: 700
BVH: 14
UL: 0
UH: 0

Values in lumens

Iso-Illuminance Plot



Template grid spacing = 15 ft x 15 ft
Mounting height = 25 ft

Arm length = 6 ft
LLF= 0.74

Data Sheet

GE Lighting

Catalog #MSCL10T0E21FSC2

Lamp type: Induction
Power: 109.9W
Voltage: 120V
Luminaire lumens: 6100*
Street side lumens: 3100*
Luminaire efficacy: 55.6* lm/W

Lateral class: II
Vertical class: Very Short
Cutoff class: Full Cutoff
Bug rating: B2-U0-G2*

Electrical

Power factor: 1.00

Pricing

Luminaire: $580.00
Lamp: $215.00
Module replacement: N/A

Application

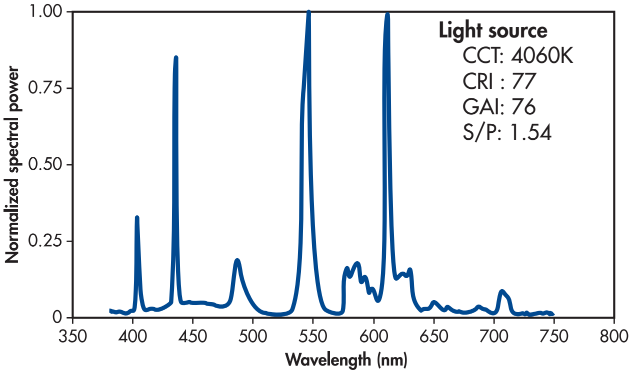
LSAE (25 ft height): 15.9 lm/W
Pole spacing (single side): 120 ft
Pole spacing (staggered): 245 ft

Discomfort Glare

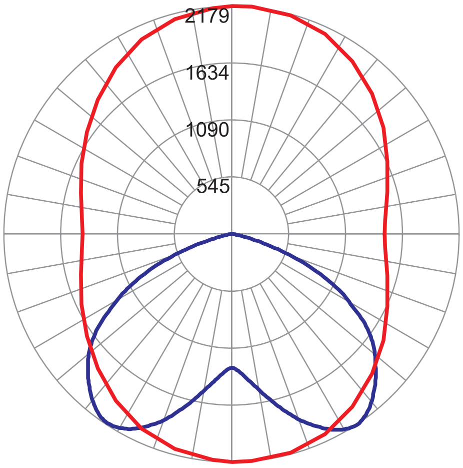
De Boer rating (rural): 2.6
De Boer rating (suburban): 3.0
De Boer rating (urban): 3.4

* Indicates results based on relative photometry

Spectral Power Distribution

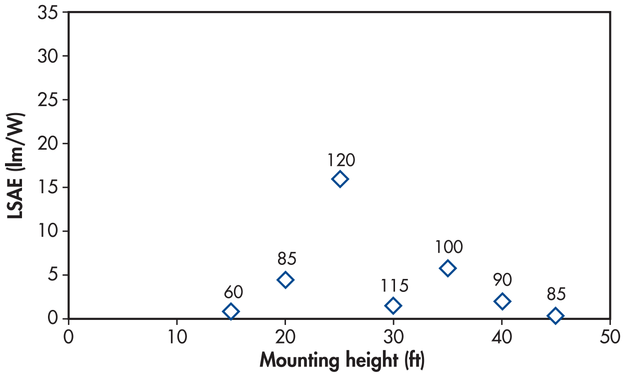


Intensity Distribution Curve



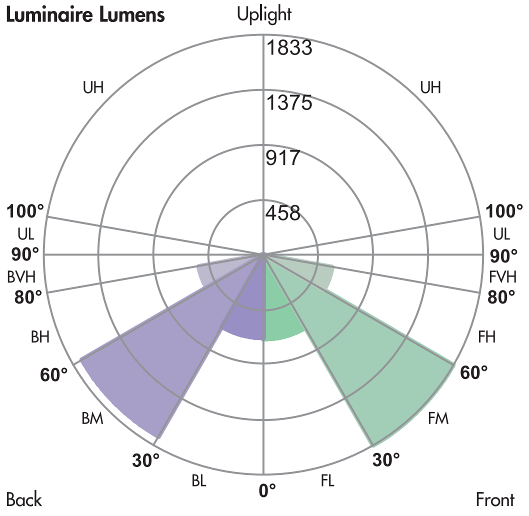
Red line - Horizontal plane through max cd vertical angle
Blue line - Vertical plane through max cd horizontal angle

Luminaire System Application Efficacy



Data labels indicate pole spacing (ft) for single-sided configuration

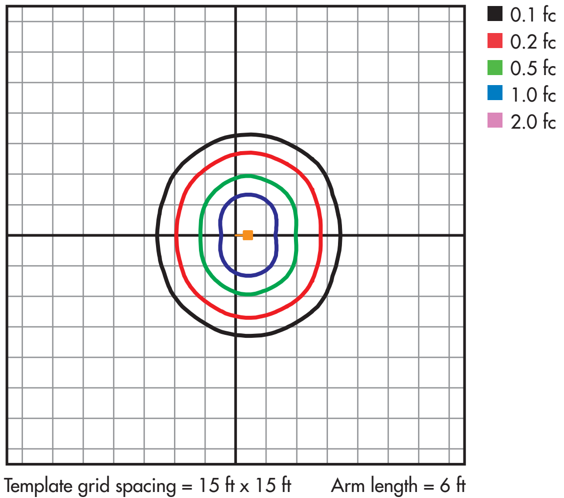
Luminaire Classification System



FL: 700
FM: 1800
FH: 600
FVH: 8
BL: 700
BM: 1700
BH: 500
BVH: 6
UL: 0
UH: 0

Values in lumens

Iso-Illuminance Plot



Template grid spacing = 15 ft x 15 ft
Mounting height = 25 ft

Arm length = 6 ft
LLF= 0.62

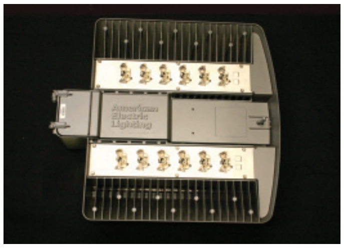
Data Sheet

American Electric Lighting

Catalog #LEDR 10LED E35 MVOLT AR2

Lamp type: LED
Power: 90.1W
Voltage: 120V
Luminaire lumens: 5900
Street side lumens: 4800
Luminaire efficacy: 65.4 lm/W

Lateral class: I
Vertical class: Medium
Cutoff class: Non-Cutoff
Bug rating: B1-U1-G1



Electrical

Power factor: 1.00

Pricing

Luminaire: $1,031.25
Lamp: $N/A
Module replacement: $355.00

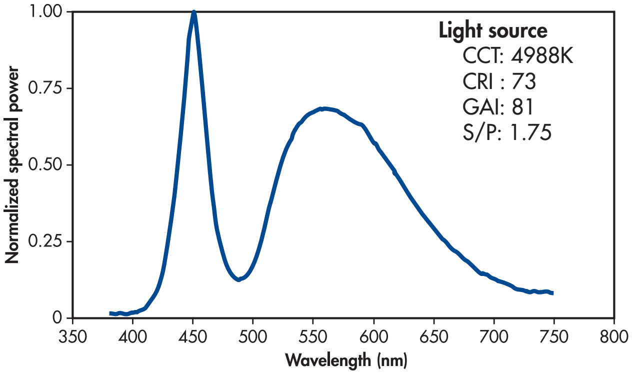
Application

LSAE (25 ft height): 6.6 lm/W
Pole spacing (single side): 155 ft
Pole spacing (staggered): 265 ft

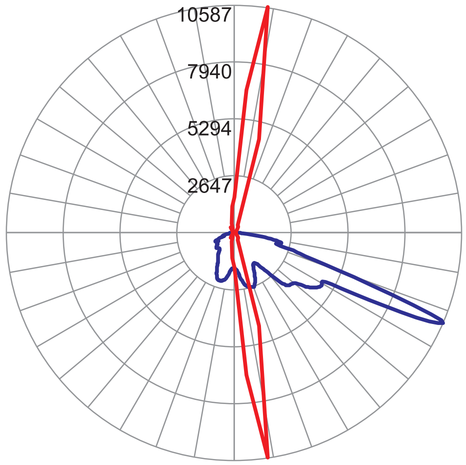
Discomfort Glare

De Boer rating (rural): 4.1
De Boer rating (suburban): 4.8
De Boer rating (urban): 5.6

Spectral Power Distribution

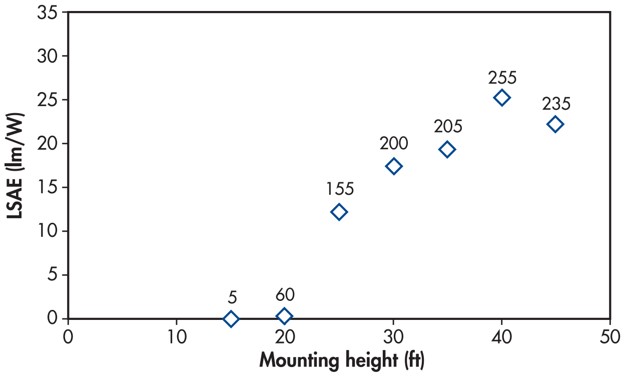


Intensity Distribution Curve



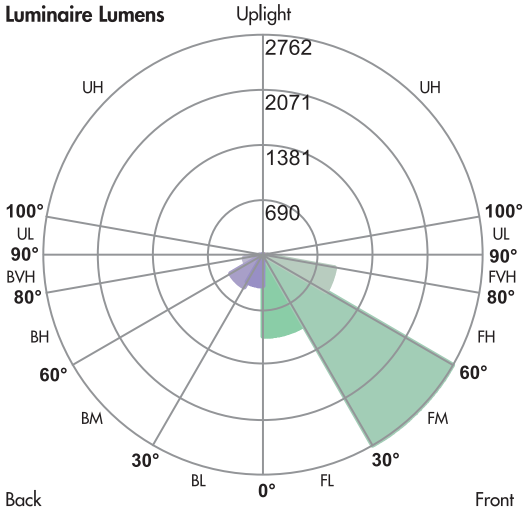
Red line - Horizontal plane through max cd vertical angle
Blue line - Vertical plane through max cd horizontal angle

Luminaire System Application Efficacy



Data labels indicate pole spacing (ft) for single-sided configuration

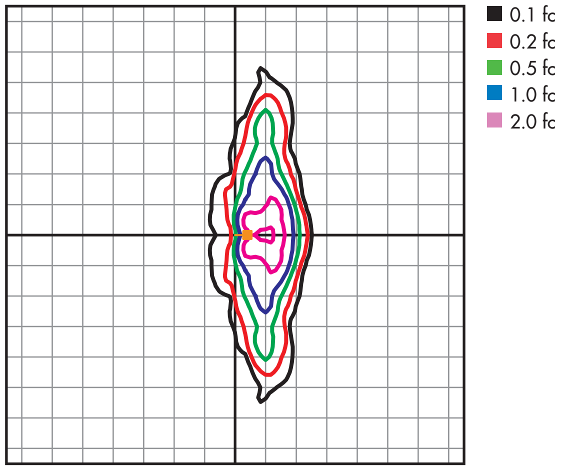
Luminaire Classification System



FL:	1000
FM:	2800
FH:	900
FVH:	59
BL:	400
BM:	500
BH:	200
BVH:	42
UL:	0
UH:	0

Values in lumens

Iso-Illuminance Plot



Template grid spacing = 15 ft x 15 ft
Mounting height = 25 ft

Arm length = 6 ft
LLF= 0.7

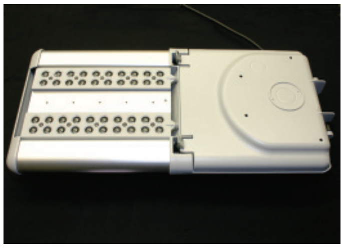
Data Sheet

Beta Lighting

Catalog #STR-LWY-2M-HT-04-C-UL-SV

Lamp type: LED
Power: 72.9W
Voltage: 120V
Luminaire lumens: 4600
Street side lumens: 3100
Luminaire efficacy: 62.8 lm/W

Lateral class: II
Vertical class: Medium
Cutoff class: Non-Cutoff
Bug rating: B1-U1-G1



Electrical

Power factor: 1.00

Pricing

Luminaire: $626.75
Lamp: $N/A
Module replacement: $300.00

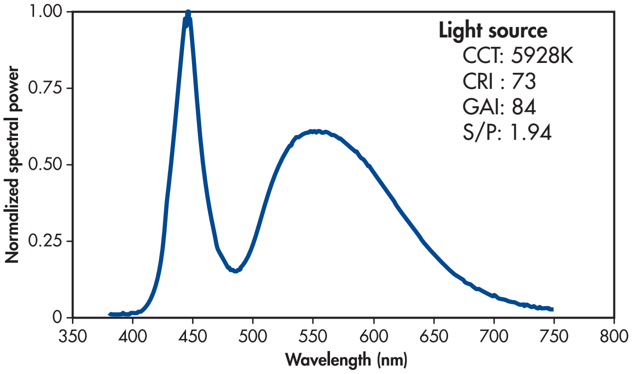
Application

LSAE (25 ft height): 19.4 lm/W
Pole spacing (single side): 190 ft
Pole spacing (staggered): 340 ft

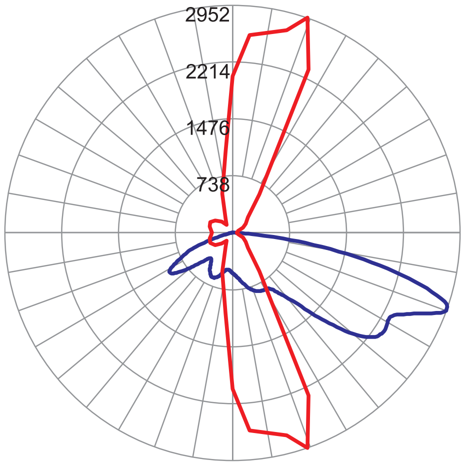
Discomfort Glare

De Boer rating (rural): 3.1
De Boer rating (suburban): 3.5
De Boer rating (urban): 4.0

Spectral Power Distribution

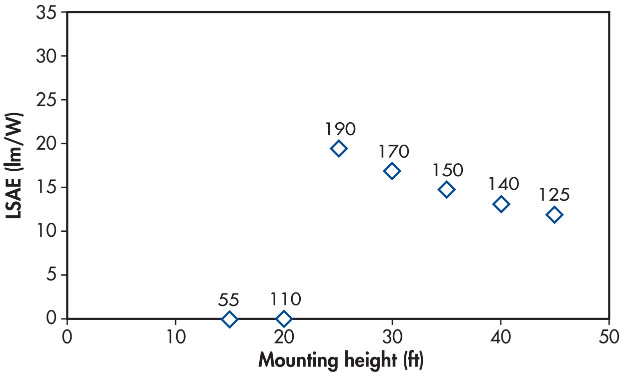


Intensity Distribution Curve



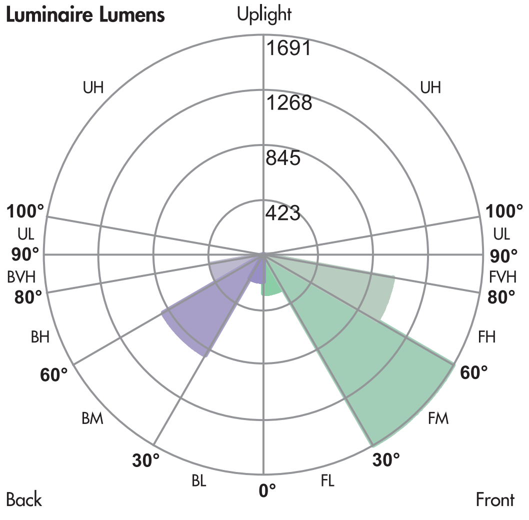
Red line - Horizontal plane through max cd vertical angle
Blue line - Vertical plane through max cd horizontal angle

Luminaire System Application Efficacy



Data labels indicate pole spacing (ft) for single-sided configuration

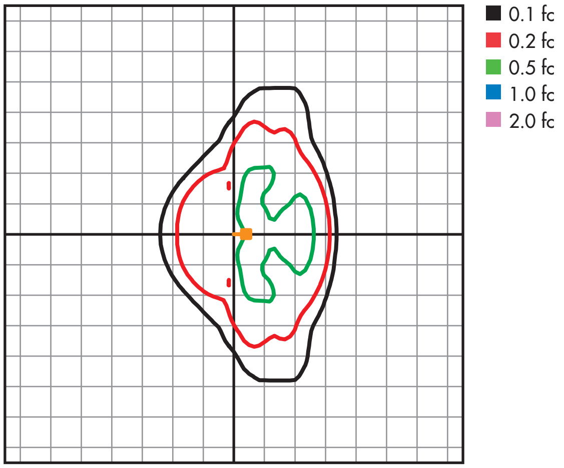
Luminaire Classification System



FL:	300
FM:	1700
FH:	1000
FVH:	67
BL:	200
BM:	900
BH:	400
BVH:	6
UL:	0
UH:	0

Values in lumens

Iso-Illuminance Plot



Template grid spacing = 15 ft x 15 ft
Mounting height = 25 ft
Arm length = 6 ft
LLF= 0.7

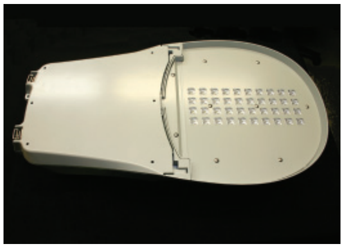
Data Sheet

Leotek Electronics

Catalog #GC1-40C-MV-CW-2M-GY

Lamp type: LED
Power: 67.3W
Voltage: 120V
Luminaire lumens: 3900
Street side lumens: 2900
Luminaire efficacy: 58.4 lm/W

Lateral class: II
Vertical class: Medium
Cutoff class: Full Cutoff
Bug rating: B1-U1-G1



Electrical

Power factor: 0.99

Pricing

Luminaire: $640.00
Lamp: $N/A
Module replacement: $640.00

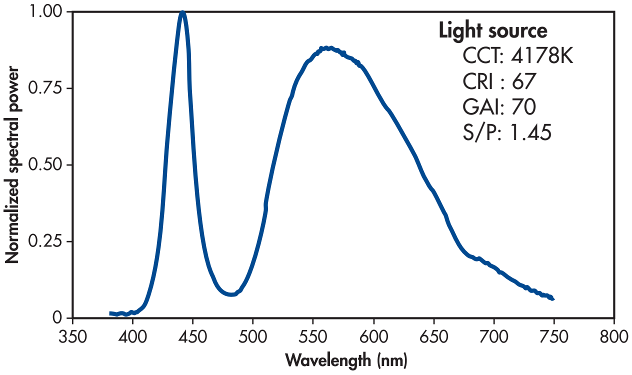
Application

LSAE (25 ft height): 8.2 lm/W
Pole spacing (single side): 125 ft
Pole spacing (staggered): 220 ft

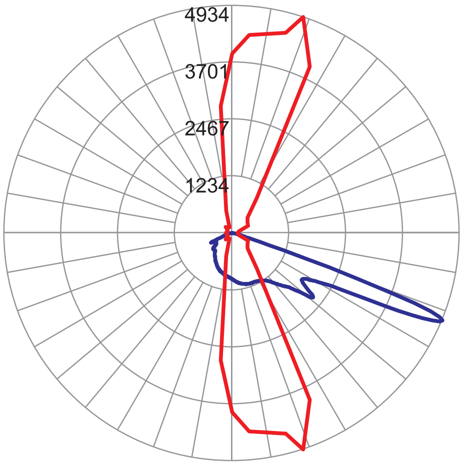
Discomfort Glare

De Boer rating (rural): 3.6
De Boer rating (suburban): 4.1
De Boer rating (urban): 4.8

Spectral Power Distribution

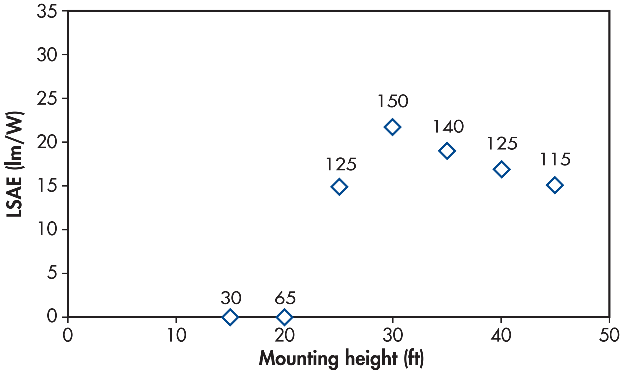


Intensity Distribution Curve



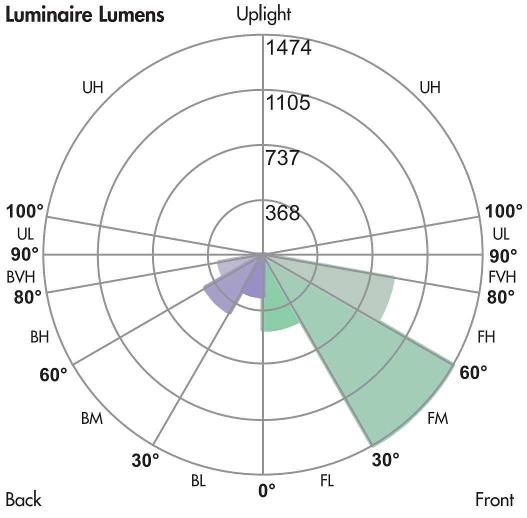
Red line - Horizontal plane through max cd vertical angle
Blue line - Vertical plane through max cd horizontal angle

Luminaire System Application Efficacy



Data labels indicate pole spacing (ft) for single-sided configuration

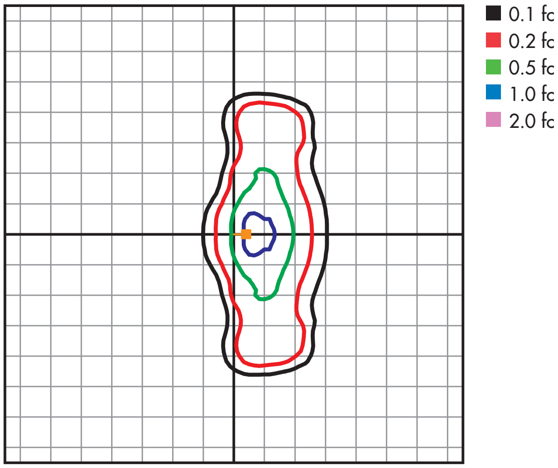
Luminaire Classification System



FL: 500
FM: 1500
FH: 900
FVH: 26
BL: 300
BM: 400
BH: 300
BVH: 36
UL: 0
UH: 0

Values in lumens

Iso-Illuminance Plot



Template grid spacing = 15 ft x 15 ft
Mounting height = 25 ft

Arm length = 6 ft
LLF= 0.7

Data Sheet

Philips Lumec

Catalog #GPLS-65W49LED4K-LE2-VOLT-BKTX

Lamp type: LED
Power: 71.6W
Voltage: 120V
Luminaire lumens: 4400
Street side lumens: 3300
Luminaire efficacy: 60.9 lm/W

Lateral class: II
Vertical class: Short
Cutoff class: Semi-Cutoff
Bug rating: B1-U1-G1

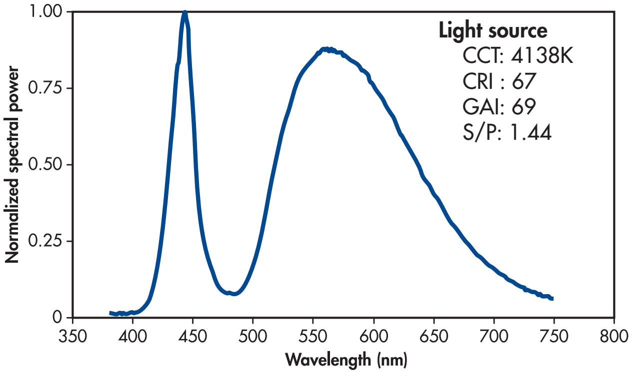
Electrical
Power factor: 0.99

Pricing
Luminaire: $656.25
Lamp: $N/A
Module replacement: $200.00

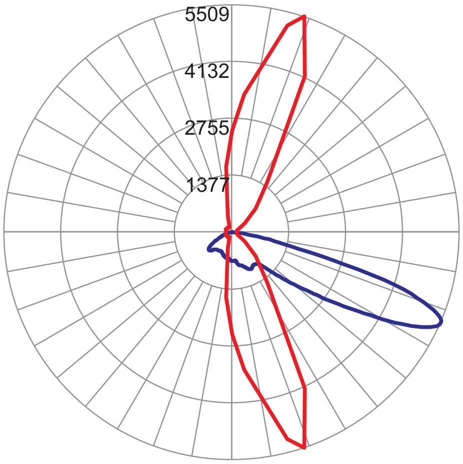
Application
LSAE (25 ft height): 18.9 lm/W
Pole spacing (single side): 145 ft
Pole spacing (staggered): 285 ft

Discomfort Glare
De Boer rating (rural): 3.9
De Boer rating (suburban): 4.5
De Boer rating (urban): 5.2

Spectral Power Distribution

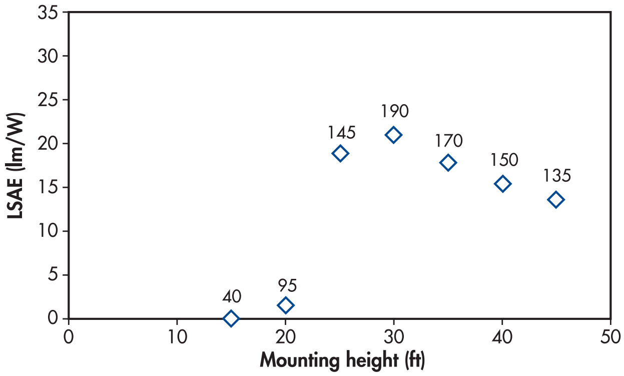


Intensity Distribution Curve



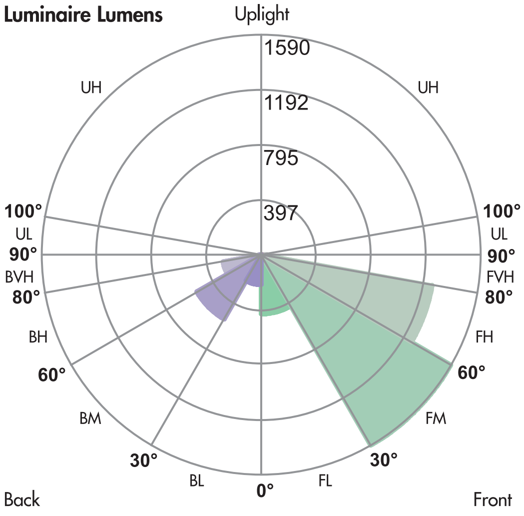
Red line - Horizontal plane through max cd vertical angle
Blue line - Vertical plane through max cd horizontal angle

Luminaire System Application Efficacy



Data labels indicate pole spacing (ft) for single-sided configuration

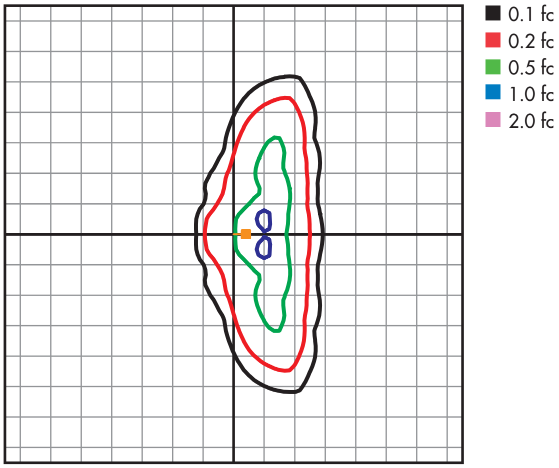
Luminaire Classification System



FL: 400
FM: 1600
FH: 1300
FVH: 44
BL: 200
BM: 500
BH: 300
BVH: 15
UL: 0
UH: 0

Values in lumens

Iso-Illuminance Plot



Template grid spacing = 15 ft x 15 ft
Mounting height = 25 ft
Arm length = 6 ft
LLF= 0.7

Further Information

NLPIP has published several reports about other topics and technologies also used in streetlights:

- **Ballasts.** For more information, refer to *Specifier Reports: Electronic Ballasts*, available online at: www.lrc.rpi.edu/nlpip/publicationDetails.asp?id=129&type=1 and *Specifier Reports, Dimming Electronic Ballasts*, available online at: www.lrc.rpi.edu/nlpip/publicationDetails.asp?id=108&type=1 and *Lighting Answers: Adaptable Ballasts*, available online at: www.lrc.rpi.edu/nlpip/publicationDetails.asp?id=886&type=2.
- **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.
- **LED lamps.** For more information, refer to *Lighting Answers: LED Lighting Systems*, available online at: www.lrc.rpi.edu/nlpip/publicationDetails.asp?id=885&type=2.
- **Light pollution.** For more information, refer to *Lighting Answers: Light Pollution*, available online at: www.lrc.rpi.edu/programs/nlpip/lightinganswers/lightpollution/abstract.asp.
- **MH lamps.** For more information, refer to *Lighting Answers: Mid-wattage Metal Halide Lamps*, available online at: www.lrc.rpi.edu/nlpip/publicationDetails.asp?id=882&type=2 or *Specifier Reports: Low-wattage Metal Halide Lighting Systems*, available online at: www.lrc.rpi.edu/nlpip/publicationDetails.asp?id=911&type=1.
- **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
- **Streetlight components.** 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.

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Streetlights for Local Roads

Volume 14 Number 1, February 2011

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Specifier Reports

Paul Lutkevich and Robert Henderson provided input for technical review. Reviewers are listed to acknowledge their contributions to the final publication. Their approval or endorsement of this report is not necessarily implied.

Production of this report involved important contributions from many faculty and staff members at the LRC: Andrew Bierman, John Bullough, Rosa Capó, Mariana Figueiro, Jean Paul Freyssinier, Russell Leslie, Lenda Lyman, Peter Morante, Nadarajah Narendran, Howard Ohlhous, Martin Overington, Mark Rea, and Bonnie Westlake.

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

Specifier Reports

Power Reducers, 1992; *Specular Reflectors*, 1992; *Cathode-Disconnect Ballasts*, 1993; *Exit Signs*, 1994; *Reflector Lamps*, 1994; *CFL Downlights*, 1995; *HID Accent Lighting Systems*, 1996; *Occupancy Sensors*, 1998; *Lighting Circuit Power Reducers*, 1998; *Screwbase Compact Fluorescent Lamp Products*, 1999; *Energy-Efficient Ceiling-Mounted Residential Luminaires*, 1999; *Dimming Electronic Ballasts*, 1999; *Electronic Ballasts*, 2000; *Parking Lot and Area Luminaires*, 2004; *Low-wattage Metal Halide Lighting Systems*, 2006; *Photosensors*, 2007; *CFL Residential Downlights*, 2008; *Streetlights for Collector Roads*, 2010

Specifier Reports Supplements

Exit Signs, 1995, 1998; *Energy-Efficient Ceiling-Mounted Residential Luminaires*, 2000;*HID Accent Lighting*, 2000; *Screwbase Compact Fluorescent Lamp Products*, 2000

Lighting Answers

Multilayer Polarizer Panels, 1993; *Task Lighting for Offices*, 1994; *Dimming Systems for High-Intensity Discharge Lamps*, 1994; *Electromagnetic Interference Involving Fluorescent Lighting Systems*, 1995; *Power Quality*, 1995; *Thermal Effects in 2′ x 4′ Fluorescent Lighting Systems*, 1995; *T10 and T9 Fluorescent Lamps*, 1995; *T5FT Lamps and Ballasts*, 1996; *Controlling Lighting with Building Automation Systems*, 1997; *Alternatives to Halogen Torchieres*, 2000; *T5 Fluorescent Systems*, 2002; *MR16 Lamps*, 2002; *Mid-wattage Metal Halide Lamps*, 2003; *Light Pollution*, 2003; *LED Lighting Systems*, 2003; *Adaptable Ballasts*, 2003; *Full-Spectrum Light Sources*, 2003; *Light Sources and Color*, 2004; *T8 Fluorescent Lamps*, 2006; *High-wattage Fluorescent Lamps*, 2006; *Photovoltaic Lighting*, 2006; *Availability of LED Lighting Products for Consumers*, 2009; *LED Residential Under-cabinet Luminaires*; 2010; *Dynamic Outdoor Lighting*, 2010

Lighting Diagnostics

Dimming T8 Fluorescent System Problems, 2006

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