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Demonstration Assessment of LED Roadway Lighting

NE Cully Boulevard
Portland, OR

June 2012

Final Report prepared in support of the U.S. DOE GATEWAY Solid-State Lighting Technology Demonstration Program

Prepared for:

Solid-State Lighting Program
Building Technologies Program
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Prepared by:

Pacific Northwest National Laboratory

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Host Site: NE Cully Boulevard, Portland, OR

Final Report prepared in support of the
U.S. Department of Energy GATEWAY Solid-State
Lighting Technology Demonstration Program

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under Contract DE-AC05-76RL01830

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Preface

This document includes observations and results obtained from a lighting demonstration project conducted under the U.S. Department of Energy (DOE) GATEWAY Solid-State Lighting Technology Demonstration Program. The program supports demonstrations of solid-state lighting (SSL) products in order to develop empirical data and experience with field applications of this advanced lighting technology. The GATEWAY program focuses on providing a source of independent, third-party data for consideration in decision making by lighting users and professionals; this data should be considered in combination with other information relevant to the application under examination. Each GATEWAY demonstration compares one or more SSL products with the incumbent technology used in that location. Depending on available information and circumstances, the SSL product(s) may also be compared to other alternative lighting technologies. Although products demonstrated by the GATEWAY program may have been prescreened and tested to verify their actual performance, DOE does not endorse any commercial product or guarantee that users will achieve the same results.

Note: The original version of this report was published in June 2012. It was revised in August 2012 to correct the catalog number of the LED product from GE Lighting Solutions (type D). The manufacturer's claimed values for this product were changed accordingly, resulting in improved agreement between measured and predicted performance.

Summary

A new roadway lighting demonstration project was initiated in late 2010, which was planned in conjunction with other upgrades to NE Cully Boulevard, a residential collector road in the northeast area of Portland, OR. With the NE Cully Boulevard project, the Portland Bureau of Transportation hoped to demonstrate different light source technologies and different luminaires side-by-side.

This report documents the initial performance of six different newly installed luminaires, including three LED products, one induction product, one ceramic metal halide product, and one high-pressure sodium (HPS) product that represented the baseline solution. It includes reported, calculated, and measured performance; evaluates the economic feasibility of each of the alternative luminaires; and documents user feedback collected from a group of local Illuminating Engineering Society (IES) members that toured the site. This report does not contain any long-term performance evaluations or laboratory measurements of luminaire performance.

Although not all of the installed products performed equally, the alternative luminaires generally offered higher efficacy, more appropriate luminous intensity distributions, and favorable color quality when compared to the baseline HPS luminaire. However, some products did not provide sufficient illumination to all areas—vehicular drive lanes, bicycle lanes, and sidewalks—or would likely fail to meet design criteria over the life of the installation due to expected depreciation in lumen output.

While the overall performance of the alternative luminaires was generally better than the baseline HPS luminaire (Table S1), cost remains a significant barrier to widespread adoption. Based on the cost of the small quantity of luminaires purchased for this demonstration, the shortest calculated payback period for one of the alternative luminaire types was 17.3 years. The luminaire prices were notably higher than typical prices for currently available luminaires purchased in larger quantities. At prices that are more typical, the payback would be less than 10 years.

In addition to the demonstration luminaires, a networked control system was installed for additional evaluation and demonstration purposes. The capability of control system to measure luminaire input power was explored in this study. A more exhaustive demonstration and evaluation of the control system will be the subject of a future GATEWAY report(s).

Table S1. Key initial performance characteristics for the six demonstration luminaires installed on NE Cully Boulevard. The metrics shown are defined in the body of this report.

Area / Luminaire Type: **Source Type**	**A** **LED**	**B** **Induction**	**C** **LED**	**D** **LED**	**E** **CMH**	**F** **HPS**
Measured Input Power (W)	79	101	79	68	69	142
Manufacturer's Listed Output (lm)[1]	3,700	6,298	5,712	3,700	5,642	6,691
Luminous Efficacy (lm/W)	47	63	73	54	82	47
Drive Lane Delivery Efficiency	30%	21%	31%	29%	44%	24%
Drive Lane Application Efficacy (lm/W)	13.8	13.0	22.6	23.1	35.7	11.3
Total Delivery Efficiency	44%	44%	65%	42%	65%	48%
Total Application Efficacy (lm/W)	20.7	27.2	47.2	33.4	53.6	22.7

1. Total lumen output was not measured; manufacturers' listed values were used in all calculations, where applicable.

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Acronyms and Abbreviations

ANSI	American National Standards Institute
CMH	ceramic metal halide
CCT	correlated color temperature
CRI	color rendering index
DOE	United States Department of Energy
HPS	high-pressure sodium
IES	Illuminating Engineering Society of North America
LED	light-emitting diode
MPH	miles per hour
PBOT	Portland Bureau of Transportation
PGE	Portland General Electric
PNNL	Pacific Northwest National Laboratory
RMS	root mean square
SSL	solid-state lighting

Units of Measurement

A	amperes
cd	candela
fc	footcandles
lm	lumens
V	volts
W	watts

1 Introduction

This report describes a demonstration of solid-state lighting (SSL) technology used for roadway lighting in Portland, Oregon. The demonstration was conducted by the Pacific Northwest National Laboratory (PNNL) in conjunction with the City of Portland, and supported by the U.S. Department of Energy (DOE) GATEWAY Solid-State Lighting Demonstration Program. The City of Portland performed design calculations, and ultimately selected, purchased, and installed the demonstration luminaires. PNNL assisted with the specification process, took measurements, obtained feedback, and analyzed the results.

PNNL manages the GATEWAY demonstration program for DOE and represents DOE's perspective in the conduct of the work. DOE supports demonstration projects to develop real-world experience and data with SSL products in general illumination applications. The GATEWAY approach is to carefully match applications with suitable products and form project teams to carry out the evaluation. Other project reports and related information are available on DOE's SSL website, http://ssl.energy.gov/.

Portland Street Lighting

The typical street lighting in Portland uses high-pressure sodium (HPS) lamps and cobrahead-style luminaires, although decorative fixtures are installed in select locations. The nominal input power of the lamps ranges from 100 to 400 W. There are approximately 54,000 streetlights within the city, approximately 80% of which are maintained by Portland General Electric (PGE), the local utility. The others are maintained by the Portland Bureau of Transportation (PBOT).

Portland has been actively investigating alternatives to the existing HPS street lighting for several years, with the primary alternative technologies being LED and induction. A number of demonstration projects have been conducted to evaluate new products, but widespread adoption has yet to occur. Portland's Citywide Sustainability Goals call for investment in all energy-efficiency measures with a payback period of 10 years or less [1].

NE Cully Boulevard Demonstration

A new street lighting demonstration project was initiated in late 2010, in conjunction with other upgrades to NE Cully Boulevard, a residential collector road in the northeast area of the city. With the NE Cully Boulevard project, PBOT hoped to evaluate different light source technologies and multiple LED luminaires side-by-side. The installation also included a system capable of adaptive control and remote monitoring of the street lighting.

This report documents the initial performance of the installed lighting systems—including reported, calculated, and measured values—evaluates the economic feasibility of each of the demonstration luminaires, and documents user feedback collected from a group of local Illuminating Engineering Society (IES) members that toured the site. This report does not contain any long-term performance evaluations or laboratory measurements of luminaire performance.

2 Project Description

Site Description

The portion of NE Cully Boulevard in use for the demonstration—between NE Prescott Street and NE Emerson Street—is relatively straight, oriented in a southwest-northeast direction, and intersects the typical street grid at an angle (Figure 1). The street is classified as a neighborhood collector road, and the posted speed limit is 35 MPH. It carries approximately 4,600 vehicles per day, including residential, commercial, and industrial traffic. In addition to being a vehicular throughway, the street serves both bicyclists and pedestrians.

NE Cully Boulevard Green Street Project

The new lighting was one component of a complete renovation of the corridor. The Green Street project included repaving the two 11-foot asphalt vehicular travel lanes, installing 6-foot sidewalks separated from the roadway by 4-foot planters, expansion of the existing bicycle lanes to 7.5-foot buffered lanes that are separated from the main travel lanes by parking, and narrowing of the skewed intersections (often with rain gardens, or *bioswales*, to manage storm water). The lighting demonstration project included the installation of six different luminaires and four light source technologies: three LED, one induction, one ceramic metal halide (CMH), and one HPS. Each area/luminaire type was assigned an identification letter from A through F. The luminaires were mounted on newly installed metal poles, and energized by new 240 VAC electrical circuits. Two current photos of the site are shown in Figure 2.

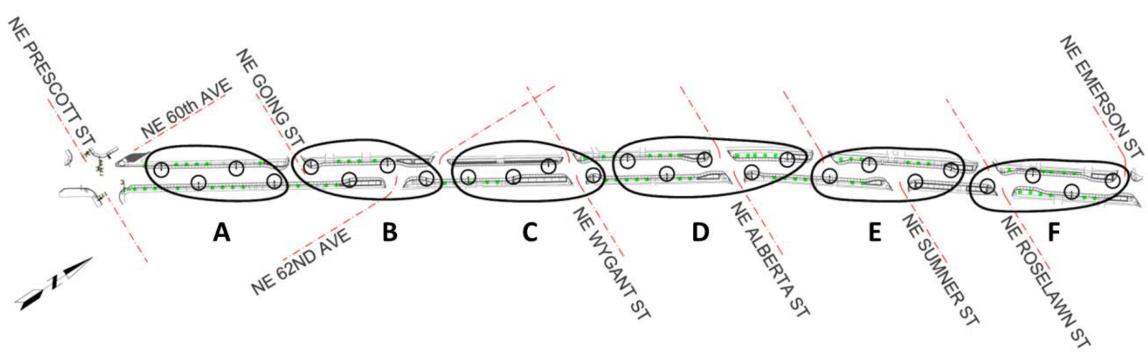

Figure 1. Diagram of the six areas along NE Cully Boulevard in Portland, OR. A different luminaire was installed in each area.

Figure 2. Daytime views of NE Cully Boulevard. The lighting demonstration followed numerous upgrades to the corridor including repaving, the addition of planters, and modifications to the bicycle lanes.

Previous Lighting

Prior to the Green Street project, NE Cully Boulevard was illuminated with GE M-400 Powr/Door roadway luminaires with cutoff optics (model MDCL-20-S-3-M-2-2-F-MC3), spaced at approximate 200 feet. All luminaires were mounted on electric utility poles on the east side of the roadway, and each luminaire was outfitted with a 200 W HPS lamp. This style of street light remains in place on the segments of NE Cully Boulevard adjacent to the demonstration site.

Design Criteria

The City of Portland established street lighting standards in 1980 [2]. These standards are similar, although not identical, to the ANSI/IESNA RP-8-00 recommended practice [3]. According to the Portland street lighting standards document, NE Cully Boulevard could be classified as either a Class 4 (Neighborhood Collector – Major Transit) or Class 5 (Neighborhood Collector – Minor Transit) roadway. According to the former, travel lanes should be illuminated to an average of ≥ 0.7 fc (horizontal), whereas the latter recommends the travel lanes be illuminated to an average of ≥ 0.5 fc (horizontal). The same criterion also applies to bicycle lanes, although in this case they are separated from the vehicular travel lanes by parking spaces, which do not have a requirement. Under either classification, the average to minimum illuminance ratio (avg:min) must be ≤ 3.0, and the maximum to minimum ratio (max:min) must be ≤ 9.0. The minimum average illuminance for the sidewalks is 0.2 fc (horizontal). There are no additional illuminance criteria for intersections according to Portland's street lighting standards. In this document, NE Cully Boulevard is considered a Class 5 roadway.

According to RP-8-00, the average illuminance for a collector road with low pedestrian conflict and R3 pavement should be ≥ 0.6 fc (horizontal), with an average to minimum illuminance ratio ≤ 4.0. Bicycle lanes should have an average horizontal illuminance of ≥ 0.3 fc, an average vertical illuminance of ≥ 0.08 fc, and an average to minimum ratio of ≤ 6.0.

Demonstration Luminaires

Six different luminaires were installed in groups of four or five. The luminaires were installed in adjacent groupings on newly installed 30-foot poles on alternating sides of the street (except where this was not possible in area C due to a large tree), spaced at approximately 100 feet. Actual spacing varied based on local conditions—the pole spacing for the illuminance field measurements ranged from 80 feet to 115 feet. The pole spacing was determined based on calculations for the baseline HPS luminaire, rather than individually for each alternative luminaire, to enable a potential return to all-HPS lighting if it was so desired.

The six luminaires are listed in Table 1 and shown in Figure 3. The luminaires were selected based on their ability to meet illuminance criteria given the pole spacing and mounting height requirements, as well as their general overall performance. Complete specification sheets for each product can be found in Appendix A.

Installation and Operation

The City of Portland has multiple arrangements with PGE regarding installation and service of streetlights. For this installation, PBOT was responsible for all installation, and is responsible for any maintenance or replacement costs associated with the luminaires and poles.

Table 1. **Products installed along NE Cully Boulevard.** Complete specification sheets are available in Appendix A.

Area / Type	Lamp Type	Manufacturer	Product Family	Model Number
A	LED	Philips Hadco	Evolaire	WL70N-HT2-I-22-35-N-N
B	Induction	GE Lighting Solutions	M-400	MSCL-10-T-0-E-2-1-F-SC2
C	LED	Cooper Lumark	RC LED	LDRC-T3-A03-E-BZ
D	LED	GE Lighting Solutions	Evolve	ERMC-0-A8-43-A-1-GRAY
E	CMH[1]	Philips Lumec	Helios	HBS-60CW-SC2-240-RC-GLB
F	HPS	GE Lighting Solutions	M-250	M2AC-10-S-0-N-2-G-MC3

1. Specifically, this is a horizontally oriented Philips CosmoPolis lamp, which is sometimes referred to as "eCMH."

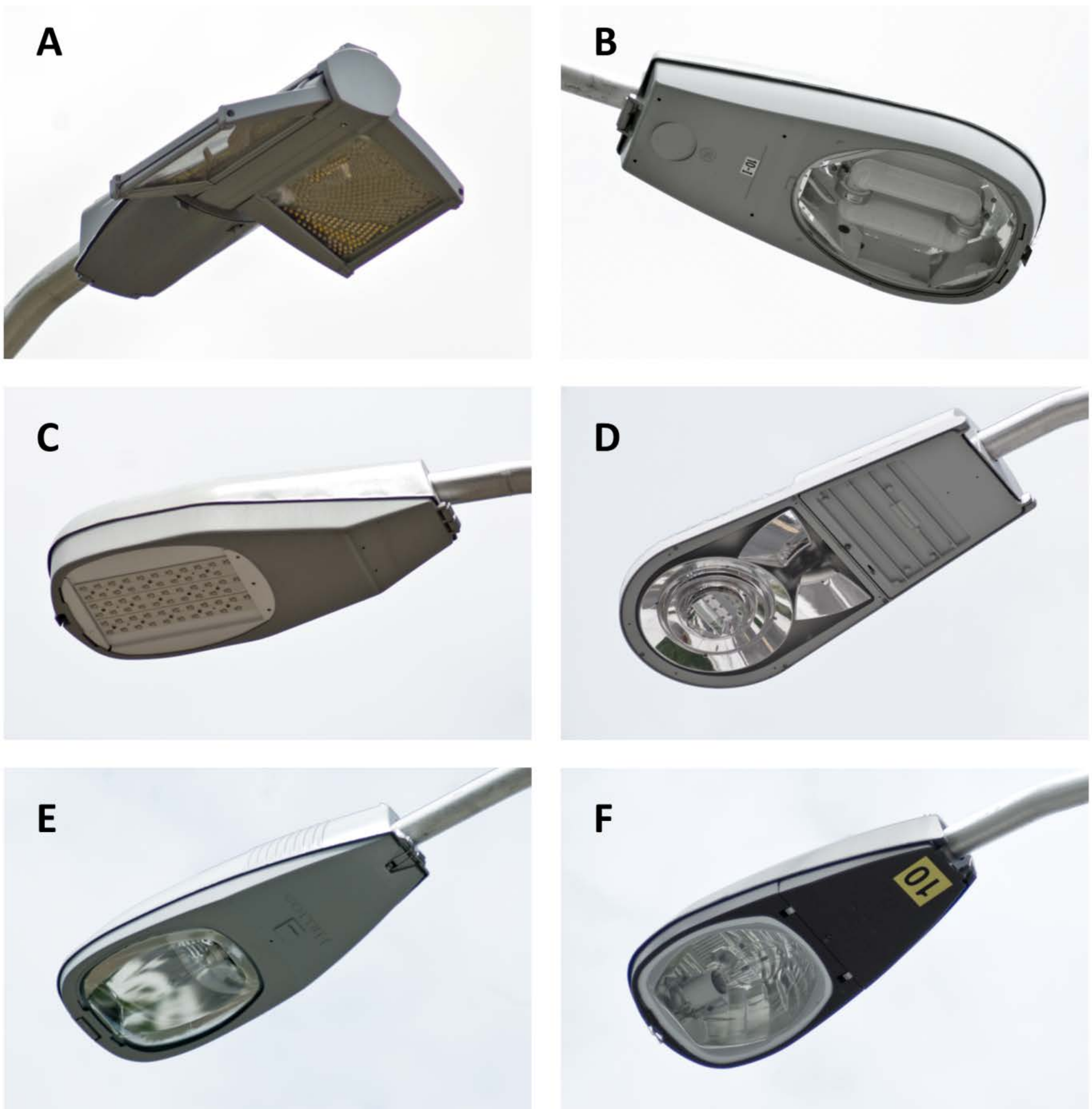

Figure 3. Photographs of the six demonstration products installed on NE Cully Boulevard. Besides relying on different light source technologies, the luminaires use different optical systems to deliver light to the target areas.

3 Performance Analysis

There are many ways to evaluate prospective and/or installed luminaires, all providing useful information. For this report, the demonstration luminaires were evaluated based on their listed performance according to the manufacturer, their performance determined by computer calculations, and their in-the-field performance via physical measurements.

Product Comparison

The ability of an installed luminaire to meet the needs of an application begins with choosing a suitable product. The luminaires selected for this demonstration project were chosen by PBOT and/or PNNL following a design simulation of each to ensure its performance was up to the task. Given the scope of the project, it was not possible to evaluate or select every luminaire that could be used in lieu of the baseline 100 W HPS luminaire.

Table 2 provides performance characteristics for the six demonstration products. The values were collected from manufacturer specification sheets or IES-format files. For two of the products (luminaire types E and F), the lamp lumens had to be modified to reflected the actual lamp used—information was only available for a different configuration. Figure 4 shows polar plots of the luminous intensity distribution for each product.

Control System

A Virticus Lighting Management System capable of adaptive control and remote monitoring was installed on all demonstration luminaires for additional evaluation and demonstration purposes. Luminaire controllers were mounted on the pole, rather than within the luminaire, due to the variation in luminaire form factors. Although a demonstration of the full capability, performance, and reliability of the Virticus system was not the focus of this study, its ability to measure power was utilized as a means to compare with manufacturer reported values. Furthermore, the accuracy of the values reported by the control system was evaluated by separately measuring power using a Fluke 434 Power Quality Analyzer.

Table 2. Manufacturer data for products installed along NE Cully Boulevard. Complete specification sheets are available in Appendix A. Correlated color temperature (CCT) and color rendering index (CRI) are nominal values. The listed values do not necessarily represent actual performance.

Area / Type	Input Power (W)	Lamp Output (lm)	Luminaire Efficiency	Luminaire Output (lm)	Luminaire Efficacy (lm/W)	CCT (K)	CRI	Distribution	BUG Rating
A	77.4	-	-	3,700[1]	47.8	3500	80	Type III, V. Short	B1-U0-G1
B	107.0	8,000	79%	6,298	58.9	4100	80	Type II, V. Short	B2-U0-G2
C	76.3	-	-	5,712	74.9	4000	70	Type III, Short	B2-U0-G2
D	65.0	-	-	3,700	56.9	4300	70	Type IV, Med	B1-U1-G1
E	67.3	7,200	78%	5,642	83.8	2800	70	Type II, Short	B1-U1-G1
F	125.0	9,500	70%	6,691	53.5	2100	22	Type III, Med	B2-U0-G2

1. IES file dated 2010-05-25 indicates 1,873 lumens, but product specification sheet indicates 3700 lumens.

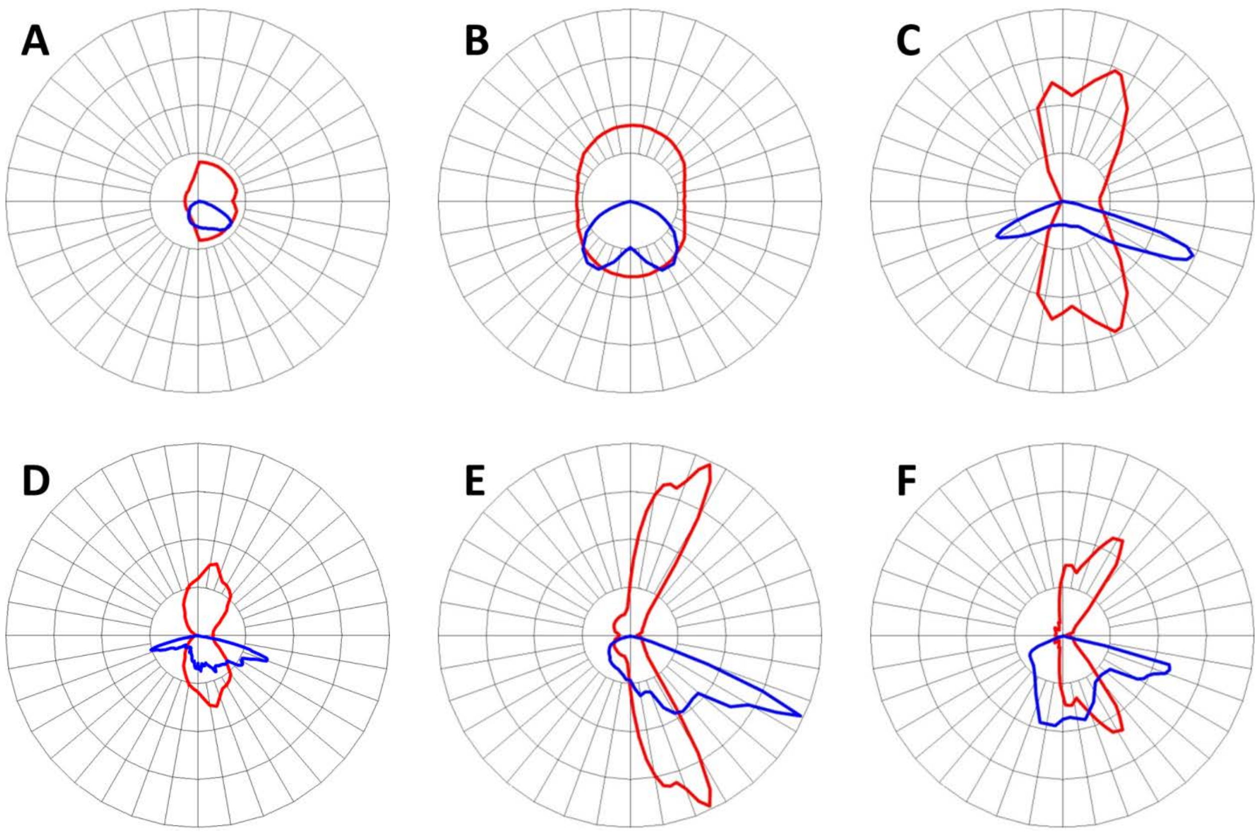

Figure 4. Polar plots of the luminous intensity distribution for the six demonstration luminaires. The maximum value for each plot is 5,500 cd. The red line represents a horizontal cone through the vertical angle of maximum candela. The blue line shows a vertical plane through the horizontal angle of maximum candela. The right side of each plot is the street side. The plot for luminaire type D was scaled from the IES file for a 6300 K version.

Measurements were taken at the base of two poles for each luminaire type on December 5, 2011, starting at approximately 10:00 a.m. and finishing at approximately 2:00 p.m. The temperature was approximately 32–40 °F over the course of the measurement period. The luminaires were turned on and allowed to stabilize for a period of 1 hour prior to measurement. Detailed results are available in Appendix B.

Table 3 compares the mean values for the luminaire input power as metered using the Fluke 434 and as reported in manufacturers' data (nominal values from specification sheets or IES-format files). Power measurements were fairly consistent with their corresponding expected values.

It was not possible to calculate active power from the control system measurements—a pending software upgrade is expected to address this issue—so they are not shown in Table 3. Although some values had more substantial deviation, the mean difference between the metered apparent power and the apparent power reported by the control system was less than 2%. This measured accuracy appears to meet the requirements reported by various utilities for potentially using such remote monitoring systems to determine energy use for billing purposes.

Table 3. **Nominal versus metered power for products installed along NE Cully Boulevard.** The metered values are the mean of two measurements taken with the Fluke 434. Complete information is available in Appendix B.

Area / Type	**RMS Voltage (V)**		**RMS Current (A)**		**Apparent Power (VA)**		**Active Power (W)**	
	Nominal	Metered	Nominal	Metered	Nominal	Metered	Nominal	Metered
A	240	248.1	0.329	0.332	79.0	81.9	77.4	79.3
B	240	247.7	-	0.418	-	102.2	107	100.7
C	240	249.0	0.3845	0.332	84.8	81.6	76.3	78.7
D	240	248.8	0.30	0.305	72.2	71.1	65	67.9
E	240	249.2	-	0.289	-	70.0	67.3	68.8
F	240	249.4	-	1.276	-	316.4	125	141.9

Calculated Illuminance

The entire demonstration area was modeled in AGI-32,[1] using two different sets of calculation points:

1. *Method One* – Illuminance was calculated using the original engineering drawing, with each type of luminaire used for the entire span of the demonstration site. *This method provides a uniform basis for comparison of the products, negating the effects of the substantial difference in pole spacing between areas.* Calculation grids were centered on the width of the vehicle lanes, bicycle lanes, and sidewalks similar to the procedure prescribed by RP-8-00, with longitudinal spacing at 11 feet throughout.

2. *Method Two* – Illuminance was calculated using grids designated to match the physical measurement points. The calculations were for the specific area that was evaluated in the field, with the pole spacing adjusted to match field measurements (rather than the engineering drawing).[2] *This method allows for a direct comparison of the calculated and measured results.*

Detailed results for both calculation methods are presented in Appendix C. Key summary statistics for the vehicular travel lanes (using both calculation methods) are reported in Table 4. For calculations of maintained illuminance provided in this report, a total light loss factor of 0.70 was specified; however, methods that are more accurate (i.e., consider individual factors and are customized for each luminaire) should be utilized during actual design. While calculating maintained illuminance is key to the design and specification process, the calculated values for initial illuminance are more relevant to this report; because the luminaires had been installed for less than six months at the time of measurement, the performance should have been similar to the initial calculations. Notably, calculated values cannot perfectly predict actual performance for a variety of reasons.

[1] AGI-32 is lighting calculation and rendering software from Lighting Analysis, Inc. (www.agi32.com). The IES-format files used in the calculation match the data in Table 2. An engineering drawing was provided by PBOT.
[2] The measured pole spacing for areas B and C were slightly different from the engineering drawing. It is likely that poles were shifted during installation to avoid a conflict.

Table 4. **Comparison of calculated and measured illuminance for the vehicular travel lanes of NE Cully Boulevard.** "Calc. 1" is for the entire demonstration area. Maintained values are 70% of initial values. "Calc. 2" is for specific measurement grids intended to replicate the physical measurements. Initial measured values were recorded approximately five months after installation. Red values fail to meet PBOT street lighting criteria.

			Average Illuminance			Avg:Min Ratio		
			Calc. 1	Calc. 2	Measured	Calc. 1	Calc. 2	Measured
PBOT Criteria		**Maintained**	**≥ 0.5**	**≥ 0.5**	**≥ 0.5**	**≤ 3**	**≤ 3**	**≤ 3**
IES RP-8-00 Criteria		**Maintained**	**≥ 0.6**	**≥ 0.6**	**≥ 0.6**	**≤ 4**	**≤ 4**	**≤ 4**
Area / Luminaire Type	**A**	Initial	0.49	0.50	0.55	2.23	1.67	1.57
		Maintained	0.34	0.35				
	B	Initial	0.68	0.63	0.57	3.58	2.42	2.43
		Maintained	0.48	0.44				
	C	Initial	0.73	0.86	1.01	1.28	1.25	1.26
		Maintained	0.51	0.60				
	D	Initial	0.90	0.61	0.77	2.20	1.65	1.79
		Maintained	0.63	0.43				
	E	Initial	1.02	0.87	0.98	3.64	2.90	2.93
		Maintained	0.71	0.61				
	F	Initial	0.80	0.78	0.75	2.05	1.66	1.83
		Maintained	0.56	0.55				

Measured Illuminance

Field illuminance measurements were taken December 8, 2011 between 7: 15 p.m. and 2:30 a.m. The air temperature was approximately 32 °F, with clear skies and a heavy frost. Nautical twilight occurred at 5:38 p.m. A full moon rose at 3:11 p.m. and set the next morning at 7:45 a.m. The moon was measured to provide approximately 0.01 fc; this was not accounted for in the results provided in this report because it is within the reasonable margin of error for measurements.

Prior to completing the illuminance survey, all measurement points were marked using temporary paint. The measurement points were determined according to RP-8-00 procedures: vehicular travel lanes were each marked with two parallel rows of grid points at the quarter point of the lane. The measurements were taken between the pair of poles at the center of the string of a specific luminaire type. For luminaire types A, B, C, and F, there were 10 measurement points for each row spanning the two poles; for luminaire type D, there were 9 measurement points;[3] and for luminaire type E, there were 12

[3] The minimum number of points recommended in RP-8-00 is 10. The use of nine points for area D was unintentional.

measurement points. The bicycle lanes and sidewalks each had a single row of measurement points at the center of the path.[4]

Illuminance was measured with a Minolta T-10, which was within its initial calibration period. A custom-built apparatus was used to slide the meter between measurement points and level the head at each point. Using this apparatus, the illuminance meter was elevated approximately 6.5 inches above the ground. Key measurement results are presented in Table 4, with complete results available in Appendix D.

Analysis

Although area C (LED) had the highest average measured illuminance and area A (LED) had the lowest average measured illuminance, the results are much more complex. Importantly, the pole spacing for each of the measured areas was not equal; thus, each of the luminaire types was responsible for delivering illumination to a different size target area. This is a substantial confounding variable, but it can be accounted for by examining additional metrics such as delivery efficiency or application efficacy (Table 5).

Figure 5 compares the six luminaire types *without considering the surface area illuminated*, showing that although luminaire types B (Induction) and F (HPS) emit more lumens, they do not provide higher average illuminance for the vehicular travel lanes. This analysis is limited, however, because it does not consider illumination of the bicycle lanes and sidewalks. As shown in Table 5, luminaire types B, C, E, and F meet Portland's criteria for these areas, whereas luminaire types A and D (both LED) do not. These findings are a result of not only the total lumen output, but also the distribution characteristics of each luminaire type. These results can be compared to the results of subjective evaluations (Section 5).

Of the six demonstration fixtures, type E (CMH) had the highest measured *drive lane efficacy*[5] and *total application efficacy*.[6] Similarly, luminaire type E had the highest delivery efficiency, with 44% of the emitted lumens reaching the vehicular travel lanes and 65% reaching the vehicular, bicycle, or pedestrian travel areas. LED luminaire type C had the same total delivery efficiency (65%) and had a higher total application efficacy than the other LED products. Considering only the drive lanes, however, LED luminaire type D had the highest delivery efficiency and application efficacy of the three LED products. Notably, the ratio of drive lane efficacy to total application efficacy for luminaire types B (Induction), C (LED), and F (HPS) are lower than the others (Figure 6); this is a direct result of the distribution of these luminaires, which emit a greater percentage of lumens backward (away from the street) or straight down. The results are the same for the ratio of drive lane delivery efficiency and total delivery efficiency. The appropriateness of this ratio depends on the application.

Measured versus Calculated Illuminance

One valuable aspect of demonstrations is the ability to compare field performance with predicted performance. As previously mentioned, two different calculation methods were used: method one modeled the entire demonstration site for each area using a continuous array of calculation points,

[4] Bicycle lanes and sidewalks were only measured on one side of the roadway. It was assumed that performance would be similar for the other side.
[5] *Drive lane efficacy* is calculated as the quotient of total lumens delivered to the vehicular travel lanes and the input power of the luminaire. The metric should not be used to compare luminaires used in different applications.
[6] *Total application efficacy* is calculated as the quotient of total lumens delivered to the vehicular travel lanes, bicycles lanes, and sidewalks and the input power of the luminaire.

Table 5. **Comparison statistics for the six areas and luminaires installed along NE Cully Boulevard.** Note that delivery efficiency and application efficacy should not be compared between substantially different sites (e.g., other roadways). Red values fail to meet the PBOT criteria.

	Area / Luminaire Type:					
	A	B	C	D	E	F
Measured Input Power (W)	79	101	79	68	69	142
Rated Output (lm)	3,700	6,298	5,712	3,700	5,642	6,691
Luminous Efficacy (lm/W)	47	63	73	54	82	47
Average Measured Illuminance (fc)						
Vehicular Travel Lanes	0.55	0.57	1.01	0.77	0.98	0.75
Bicycle Lanes	0.27	0.58	1.01	0.35	0.53	0.75
Sidewalks	0.17	0.41	0.75	0.18	0.24	0.45
Pole Spacing (ft)	90	105	80	93	114	97
Area of Travel Lanes (ft^2)	1,980	2,310	1,760	2,046	2,508	2,134
Area of Bicycle Lanes (ft^2)	1,350	1,575	1,200	1,395	1,710	1,455
Area of Sidewalks (ft^2)	1,080	1,260	960	1,116	1,368	1,164
Drive Lane Delivered Lumens	1,095	1,305	1,774	1,570	2,455	1,601
Drive Lane Delivery Efficiency	30%	21%	31%	42%	44%	24%
Drive Lane Efficacy (lm/W)	13.8	13.0	22.6	23.1	35.7	11.3
Total Delivered Lumens	1,642	2,743	3,714	2,267	3,687	3,218
Total Delivery Efficiency	44%	44%	65%	61%	65%	48%
Total Application Efficacy (lm/W)	20.7	27.2	47.2	33.4	53.6	22.7

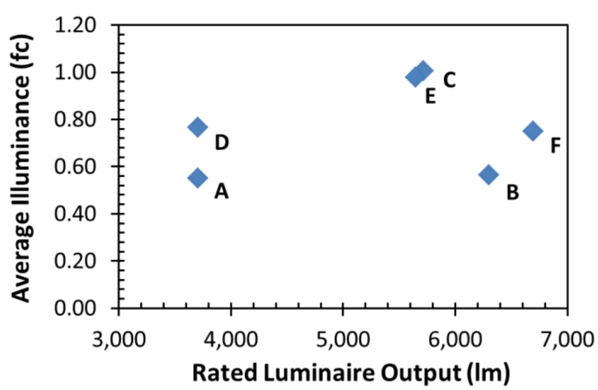

Figure 5. **Average measured illuminance of the drive lanes versus the rated output of each luminaire.** This comparison does not account for the area illuminated by each luminaire type, which differed by nearly 50%.

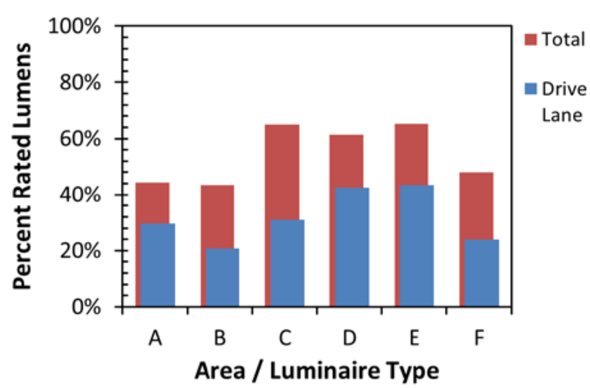

Figure 6. **Percent of total emitted lumens reaching the target area for the six demonstration luminaires/areas.** Luminaire types B, C, and F had a greater percentage of delivered lumens reaching the bicycle and sidewalk areas.

whereas method two attempted to match the exact location of the measurement points between two specific poles. Figure 7 compares the measured and calculated (initial and maintained) illuminance for the vehicular travel lanes, bicycle lanes, and sidewalks. The three charts also illustrate the difference between the two calculation methods. Because the pole spacing varied by nearly 50%, the difference between the two calculation methods was substantial:

- For areas B and E, which had a measured pole spacing substantially greater than mean for the entire site, the predicted drive lane illuminance was noticeably higher using calculation method one.
- For area C, which had measured pole spacing much less than the mean for the entire site, the predicted drive lane illuminance was higher using calculation method two.

Notably, other factors beyond pole spacing can contribute to the difference between the two calculation methods. For example, calculation method one may include points directly below luminaires. When performing design calculations, there is no prescribed method for specifying a typical spacing (assuming the spacing along a roadway is not perfectly uniform). In critical applications, modeling the entire site is preferred.

For this demonstration, the measured illuminance could be expected to be similar to the initial values calculated using *method two*, which most closely matched the field conditions. However, this was not the case for a majority of the luminaire types—a finding not unique to this demonstration project. The cause of this discrepancy has many potential explanations:

- Although close to the installation date, the measurements were actually taken approximately five months after the project was completed. The lumen output of LEDs is often highly variable over the first 1,000 hours of operation.
- Measured values include light from other sources (e.g., floodlights installed on adjacent buildings). It would be possible to determine this contribution by taking measurements with the streetlights off, but this was not an option on NE Cully Boulevard due to high traffic levels. In both area A and area C, there was a noticeable amount of ambient illumination.
- The lumen output of most lamp types is affected by temperature. LEDs prefer cold temperatures, whereas fluorescent/induction lamps tend to prefer warmer temperatures. Measurements were taken with a relatively cold ambient temperature (32 °F).
- The installed luminaire might not match the IES-format file that was used for the calculation. Some small deviation is acceptable, but major discrepancies could be attributed to inaccurate claims by manufacturers or differences between the intended and installed product. Laboratory testing of installed luminaires could determine the extent of this issue, but it was not within the scope of the NE Cully Boulevard demonstration project.
- Calculations represent an idealized site, but elevation changes, trees or other obstructions, and differences between engineering drawings and actual conditions can all lead to differences between calculated and measured values.

Overall, the comparison of measured and calculated illuminance demonstrates some of the limitations of lighting calculations. The effect of the difference between predicted and actual performance is application dependent; in some cases it may be critical, while in others not. Designers and specifiers should be cognizant of this issue.

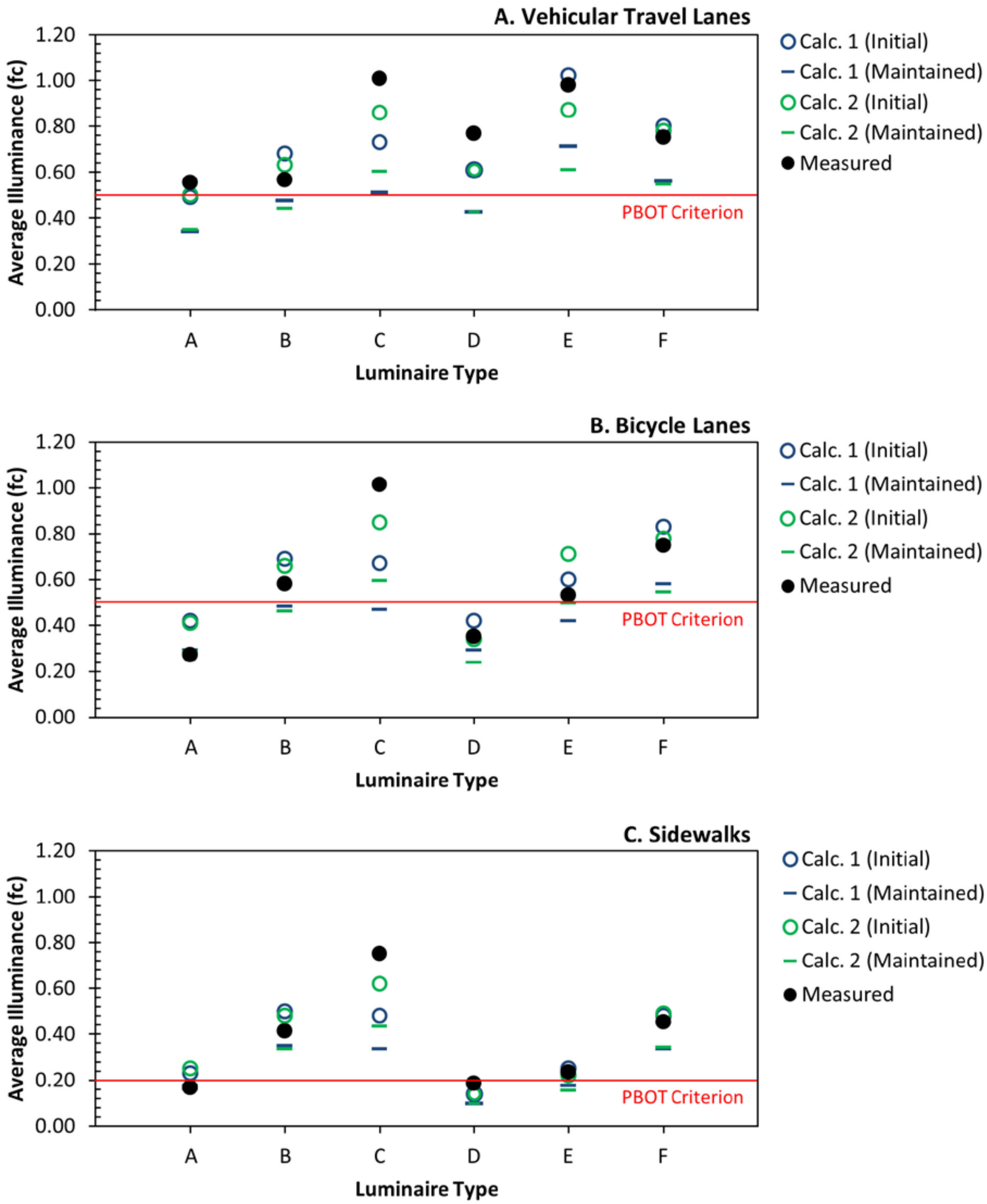

Figure 7. **Measured versus calculated illuminance.** Calculation method one includes the entire demonstration area, whereas calculation method two is specific to the pair of poles that was measured. The plots show both initial and maintained (70% of initial) illuminance.

Overall Performance Evaluation

Luminaire Type A (Philips Hadco, LED) – This luminaire struggled to provide adequate illumination across the target area. Although it met PBOT's average illuminance requirement for the vehicular travel lanes, it did not meet the requirement for the bicycle lanes or sidewalks. Further, it is unlikely to meet the requirement for the vehicular travel lanes as time progresses. Although the installed version consumes approximately 44% less power than the HPS luminaire, a higher wattage (greater lumen package) or more efficacious product would be needed to meet the design criteria.

Luminaire Type B (GE Lighting Solutions, Induction) – Similar to luminaire type A, luminaire type B barely met PBOT criteria for average horizontal illuminance in the vehicular travel lanes, and would be unlikely to meet the requirement for the life of the system. However, in this case the performance was more a result of an inappropriate luminous intensity distribution than an insufficient lumen package. Because induction lamps are a large source (as opposed to a small point source), optical control can be more challenging. The cold temperatures during measurement may have reduced the lumen output of the induction lamp.

Luminaire Type C (Cooper Lumark, LED) – This luminaire was tied for the highest percentage of lumens delivered to the target area, and also delivered a substantial proportion of the emitted lumens to the bicycle lanes and sidewalks. This could be a desirable feature in some applications. Of the three LED luminaires, this product had the highest total application efficacy and was very close to luminaire type D in terms of drive lane efficacy. This luminaire delivered more lumens than predicted by calculations.

Luminaire Type D (GE Lighting Solutions, LED) – This luminaire had the lowest measured input power. Although this luminaire type was effective in illuminating the vehicular drive lanes—it had a similar drive lane delivery efficiency to the other LED products—it did not provide enough lumens to meet PBOT's average illuminance criteria for bicycle lanes and sidewalks. This product may be more effective when sidewalk illumination is not needed.

Luminaire Type E (Philips Lumec, CMH) – This luminaire had the highest luminous efficacy (82 lm/W) and delivered the greatest percentage of lumens to the target area. Nonetheless, it may not deliver enough lumens to the sidewalks and bicycle lanes to meet the PBOT average illuminance criteria over the life of the installation. Furthermore, it provided the worst uniformity of the six demonstration luminaire types and was the only fixture that emitted substantial uplight, which is a consequence of the sag lens.

Luminaire Type F (GE Lighting Solutions, HPS) – This baseline luminaire was generally effective in meeting PBOT street lighting criteria, although the bicycle lanes were not as uniform as required. This is likely because the luminaire delivers a substantial proportion of lumens straight down. It was generally the least energy-efficient of the six demonstration luminaires, and offers comparatively poor color quality.

4 Economic Analysis

Although the purpose of this demonstration was not to explicitly examine the financial viability of LED streetlights, economics are a deciding factor for many potential adopters. Given Portland's sustainability plan, it is important to determine if the alternative luminaires installed for this demonstration can meet the 10-year payback period requirement. However, these calculations are currently speculative because the City has not yet reached a new tariff agreement with PGE for LED streetlights.[7] This common situation has led to slow adoption in other cities as well. Maintenance rates were also estimated.

Existing and Estimated Costs

PGE offers three different rate schedules, depending on the owner and maintenance agreement. Specifically as they relate to PBOT:

1. *Option A* is for luminaires that are owned, operated, and maintained by PGE. This rate structure is not currently in use by PBOT.
2. For *Option B* luminaires, the City pays a monthly combined energy use and maintenance fee for city-owned luminaires. In return, PGE performs all maintenance on the system, including relamping, cleaning, and replacement of the fixture if damaged. The maintenance fee does not cover replacement at end-of-life.[8]
3. Under *Option C*, the City performs maintenance on city-owned luminaires, but still pays PGE a monthly energy use fee. The fees are based on a luminaire schedule rather than the actual energy used.

The luminaires installed along NE Cully Boulevard fall under the Option C arrangement. Energy use is billed based on the following rates (effective for service on and after January 1, 2011):

- Transmission and related service charge: $0.00188/kWh
- Distribution charge: $0.03391/kWh
- Energy charge: $0.05452/kWh

Thus, the melded energy rate is $0.09031/kWh. This rate is billed based on the expected energy use listed in a schedule provided by PGE, which includes all luminaire types common on Portland streets. For example, a 100 W HPS cobrahead is listed at 43 kWh/month,[9] which is based on 4,100 annual burning hours. Given these values, the annual energy cost is $46.60 for each 100 W HPS luminaire. There is presently no individual tariff for LED luminaires, so actual energy use (as metered) was used for the included payback analysis.

Because the luminaires installed along NE Cully Boulevard are under the Option C rate structure, PBOT is responsible for all maintenance. However, PBOT does not track maintenance expenditures on a per luminaire basis. Thus, to complete an economic analysis, it was necessary to estimate the monthly maintenance expenditure for the five non-HPS luminaire types, and assume the PGE rate for the 100 W HPS luminaire is the same cost as would be incurred by PBOT ($2.58/month). The LED, induction, and

[7] A new tariff is expected to be adopted in late 2012.

[8] End-of-life is reached when the luminaire cannot be fixed by relamping or repair/replacement of the photocell, lens, starter, or power door (if applicable).

[9] This value listed by PGE coincides with the nominal 125 W rating, but is different from the metered power for the 100 W HPS luminaire on NE Cully Boulevard (142 W, 58.52 kWh/month).

CMH luminaires were estimated to cost $2.05 per month, which is the rate listed by PGE for an 85 W induction luminaire. Importantly, these monthly maintenance rates include relamping, and are likely conservative estimates of the actual costs incurred by PBOT. The input values and results of a simple payback analysis are listed in Table 6.

Simple Payback Analysis

Simple payback is a limited tool, but it can provide basic information quickly and easily. For this demonstration, the shortest calculated payback period for a new installation relative to the baseline HPS luminaire was 17.3 years. This is well outside the 10-year timeframe approved by the City of Portland for energy efficiency projects. In order to meet the 10-year requirement—assuming the energy costs are fixed—the monthly maintenance rate would need to be less than $0.35 for each of the alternative luminaires (or approximately $2.23 less than the true average monthly maintenance cost for the baseline HPS luminaire type). The feasibility of maintenance costs reaching this point is difficult to determine. Undoubtedly, the $2.05/month rate is conservative given the extended lifetime of LED luminaires. However, it is presumably difficult for PGE to establish a lower rate for alternative streetlights given the lack of long-term maintenance expenditure data.

Although the input values used in this analysis are only estimates, it is unlikely that using more precise values (or completing a more comprehensive payback analysis) would make the outcome more favorable to the alternative luminaires at the present pricing. Each of the alternative luminaires cost

Table 6. Simple payback analysis for the demonstration luminaires. Given the high prices paid for the small quantity of luminaires needed for this demonstration, the payback periods are much longer than Portland's target of 10 years.

	Area / Luminaire Type:					
	A	**B**	**C**	**D**	**E**	**F**
Lighting Technology	LED	Induction	LED	LED	CMH	HPS
Initial Luminaire Cost ($)[1]	604.00	625.00	679.00	618.58	632.00	136.78
Total Annual Energy Cost ($)	29.36	37.29	29.12	25.12	25.46	46.60[3]
Measured Input Power (W)	79	101	79	68	69	142
Annual Use (Hours)	4,100	4,100	4,100	4,100	4,100	4,100
Energy Use Rate ($/kWh)	0.09031	0.09031	0.09031	0.09031	0.09031	0.09031
Total Annual Maintenance Cost ($)[2]	24.60	24.60	24.60	24.60	24.60	30.96
Annual Cost Savings ($)	23.60	15.67	23.84	27.84	27.50	-
Simple Payback (Years)	19.8	31.1	22.7	17.3	18.0	-

1. Initial luminaire costs are the actual prices paid for the small quantities ordered in this study. The cost per fixture would likely be lower for a larger order.
2. Annual maintenance costs are estimated based on PGE rates. PGE rates for LED and CMH luminaires have not yet been established, so a monthly rate of $2.05 was applied; $2.05 is the rate for a Hadco Victorian 85 W induction luminaire. Especially for the CMH luminaire, this may be a conservative estimate. Using a more expensive rate would extend the payback period.
3. Rate based on PGE-listed tariff, not actual metered power.

more than four times as much as the baseline HPS luminaire at the time they were acquired. It is notable, however, that the listed prices are for small quantity purchases and do not reflect current prices for large quantity purchases of LED luminaires. If luminaire type D cost $400, the simple payback period would be approximately 9.5 years. As of May 2012, many currently available LED luminaires intended to replace 100 W HPS luminaires cost well under $300, with a few pushing the $200 threshold.

5 Subjective Evaluation

A valuable aspect of lighting demonstrations is the subjective evaluation that can be made by human observers. Although numerical metrics and design calculations are invaluable to understanding the performance of a given luminaire, evaluations of real installations often provide critical information, such as general public acceptability, that cannot be obtained in other ways. Demonstrations also serve as important tools for educating the public about alternative street lighting solutions.

For reference, photographs of each site are available in Appendix E. However, photographs can misrepresent the actual illuminated scene. For example, in this case the photographs were taken from an elevated position and therefore do not show the typical view of a driver, bicyclist, or pedestrian.

Questionnaire and On-site Evaluation

Methodology

An event was held on October 26, 2011 to evaluate the performance of the six different luminaires. Participants became aware of the activity through a local chapter meeting of the IES or through related personal contacts. After a brief introduction, the participants were given a questionnaire form and allowed to walk the site at their own pace. They began their evaluations at approximately 7:30 p.m. on a Wednesday evening, starting at the southwest end of the demonstration area. The weather was partly cloudy, the temperature was approximately 40 °F, and the pavement was dry.

Each form included six sections, one for each type of luminaire. Each of the six identical sections included twelve statements to be rated, one question, and a space for additional comments. The survey was adapted from the work of Boyce and Eklund [5]. The twelve statements were evaluated on a scale of one to five, with one indicating strong disagreement, three being neutral, and five indicating strong agreement. The participants could also respond “Don’t Know.” The question, *how does the lighting in this area compare with the lighting of similar Portland city streets at night,* had five possible answers: much worse, worse, about the same, better, or much better—these correspond to one through five, respectively, in this document. The items were as follows:

1. It would be safe to walk here, alone, during daylight hours.
2. It would be safe to walk here, alone, during darkness hours.
3. The lighting is comfortable.
4. There is too much light on the street.
5. There is not enough light on the street.
6. The light is uneven (patchy).
7. The light sources are glaring.
8. It would be safe to walk on the sidewalk here at night.
9. I cannot tell the colors of things due to the lighting.
10. The lighting enables safe vehicular navigation.
11. I like the color of the light.
12. I would like this style lighting on my city streets.
13. How does the lighting in this area compare with the lighting of similar Portland city streets at night?

Note that the questionnaire was not a scientific survey (i.e., it did not rely upon sampling methods or adhere strictly to protocols for collecting data intended to be applied in a broader context). Therefore, the information presented herein should not be applied to applications beyond NE Cully Boulevard.

Results

Thirty-eight participants returned questionnaire forms. In general, the response range was wide. For all but one item (number four, in areas B and F), the highest response was a five (strong agreement). For a majority of items, the lowest response was one, although a fair amount had a low response of two and item one had a low response of three in four out of the six areas. Histograms, as well as tables of the mean and mode responses, can be found in Appendix F.

The questions can be grouped into six categories: light level, distribution, glare/comfort, safety, color characteristics, and overall impression. As with most field evaluations, many external factors may have affected the participants' judgment; therefore, it was not possible to explicitly isolate specific differences as causes for any given outcome. The results can be summarized as follows:

Light Level:

- The mean responses for questions four and five show that the respondents tended to disagree with both the statement that the lighting was too bright and the statement that the lighting was too dim. In many cases, the responses were approximately neutral, especially in regards to having not enough light.

- The mean response regarding question five for area C (1.8) was significantly lower than any of the other mean responses—the respondents showed stronger disagreement with the statement that there was not enough light on the street. Area C did have the highest measured average illuminance for the vehicular travel lanes, as well as noticeably higher average illuminance for the bicycle lanes and sidewalks.

Glare and Comfort:

- The mean responses for questions three (comfort) and seven (glare) showed a mild correlation (r^2 = 0.27)—products rated as more comfortable were rated as being less glaring.

Distribution of Light:

- The mean response regarding question six for area C (2.0) was significantly lower than any of the other mean responses—the respondents showed stronger disagreement with the statement that the light was uneven or patchy. Area C was measured to have the best uniformity of the six demonstration areas.

- The mean response regarding question seven for area A (2.1) was significantly lower than any of the other mean responses—the respondents showed stronger disagreement with the statement that the sources were glaring. Notably, luminaire type A had substantially lower lumen output. Area A also had a noticeably higher level of ambient illumination from neighboring properties.

- There was minimal difference in the ratings for questions two and eight, both of which addressed pedestrian safety.

Safety:

- The mean ratings for the statement that the lighting enables safe vehicular navigation show a negligible positive correlation with glare ($r^2 = 0.05$) and having too much light on the street ($r^2 = 0.16$). They also show a moderate negative correlation with having not enough light on the street ($r^2 = 0.56$) and patchiness ($r^2 = 0.31$).

Color:

- The mean response regarding question nine for area F (4.0) was significantly higher than any of the other mean responses—the respondents showed stronger agreement with the statement that they could not tell the color of things due to the lighting.

- The mean response regarding question eleven for area F (2.1) was significantly lower than any of the other mean responses—the respondents showed stronger disagreement with the statement that they liked the color of the light.

Overall Impression:

- Area B (3.4) and area C (3.3) had mean ratings that showed slight agreement with the statement that the participants would like the given style of lighting on their street, whereas the others showed slight disagreement. However, most responses should be considered neutral.

- Area B (3.6) and area C (4.1) were the only two areas that had positive ratings significantly different from equal (3) when compared to existing Portland city streets at night.

Analysis

The findings from the simple questionnaire administered for this project are somewhat limited. One of the clearest outcomes is that the respondents did not like the color quality in area F, which led to overall unfavorable opinions. Conversely, the respondents preferred the color quality in areas B and C, which both were approximately 4000 K with CRIs of 80 and 70, respectively. These were generally the most favored areas. Area C was also perceived as brighter and more uniform than the other areas, which matches the measurements and calculations; however, it had the highest average rating for glare and some respondents provided unsolicited comments that there was too much light trespass.

6 Follow-up Plans

NE Cully Boulevard is intended to be the site of long-term testing and evaluation projects. This report only includes initial findings. Potential future investigations include monitoring maintained illuminance, evaluating adaptive lighting techniques and related luminaire performance, generating long-term data on environmental conditions and energy use, and a full demonstration of the capability, performance, and reliability of the control system, including comparisons to expectations and/or other installed control systems. The results of future studies will be released in supplemental reports.

In addition to supplemental analyses, PNNL and the GATEWAY program will continue to monitor and report on problems encountered with the installation. For example, one sample of luminaire type A had to be turned off early in the demonstration because it was strobing, and another was fixed at half output. The exact cause of this could not be determined as of the publication of this report, although the problems were remedied during measurement.

7 Conclusions

The primary goal of the NE Cully Boulevard demonstration project was to install and compare multiple luminaires—using several light source technologies—in one location. The results from this evaluation support the consensus that LED streetlights can effectively replace 100 W HPS streetlights while reducing energy consumption. The performance of LED products is similar to or better than other energy-efficient streetlight alternatives, such as induction or CMH.

Although not all of the installed products performed equally well, the alternative luminaires generally offered higher efficacy, more appropriate luminous intensity distributions, and favorable color quality compared to the incumbent HPS. However, some products did not provide sufficient illumination to all areas—vehicular drive lanes, bicycle lanes, and sidewalks—or would likewise fail to meet design criteria over the life of the installation. Of the LED products, luminaire type C was the most effective at meeting the needs of this specific application, based on numerical analyses and subjective evaluations. Luminaire type D also performed well and was efficient, but the uniformity was not as good as in area C and the product was not viewed as favorably by the questionnaire respondents. Higher wattage versions of LED luminaire types A and D would likely result in a different numerical analysis, and may change subjective evaluations. It is important to note that luminaire type C may not be the best option for other applications; for example, several questionnaire respondents noted that light trespass and/or glare might be a problem.

Of the non-LED alternative luminaires, type E (CMH) generally outperformed type B (induction) for this specific application. The performance of the CMH luminaire was similar to LED luminaire type C, but may be somewhat less likely to meet illuminance criteria for the bicycle lanes and sidewalks over time. Further, it was not viewed as favorably in the subjective evaluation.

In addition to the demonstration luminaires, a networked control system was installed for additional evaluation and demonstration purposes. The accuracy of the power values reported by the control system was verified to be within 2% of the metered values, on average. This measured accuracy appears to meet the requirements reported by various utilities for potentially using such remote monitoring systems to determine energy use for billing purposes.

While the overall performance of the alternative luminaires was generally better than the baseline HPS luminaire, cost remains a significant barrier to widespread adoption. Based on the cost of the small quantity of luminaires purchased for this demonstration, the shortest calculated payback period for one of the alternative luminaire types was 17.3 years. The luminaire prices were notably higher than typical prices for currently available luminaires purchased in larger quantities. At prices that are more typical, the payback would be less than 10 years. Further reduction of the payback period may be possible if maintenance costs are less than the estimated rate; new agreements between cities and utilities are essential for driving adoption of advanced lighting technologies.

8 References

1. Portland Bureau of Planning and Sustainability. Citywide Sustainability Goals. http://www.portlandonline.com/bps/index.cfm?a=156800&c=44623 <May 1, 2012>

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3. IESNA Roadway Lighting Committee, Standard Practice Subcommittee. 2000 (reaffirmed 2005). ANSI / IESNA RP-8-00, "American National Standard Practice for Roadway Lighting." Illuminating Engineering Society of North America. New York, NY.

4. Portland General Electric Company Schedule 91, Street and Highway Lighting Standard Service (Cost of Service), Original Sheet No. 91-1. Issued January 16, 2007.

5. PR Boyce and NH Eklund. 1998. Simple tools for evaluating lighting. CIBSE National Lighting Conference. CIBSE. London.

Appendix A: Product Specification Sheets

Specification sheets for the luminaires listed in Table A1 are included subsequently. The specification sheets are not marked with the specific model numbers.

Table A1. Luminaire types.

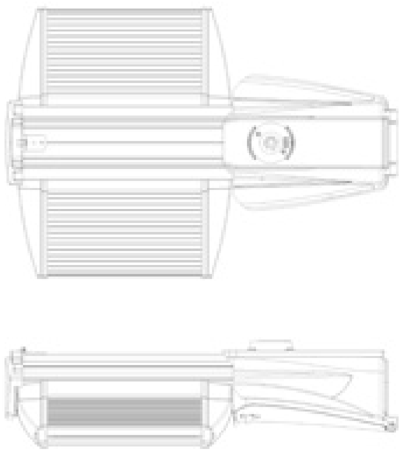
Area / Type	Lamp Type	Manufacturer	Product Family	Model Number
A	LED	Philips Hadco	Evolaire	WL70N-HT2-I-22-35-N-N
B	Induction	GE Lighting Solutions	M-400	MSCL-10-T-0-E-2-1-F-SC2
C	LED	Cooper Lumark	RC LED	LDRC-T3-A03-E-BZ
D	LED	GE Lighting Solutions	Evolve	ERMC-0-A8-43-A-1-GRAY
E	CMH[1]	Philips Lumec	Helios	HBS-60CW-SC2-240-RC-GLB
F	HPS	GE Lighting Solutions	M-250	M2AC-10-S-0-N-2-G-MC3

1. Specifically, the installed lamp was a Philips CosmoPolis lamp, sometimes referred to as "eCMH."

Evolaire LED (WL70N) Specification Sheet

Project Name:	Location:	MFG: Philips Hadco
Fixture Type:	Catalog No.:	Qty:

A



Ordering Guide

Example: WL70N HT2 A 00 35 MD N

Product Code	WL70N	Evolaire LED	
Mounting	HT2 R4 R5 S4 W	Horizontal tenon 4" - 5" O.D. Round Pole 5" - 6" O.D. Round Pole 4" - 6" Square Pole Wall Mount	 *1 *1 *1 *2
Finish	A H I	Black Bronze Gray	
Panel Angle (distribution)	00 04 09 13 18 22	0 Deg (Type 2) 4.5 Deg (Type 2) 9 Deg (Type 2) 13.5 Deg (Type 2) 18 Deg (Type 3) 22.5 Deg (Type 3)	
Color Temperature	35 43 50	3500K CCT 4300K CCT 5000K CCT	
Options	MD MS N	Midnight dimming Motion Sensing None	*3
Photo Control	N R	None Twist-lock Receptacle	

*1 Pole must be machined for luminaire
*2 Can't use a Photo Receptacle (R) with Wall Mount (W) and Round and Square Pole Mount (R4, R5, S4)
*3 If Midnight Dimming is chosen, must order a Twist-lock Receptacle (R) or use a remote photocell.

Specifications

APPLICATIONS:
The Evolaire™ is the perfect LED solution for site and roadway lighting applications and it is the ideal luminaire for both new and retrofit installations. The Evolaire™ features the unique patent pending Lightspread Technology™ design consisting of IP66 rated LED panel assemblies which are field adjustable to 6 different angles offering multiple distribution patterns. In retrofit situations, the Lightspread Technology™ allows the Evolaire™ to meet light levels and uniformity of existing luminaires regardless of existing pole heights and spacing intervals.

CONSTRUCTION:
Containing no Mercury or other hazardous chemicals, the Evolaire™ is RoHS compliant and fully recyclable. The Evolaire™ is constructed of cast and extruded aluminum components with high-impact acrylic lenses sealed to provide an IP66 ingress protection rating. Cast aluminum components are constructed from a rotary-degassed, proprietary alloy with an extremely low copper content providing superior corrosion resistance and strength. The Evolaire™ mounts to round and square poles or arm brackets with horizontal tenons typically used for cobra head style luminaires and is also available as a wall-mount in the small and medium sizes. The horizontal tenon mount accepts 1.25" O.D. to 2.375" O.D. tenon. Access to the driver, wiring compartment, and LED panel arrays does not require the use of any tools. The Evolaire™ is listed per UL1598 safety standards and is vibration tested per ANSI C136.31 for bridge mounting applications. Operating temperature range is -60°C to +45°C.

LED SPECIFICATIONS:
Consuming approximately 70 watts of energy, the WL70N delivers over 3700 lumens with a lifespan of 70,000 hours at 70% lumen maintenance (L70). 720 5mm low-power, lighting-grade LEDs (>80 CRI) from Nichia are arranged in a series/parallel matrix which provides optimal reliability and heat dissipation. The inner-mold and die-bond components within these LEDs are made from a proprietary, silicone hybrid resin designed specifically to resist discoloration and they have been tested beyond the requirements set forth by the IESNA's LM-80 standard. Each LED is individually aimed to provide glare-free illumination without the need for secondary optics which can reduce efficiency. Color temperatures available are 3500K, 4300K, and 5000K CCT.

ELECTRONIC DRIVER:
The longevity and preserved lumen level of the Evolaire™ is accomplished through the patented OptiAC™ technology designed into the electronic driver of the luminaire. The OptiAC™ technology provides a conversion efficiency of over 96% with a power factor of 0.98 and very low total harmonic distortion (THD) of less than 10%. Surge supression up to 10kV. The electronic driver automatically senses voltages between 85 and 300 VAC and frequencies between 50 and 60 Hz.

FINISH:
Thermoset polyester powdercoat is electrostatically applied after a five-stage conversion cleaning process and bonded by heat fusion thermosetting. Laboratory tested for superior weatherability and fade resistance in accordance with ASTM B-117-64 and ANSI/ASTM G53-77 specifications.

Evolaire LED (WL70N) Specification Sheet

Project Name:	Location:	MFG: Philips Hadco
Fixture Type:	Catalog No.:	Qty:

A

OPTIONS:
Options for the Evolaire™ include midnight dimming, motion sensing compatibility and NEMA twist-lock receptacle for standard photocells. The midnight dimming control feature is a program designed within the circuit of the electronic driver and gradually reduces the lumen level and energy required to 50% for approximately six hours each night before returning to full brightness. The Evolaire's microprocessor also automatically adjusts to the local time schedules and the difference in daylight between summer and winter months. The motion sensing option provides a sensible way to preserve energy in low traffic areas while still offering security and visibility. At start up, the luminaire is powered to only 50% light intensity but instantly ramps up to full brightness when the motion sensor is activated. After 10 minutes of inactivity, the luminaire gradually returns to 50% light intensity, and maximum energy savings mode.

IP RATING:
IP66: Dust-tight and sealed against direct jets of water. No Ingress of Dust. Will withstand 26.4 Gallons of water per minute. Water projected in powerful jets shall not enter the enclosure in harmful quantities.

CERTIFICATIONS:
Manufactured to ISO 9001:2000 Standards. CE, RoHS, EN/IEC Vibration tested to ANSI C136.31 for Bridge Applications. Vibration Test only completed for HT2 Mounting option. CSA Listed to U.S. Safety Standards UL1598 and CSA C22.2 No.250.0-08 for wet locations.

WARRANTY:
5 year extended warranty

Width:
17"

Height :
6.5"

Length:
24.75"

EPA:
1.05 sq. ft.

Max. Weight:
18.3 lbs

IESNA Classifications:
0% uplight at 0deg panel angle; other angles =.2%

B

M-400 INDUCTION LUMINAIRE WITH CUTOFF OPTICS

APPLICATIONS

- For roadway, highway or parking lot applications where light trespass could be a problem

SPECIFICATION FEATURES

- Universal two or four-bolt slipfitter
- Die-cast aluminum housing with polyester powder gray paint finish
- Average lamp life 100,000 hours
- Instant on and instant restrike
- "Dead back" tunnel type, FRP terminal board
- Minimum start -30°F
- Metal pest guard standard (not required for 2 in. pipe mounting)
- No-tool PE receptacle
- Cutoff photometrics
- External paddle type stainless steel bail latch
- True 90° cutoff—no light above 90° (meets RP8-2000 for full cutoff) with flat glass

ORDERING NUMBER LOGIC

MSCL	10	T	0	E	2	1	F	SC2	___
PRODUCT IDENT	WATTAGE	LIGHT SOURCE	VOLTAGE	BALLAST TYPE	PE FUNCTION	IGNITOR MOUNTING	LENS TYPE	IES DISTRIBUTION TYPE	OPTIONS
XXXX	XX	X	X	X	X	X	X	XXX	XXX
MSCA = M-400 with 4-Bolt Slipfitter MSCL = M-400 with Cutoff ★ Optics 2-Bolt Slipfitter ★ = Previously IESNA Full Cutoff Optics	10 = 100 15 = 150 84 = 85 (4000K) 83 = 85 (3000K)	Q = QL Induction T = Induction Induction: Supplied with lamp.	60Hz 0 = 120/208/240/277 Multivolt 1 = 120 2 = 208 3 = 240 4 = 277 5 = 480 G = 200-277	See Ballast Selection Table E = Induction Ballast	1 = None 2 = PE Receptacle NOTE: Receptacle connected same voltage as unit except as noted. Order PE Control separately.	1 = None	F = Flat Glass G = Shallow Glass Globe	See Photometric Selection Table S = Short C = Cutoff ★ 2 = Type II 3 = Type III ★ = Previously IESNA Full Cutoff Optics	F = Fusing (Not available with multivolt)

R

ROADWAY LIGHTING

PHOTOMETRIC SELECTION TABLE

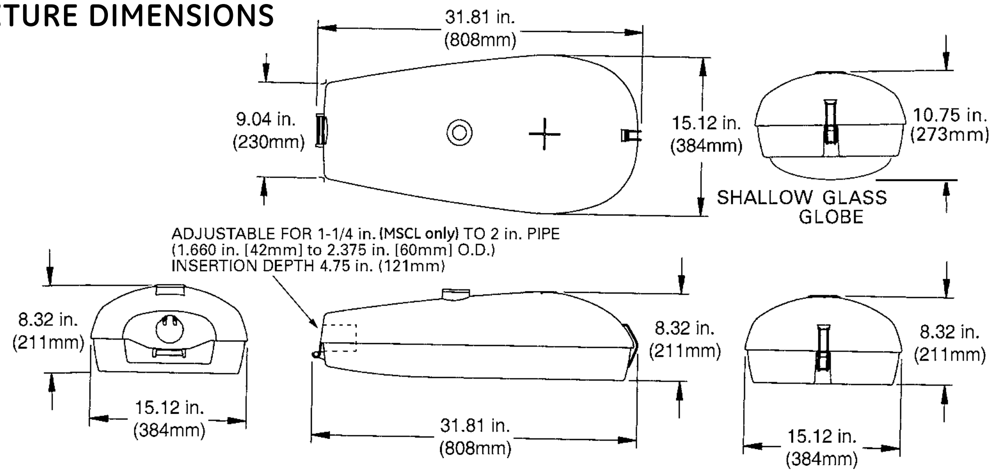
CLEAR REFRACTORS. All light sources are clear.

		IES Distribution Type Photometric Curve Number 35-45xxxx		
		Flat Glass "F"		Sag Glass "G"
Wattage	Light Source	SC2	SC3	SC2
85Q	IND	N/A	3614	N/A
100T	IND	2870	N/A	N/A
150T	IND	N/A	N/A	4196

NOTE: N/A = Not Available   C/F = Contact Factory

M-400 INDUCTION LUMINAIRE WITH CUTOFF OPTICS

FIXTURE DIMENSIONS



DATA

Approximate Net Weight	29 lbs	15-18 kgs
Effective Projected Area	1.1 sq. ft. max	0.1 sq. M max
Suggested Mounting Height	30-50 ft.	9-15 M

REFERENCES

See Page R-48 for start of Accessories.
See Page R-52 for Explanation of Options and Other Terms Used.
See Pole and Bracket Section Page P-2 for pole selection.

BALLAST SELECTION TABLE

		BALLAST TYPE/VOLTAGE						
		60HZ						
Wattage	Light Source	Multi-volt	120	208	240	277	480	200-277
85 Q	IND	N/A	E	E	E	E	N/A	E
100 T	IND	E	E	E	E	E	E	N/A
150 T	IND	E	E	E	E	E	E	N/A

MSCL — SUGGESTED CATALOG ORDERING NUMBERS

Catalog Number	Wattage	Light Source	Voltage (60 Hz)	Ballast Type	Refractor Type	Photometric Distribution
MSCL84Q1E21FSC3	85	Induction	120	Electronic	Glass	SC3
MSCL10T0E21FSC2C	100	Induction	Multivolt	Electronic	Glass	SC3

All GE suggested catalog ordering numbers come with PE receptacle. PE control must be ordered separately. Order and install SCCL-PECTL if no PE is desired.

Multivolt ballasts can be for either 120, 208, 240, or 277 volt incoming power supply.

energy solutions

DESCRIPTION

The RC LED area luminaire provides uncompromising optical performance and outstanding versatility for a wide variety of area and roadway applications. Patent pending modular LightBAR™ technology delivers uniform and energy conscious illumination to walkways, parking lots, and roadways. UL and cUL Listed for wet locations.

Catalog #		Type
Project		C
Comments		Date
Prepared by		

SPECIFICATION FEATURES

Construction
Heavy-duty cast aluminum housing and removable door 3G vibration tested to ensure strength of construction and longevity in application. Die-cast aluminum door frame features integral hinges for toolless maintenance access.

Optics
Choice of fifteen (15) high efficiency, patented AccuLED Optics™ manufactured from injection molded acrylic. Optics are precisely designed to shape the distribution maximizing efficiency and application spacing. AccuLED Optics create consistent distributions with the scalability to meet customized application requirements. Offered standard in 4000K (+/- 275K) CCT and >70 CRI.

Electrical
LED drivers hard mounted to die-cast aluminum back casting for optimal heat sinking and operation efficiency. Shipped standard with the Cooper Lighting proprietary circuit module designed to withstand 10kV of transient line surge. Thermal management incorporates both conduction and natural convection to transfer heat rapidly away from the LED source and retain optimal efficiency and light output. The RC LED luminaire is suitable for low temperature operation down to -30°C. Standard three position tunnel type compression terminal block. Expected lifetime is 60,000 hours with greater than 70% lumen maintenance. LightBARS feature IP66 enclosure rating.

Mounting
Two-bolt/one bracket slipfitter with cast-in pipe stop and leveling steps. Fixed-in-place birdguard seals around 1-1/4" or 2" mounting arms.

Finish
Components finished in a standard grey 5 stage super premium TGIC polyester powder coat paint, 2.5 mil nominal thickness for superior protection against fade and wear. Consult your Cooper Lighting representative for a complete selection of standard colors including black and bronze. RAL and custom color matches available.

Warranty
RC LED features a 5 year limited warranty.

RC LED
ROADWAY SMALL CUTOFF COBRAHEAD

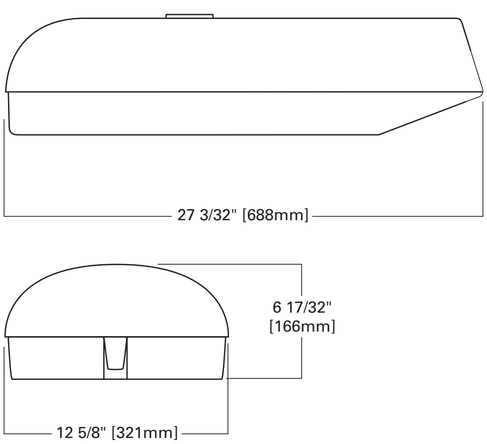
1 - 4 LightBARS

Solid State LED

SITE / ROADWAY LUMINAIRE

SustainabLEDesign™

DIMENSIONS



CERTIFICATION DATA
40°C Ambient Temperature Rating
UL and cUL Listed
LM79 / LM80 Compliant
IP66 LightBARS
3G Vibration Rated
ARRA Compliant
ISO 9001

ENERGY DATA
Electronic LED Driver
>0.9 Power Factor
<20% Total Harmonic Distortion
120-277V/50 & 60Hz, 347V/60Hz, 480V/60Hz
-30°C Minimum Temperature

EPA
Effective Projected Area: (Sq. Ft.).80

SHIPPING DATA
Approximate Net Weight:
21 lbs. (9.5 kgs.)

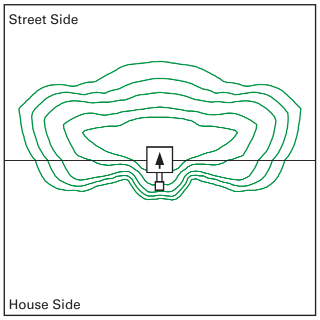
SYSTEMS ISO CERTIFIED

POWER AND LUMENS BY BAR COUNT

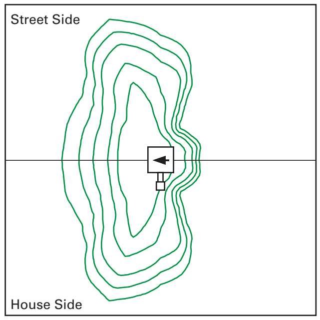
# of Bars	System Watts	Type SL2 Lumens	Type SL3 Lumens	Type FT Lumens	Type 5WQ Lumens	Ambient Temperature	Lumen Multiplier
1 Bar	26	1,626	1,724	1,677	1,868	10°C	1.04
2 Bars	53	3,252	3,447	3,354	3,735	15°C	1.03
3 Bars	80	4,878	5,170	5,031	5,602	25°C	1.00
4 Bars	103	6,504	6,894	6,708	7,469	40°C	0.96

NOTE: Lumen values based upon 4000K CCT, 350mA drive current, 25°C ambient operating temperature.

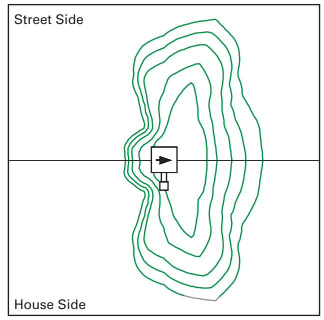
OPTIC ORIENTATION



Standard



Optics Rotated Left @ 90° [L90]



Optics Rotated Right @ 90° [R90]

ORDERING INFORMATION

Sample Number: LDRC-T2S-A01-E

Lamp Type
LD=Solid State Light Emitting Diodes (LED)

Series
RC=Roadway Small Cutoff Cobrahead

Distribution
T2=Type II
T3=Type III
T4=Type IV
T2S=Type II Short
T3S=Type III Short
T4S=Type IV Short
5MQ=Type V Square Medium
5WQ=Type V Square Wide
5XQ=Type V Square Extra Wide
5MR=Type V Round Medium
5WR=Type V Round Wide
RW=Rectangular Wide
SL2=Type II w/Spill Control
SL3=Type III w/Spill Control
SL4=Type IV w/Spill Control
SLL=90 Degree Spill Light Eliminator Left
SLR=90 Degree Spill Light Eliminator Right

Number of Lightbars [1]
A01=1 Bar
A02=2 Bars
A03=3 Bars
A04=4 Bars

Voltage
E=Electronic (120 - 277V)
347=347V
480=480V

Options [2]
BK=Black
BZ=Bronze
K=Level Indicator
L90=Optics Rotated Left 90 Degrees
R90=Optics Rotated Right 90 Degrees
PER=NEMA Twistlock Photocontrol Receptacle
7060=70CRI/6000K CCT[3]
LCF=LightBAR Cover Plate Matches Housing Finish

Accessories [4]
OA/RA1013=Shorting Cap
OA/RA1014=Photoelectric Control, 120 Volt NEMA Type
OA/RA1016=Photoelectric Control 105-285V NEMA Type
OA/RA1027=Photoelectric Control 480V NEMA Type
OA/RA1201=Photoelectric Control 347V NEMA Type
MA1253=10kV Circuit Module Replacement

Notes:
1 Standard 4000K CCT and greater than 70 CRI.
2 Add as suffix.
3 Consult factory for lead time and lumen multiplier.
4 Order separately.

GE EVOLVE™ LED SERIES

Roadway Medium Cobrahead (R150)

D

APPLICATIONS

- System that provides an advanced LED optical system providing high uniformity, glare control, improved vertical light distribution, and reduced light trespass for effective Roadway Lighting.

Housing: Die cast aluminum housing. Aesthetically inspired by a traditional roadway (Cobrahead) fixture, it incorporates a heat sink directly into the unit ensuring maximum heat transfer, long LED life and a reduced EPA. Meets ANSI 2G vibration standards. For 3G rating contact factory. Power door assembly with retention latch.

LED and Optical Assembly: Structured LED array for optimized roadway photometric distribution. Evolve™ Light Engine consisting of nested concentric directional reflectors designed to optimize application efficiency and minimize glare. Utilizes High Brightness LEDs, 70 CRI at 6000K typical. Photometric measurements in accordance with LM-79. Rated at –40° to 50°C.

Lumen Maintenance: System rating is 50,000 hours @ L80.

Ratings: UL/cUL listed, suitable for wet locations. IP 65 rated optical enclosure.

Mounting: 4-Bolt Slipfitter with + -5 degrees of adjustment for leveling. Cast end pipe stop. Wildlife intrusion protection at mounting arm. Adjustable for 1.25 in. or 2.0 in. pipe.

Finish: Corrosion resistant polyester powder paint. Standard color: Gray. For custom colors contact factory. Standard warranty applies.

Electrical: 120-277 volt universal electronic driver. 347-480 volt available. Drive current 467mA typical. System power factor is >90% and THD <20% full load. Class "A" sound rating
Integral Surge protection per IEEE/ANSI C62.41-1991.
• 277V Systems: Location Category B2
• 480V Systems: Location Category B3
PE available for all voltages.

Warranty: 5 year limited system warranty

Catalog Number:
ERMC - ___ - ___ - ___ - ___ - ___ - ____ - ____

ORDERING NUMBER LOGIC

Sample Number - ERMC0XX60A1GRAYXXX

BELOW - SUGGESTED ORDER LOGIC

ERMC	0	XX	60	A	1	GRAY	XXX
PROD. ID	**VOLTAGE**	**PHOTOMETRIC (6000K/4300K CCT LUMEN LEVELS)**	**LED COLOR TEMP**	**LENS TYPE**	**PE FUNCTION**	**COLOR**	**OPTIONS**
E = LED Product Platform **R** = Roadway **M** = Medium **C** = Cobrahead	0 = 120 - 277 H = 347 - 480 1 = 120* 2 = 208* 3 = 240* 4 = 277* 5 = 480* D = 347* *Specify single voltage only if fuse option is selected	A1 = Asymmetric Wide (6000/5400) A2 = Asymmetric Wide (8700/7800) A3 = Asymmetric Wide (9600/8600) A4 = Asymmetric Short (5100/4600) A5 = Asymmetric Short (7000/6300) A6 = Asymmetric Short (7800/7000) A7 = Asymmetric Wide (3100/2800) A8 = Asymmetric Wide (4100/3700) B1 = Asymmetric Short (6000/5400) B4 = Asymmetric Medium (5100/4600) B5 = Asymmetric Medium (7000/6300) B6 = Asymmetric Medium (7800/7000) B7 = Asymmetric Short (3100/2800) B8 = Asymmetric Short (4100/3700)	60 = 6000K 43 = 4300K	A = Acrylic	1 = None 2 = PE Rec. 4 = PE Rec. with Shorting Cap 5 = PE Rec. with Control *PE control not available for 347-480V. Must be a discrete voltage.	GRAY = Gray	C = CE Approved D = Dimmable (0-10 Volt Input) E = GE Level F = Fusing L = Tool-Less Entry S = Shield T = Extra Surge Protection (Pass 6kV/3kA x 120 @ 120-480V) XXX = Special Options

PHOTOMETRIC SELECTION TABLE

Distribution	Typical Initial Lumens 6000K/4300K	Typical System Wattage 120-277V	Typical System Wattage 347-480V	Pole Spacing (2-4 lanes)	Photometric Curve Number 6000K/4300K
A 1.) Asymmetric Wide - Medium	6000/5400	95	100	4-6:1	454237/454245
A 2.) Asymmetric Wide - Medium	8700/7800	142	149	4-6:1	454238/454246
A 3.) Asymmetric Wide - Medium	9600/8600	157	165	4-6:1	454239/454247
A 4.) Asymmetric Short	5100/4600	80	84	2-4:1	454240/454248
A 5.) Asymmetric Short	7000/6300	115	121	2-4:1	454241/454249
A 6.) Asymmetric Short	7800/7000	127	133	2-4:1	454242/454250
A 7.) Asymmetric Wide	3100/2800	52	55	4-6:1	454242/454251
A 8.) Asymmetric Wide	4100/3700	65	68	4-6:1	454244/454252
B 1.) Asymmetric Short	6000/5400	95	100	4-6:1	TBD
B 4.) Asymmetric Medium	5100/4600	80	84	2-4:1	TBD
B 5.) Asymmetric Medium	7000/6300	115	121	2-4:1	TBD
B 6.) Asymmetric Medium	7800/7000	127	133	2-4:1	TBD
B 7.) Asymmetric Short	3100/2800	52	55	2-4:1	TBD
B 8.) Asymmetric Short	4100/3700	65	68	2-4:1	TBD

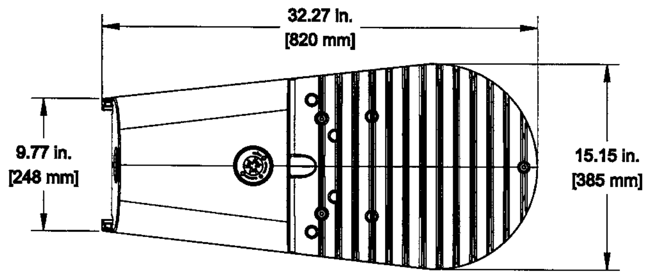
Note: Values supplied above may be subject to revision based on final LM-79 test results.

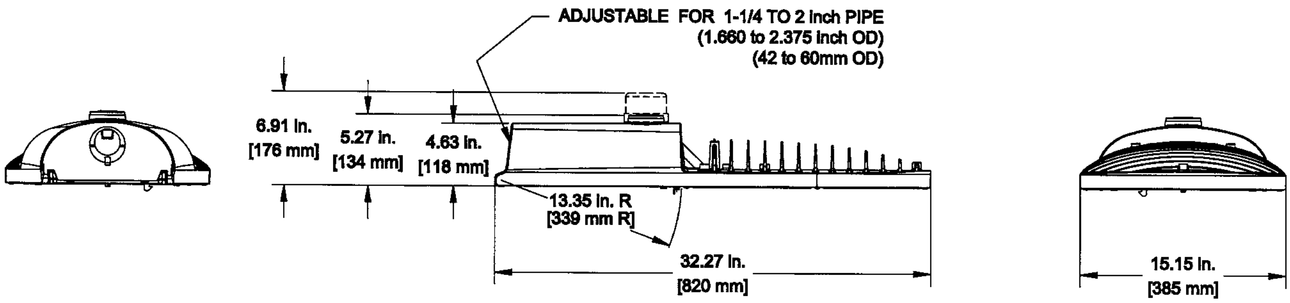
GE EVOLVE™ LED SERIES

Roadway Medium Cobrahead (R150)

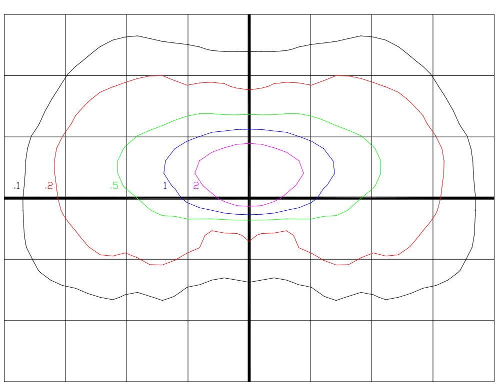
D

FIXTURE DIMENSIONS



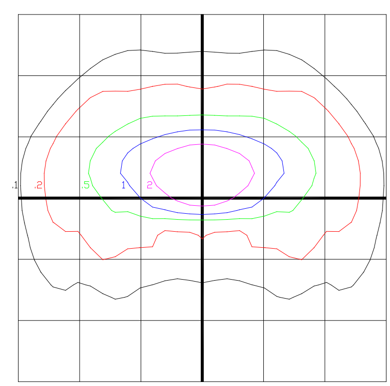


Iso - Illuminance Plot - A1, A2, A3



ASYMMETRIC WIDE

Iso - Illuminance Plot - A4, A5, A6



ASYMMETRIC SHORT

DATA

Approximate Net Weight	35 lbs	16 kgs
EPA with Slipfitter	1.1 sq ft max	0.10 sq M max

Information provided is subject to change without notice. All values are design or typical values when measured under laboratory conditions.

E

Helios

An innovative classic

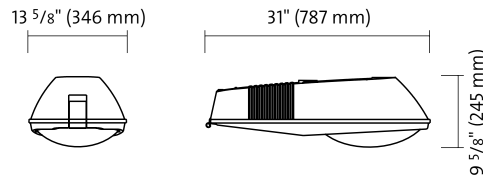
Philips Helios roadway luminaire series with *Smartseal* technology

PHILIPS

Lamps/HID

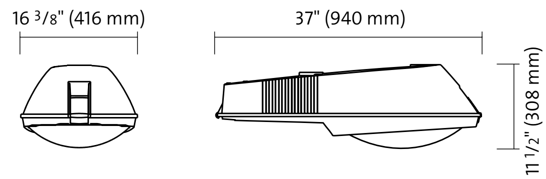
Wattage	HBS type	HBM type
70 MH, medium	ED17	ED17
100 MH, medium	ED17 ED23 ½	ED17
150 MH, medium	ED17 ED23 ½	ED17
70 HPS, mogul	ED23 ½	ED23 ½
100 HPS, mogul	ED23 ½	ED23 ½
150 HPS, mogul	ED23 ½	ED23 ½
200 HPS, mogul	ED18	ED18
250 HPS, mogul	ED18	ED18
310 HPS, mogul	N/A	ED18
400 HPS, mogul	N/A	ED18
175 PSMH, mogul	ED28	ED28
250 PSMH, mogul	ED28	ED28
400 PSMH, mogul	N/A	ED28

Physical characteristics



HBS

SAG LENS OPTICS	FLAT LENS OPTICS
EPA: 1.47 sq. ft.	EPA: 1.40 sq. ft.
Weight: 27 lbs	Weight: 26 lbs



HBM

SAG LENS OPTICS	FLAT LENS OPTICS
EPA: 1.59 sq. ft.	EPA: 1.52 sq. ft.
Weight: 32 lbs	Weight: 31 lbs

Lamps/eHID

Wattage	HBS type	HBM type	CCT
60 CW	T9	N/A	2800K
90 CW	T9	N/A	2800K
140 CW	T9	N/A	2800K
210 MCE	N/A	T12	3000K * 4200K
315 MCE	N/A	T12	3000K * 4200K

* 3000K standard

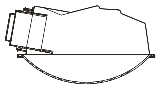
Lamps/QL

Wattage	HBS type	HBM type
55 QL	✓	
85 QL	✓	
165 QL		✓

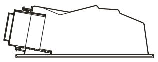
High frequency generator for induction lamp (4000K). Instant start. Operating range 50-60 Hz or DC. Lamp minimum starting temperature -40F (-40 C).

✓ = available

Optical systems / HID and eHID



	HBS		HBM	
SAG lens optics Hydroformed reflector permanently sealed on a sag tempered-glass lens.	**MC2:**	Medium cut-off (II)	**MC2:**	Medium cut-off (II)
	MC3:	Medium cut-off (III)	**MS2:**	Medium semi cut-off (II)
	MS2:	Medium semi cut-off (II)	**MN2:**	Medium non cut-off (II)
	SC1:	Short cut-off (I)	**MN3:**	Medium non cut-off (III)
	SC2:	Short cut-off (II)		
	SC3:	Short cut-off (III)		



	HBS		HBM	
Flat lens optics Hydroformed reflector permanently sealed on a flat tempered-glass lens.	**SC1F:**	Short cut-off (I)	**MC2F:**	Medium cut-off (II)
	SS2F:	Short semi cut-off (II)	**MC3F:**	Medium cut-off (III)
	MN3F:	Medium none cut-off (III)		
	MS3F:	Medium semi cutoff (III)		
	MC1F:	Medium cutoff (I)		
	MC2F:	Medium cutoff (II)		
	MC3F:	Medium cutoff (III)		

* Lamps not included on HID. Lamps included on eHID.

Photometry available on Philips Roadway Lighting website www.philips.com/roadwaylighting. Consult factory for additional distribution.

Voltage / HID

120 / 208 / 240 / 277 / 347 / 480

*Multi-tap ballast also available.

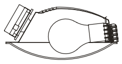
Voltage / eHID

CW 120 / 208 / 240 / 277

MCE 208 / 240 / 277

Optical systems / QL

HBS :

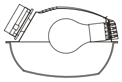


SAG LENS optics

Hydroformed reflector permanently sealed on a sag tempered-glass lens.

SC3: Short cut-off (III)

HBS/HBM :



PRISMATIC LENS optics

Hydroformed reflector permanently sealed on a sag acrylic lens.

SA: Short semi cut-off (III)

* Lamps included. Photometry available on Philips Roadway Lighting website www.philips.com/roadwaylighting.

Voltage / QL

120 / 208 / 240 / 277

Luminaire options

BL	Bubble level
HDB	Heavy duty block connector
HS	House shield
PH8	Photoelectric cell
RC	Receptacle for a twist-lock photoelectric cell or a shorting cap
SP	Line surge protection
SQD	Starter with quick disconnect
STB	Anti-vibration kit
STP	Protective starter

Finishes

The specially formulated Lumital powder coat finish is available in white, grey, black and bare. Additional colors are available. Consult factory for complete specifications.

Maintenance

Access to lamp

A simple quarter-turn of the sealed shutter provides easy access to the lamp. Quick-disconnect terminals between the lamp and the ballast tray ensure safe and easy lamp replacement.

Access to ballast

The tool free drop-in unitized ballast tray is slipped into the ballast box which rests on the optical support plate. The use of quick-disconnect terminals ensures safe and easy ballast maintenance.

M-250A2 POWR/DOOR® LUMINAIRE WITH CUTOFF OPTICS

F

APPLICATIONS

- For residential streets, access roads, parking lots where light trespass could be a problem

SPECIFICATION FEATURES

- Powr/Module ballast assembly
- Filtered optics
- Universal two-bolt slipfitter
- Die-cast aluminum housing with polyester powder gray paint finish
- Street Side Adjustable E39 mogul base socket standard where lamp is available in mogul base (E26 Medium base otherwise)
- ALGLAS® finish on reflector
- No-tool PE receptacle
- Plug-in ignitor
- True 90° cutoff—no light above 90° (meets RP8-2000 for full cutoff)
- External stainless steel bail latch
- UL/cUL listed for wet location available as an option
- Plastic pest guard standard (not required for 2 in. pipe)

ORDERING NUMBER LOGIC

M2AC	15	S	1	N	2	G	MC3	1	F
PRODUCT IDENT	WATTAGE	LIGHT SOURCE	VOLTAGE	BALLAST TYPE	PE FUNCTION	LENS TYPE	IES DISTRIBUTION TYPE	FILTER	OPTIONS
XXXX	XX	X	X	X	X	X	XXX	X	XXX
M2AC = M-250A2 with Cutoff Optics ★ ★ = Previously IESNA Full Cutoff Optics	05 =50 07 = 70 10 =100 15 =150 (55V) 17 =175 20 =200 21 =100/150 (55V) 25 =250 71 =70/100 NOTE: Dual wattage connected for lower wattage	E = Energy Act Compliant Pulse MH (EPMH) S = HPS P = PMH Standard: Lamp not included.	60Hz 0 = 120/208/ 240/277 Multivolt 1 =120 2 =208 3 =240 4 =277 5 =480 7 =120X240 8 = 240V Ballast 120V PE Receptacle not reconnect-able D =347 F =120X347 T =220 50Hz 6 =220 R =230 Y =240 NOTE: Dual voltage connected for lower voltage	See Ballast Selection Table A = Autoreg G = Mag-Reg with Grounded Socket Shell H = HPF Reactor or Lag J = CWI M = Mag-Reg N = NPF Reactor or Lag P = CWI with Grounded Socket Shell S = Series (in Top Housing)	1 = None 2 = PE Receptacle NOTE: Receptacle connected same voltage as unit except as noted. Order PE Control separately.	See Photometric Selection Table A = Acrylic Clear Globe G = Flat Glass ★ L = Polycarbon-ate Clear Globe S = Sag Glass Clear Globe NOTE: 150 watt Maxi-mum with Acrylic or Polycarbonate Clear Globes. ★ = Previously IESNA Full Cutoff Optics	See Photometric Selection Table S = Short M = Medium C = Cutoff ★ 2 = Type II 3 = Type III ★ = Previously IESNA Full Cutoff Optics	1 = Fiber gasket 2 = Charcoal with elasto-mer gasket	F = Fusing (Not available with multivolt or dual voltage) J = Line Surge Protector, Expulsion Type U = UL/cUL listed (all HPS and up to 175W MH) with glass or polycarbonate (60Hz only)

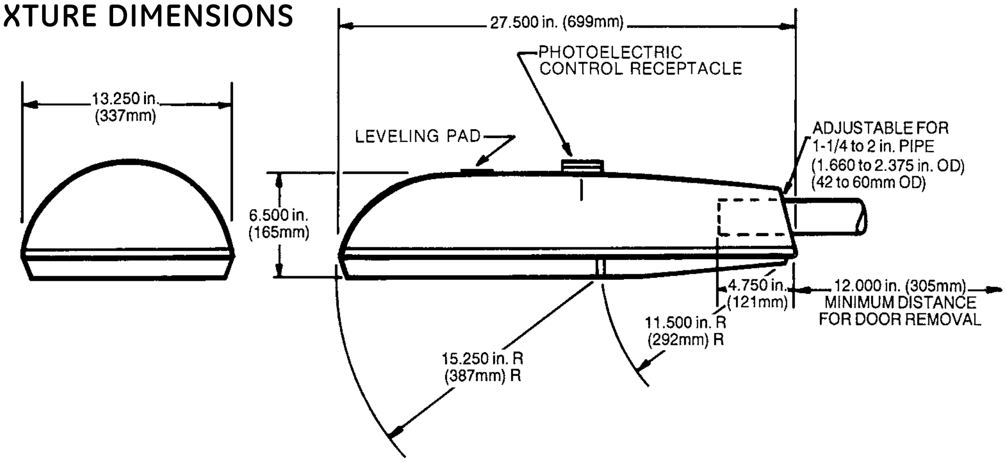
PHOTOMETRIC SELECTION TABLE

Wattage	Light Source	Lens Type	IES Distribution Type Photometric Curve Number (Socket Position) All light sources are clear unless otherwise indicated. MC2	MC3	SC2
50, 70, 100, 150 (55v)	HPS	Clear globe, acrylic or Polycarbonate	N/A	177287 (1A)	N/A
50	HPS	Clear globe, glass	452543 (2CL)	452544 (1CL)	N/A
70	HPS	Clear globe, glass	452545 (3CL)	452546 (1CL)	N/A
100	HPS	Clear globe, glass	452547(2CL)	452548 (1CL)	N/A
150 (55v)	HPS	Clear globe, glass	452549 (2CL)	452550 (1CL)	N/A
50, 70, 100, 150 (55v)	HPS	Glass, flat*	177286 (2CL)	177285 (1CL)	N/A
200	HPS	Clear globe, glass	452551 (2CH)	452552 (2DL)	N/A
250	HPS	Clear globe, glass	N/A	452553 (2CH)	N/A
200, 250	HPS	Glass, flat*	177303 (2DH)	177304 (1DH)	N/A
175, 250	EPMH	Glass, flat*	N/A	N/A	177299(1B)
**100, 150	PMH	Glass, flat*	452707	451435(2CL)	453603

NOTE: N/A=Not Available
PMH—Contact Factory
*Meets RP8-2000 for full cutoff with flat glass
**Medium Base Socket

M-250A2 POWR/DOOR® LUMINAIRE WITH CUTOFF OPTICS

FIXTURE DIMENSIONS



DATA

Approximate Net Weight	20-30 lbs	9-14 kgs
Effective Projected Area		
Flat Glass Unit	0.9 sq. ft. max	0.08 sq. M max
Clear Acrylic Globe Unit	1.0 sq. ft. max	0.09 sq. M max
Suggested Mounting Height	20-40 ft.	6-12 M

REFERENCES

See Page R-48 for start of Accessories.
See Page R-52 for Explanation of Options and Other Terms Used.
See Pole and Bracket Section Page P-2 for pole selection.

BALLAST SELECTION TABLE

Wattage	Light Source	Ballast Type/Voltage												
		60Hz										50Hz		
		Multi-volt	120	208	240	277	480	120X240	347,120X347	240/120 PE R	220	220	230	240
50	HPS	**H,N**	**H,N**	**H,N**	**H,N**	**H,N**	**H,N**	**H,N**	**H,N**	**H,N**	N/A	N/A	N/A	N/A
70, 100, 150 (55V)	HPS	**A,H,N**	**A,G,H,M,N,P**	**A,G,H,M,N**	**A,G,H,M,N,P**	**A,G,H,M,N**	**G,M**	**G,M,P**	**G*,H,M*,N**	**G,M,N**	N/A	**H,M,N**	**H**	**M††**
100/150 (55V)	HPS	N/A	**H,N**	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
200	HPS	**A,J,P**	**A,H,N,P**	**A,H,N,P**	**A,H,N,P**	**A,P**	**A**	**A,P**	N/A	**A,H,N**	N/A	N/A	N/A	N/A
250	HPS	**A,J,P**	**A,H,N,P**	**A,H,N,P**	**A,H,N,P**	**A,P**	**A,P**	**A,J,P**	**A,P**	**A,H,N**	**H**	**A,H,N**	**H**	**A,H**
175	EPMH	**A**	**A**	**A**	**A**	**A**	**A**	**A**	N/A	**A**	N/A	N/A	N/A	N/A
100**	PMH	**H,N**	**H,N**	**H,N**	**H,N**	**H,N**	**H,N**	**H,N**	**H,N**	**H,N**	N/A	N/A	N/A	N/A
150**	PMH	N/A	**A,H**	**H**	**H**	**H**	N/A	**H**	**H**	**H**	N/A	N/A	N/A	N/A
250	EPMH	**A**	**A**	**A**	**A**	**A**	**A**	**A**	N/A	**A**	N/A	N/A	N/A	N/A

NOTE: N/A=Not Available
††150(55V) only
*Not available in 120X347 volt
***Medium Base Socket

M2AC — SUGGESTED CATALOG ORDERING NUMBERS

Catalog Number	Wattage	Light Source	Voltage (60 Hz)	Ballast Type	Refractor Type	Photometric Distribution
M2AC10S1N2GMC21	100	HPS	120	NPF Reactor	Glass	MC2
M2AC15S1N2GMC21	150	HPS	120	NPF Reactor	Glass	MC2
M2AC25S0A2GMC31	250	HPS	Multivolt	Auto-Regulator	Glass	MC3

All GE suggested catalog ordering numbers come with PE receptacle. PE control must be ordered separately. Order and install SCCL-PECTL if no PE is desired.

Multivolt ballasts can be for either 120, 208, 240, or 277 volt incoming power supply.

Appendix B: Electrical Measurements

Table B1. RMS Voltage of the demonstration luminaires.

Type	Manufacturer	Lamp Type	Measurement (V)			Accuracy[1]	
			Nominal	Control	Metered	Nominal	Control
A	Philips Hadco	LED	240	246	247.9	-3.19%	-0.77%
A	Philips Hadco	LED	240	243	248.2	-3.30%	-2.10%
B	GE Lighting Solutions	Induction	240	241	248.1	-3.26%	-2.86%
B	GE Lighting Solutions	Induction	240	241	247.3	-2.95%	-2.55%
C	Cooper Lumark	LED	240	243	248.7	-3.50%	-2.29%
C	Cooper Lumark	LED	240	240	249.2	-3.69%	-3.69%
D	GE Lighting Solutions	LED	240	240	248.4	-3.38%	-3.38%
D	GE Lighting Solutions	LED	240	240	249.1	-3.65%	-3.65%
E	Philips Lumec	CMH	240	240	248.8	-3.54%	-3.54%
E	Philips Lumec	CMH	240	240	249.6	-3.85%	-3.85%
F	GE Lighting Solutions	HPS	240	240	249.4	-3.77%	-3.77%
F	GE Lighting Solutions	HPS	240	240	249.4	-3.77%	-3.77%
					Mean:	**-3.49%**	**-3.02%**

1. Accuracy is relative to metered value.

Table B2. RMS Current of the demonstration luminaires. Some nominal values were not reported.

Type	Manufacturer	Lamp Type	Measurement (A)			Accuracy[1]	
			Nominal	Control	Metered	Nominal	Control
A	Philips Hadco	LED	0.329	0.344	0.341	-3.52%	0.73%
A	Philips Hadco	LED	0.329	0.326	0.323	1.86%	0.77%
B	GE Lighting Solutions	Induction		0.421	0.420		0.12%
B	GE Lighting Solutions	Induction		0.418	0.415		0.60%
C	Cooper Lumark	LED	0.416	0.331	0.334	24.55%	-0.90%
C	Cooper Lumark	LED	0.353	0.328	0.329	7.29%	-0.30%
D	GE Lighting Solutions	LED	0.30	0.292	0.321	-6.25%	-9.03%
D	GE Lighting Solutions	LED	0.30	0.287	0.288	4.49%	-0.35%
E	Philips Lumec	CMH		0.284	0.288		-1.56%
E	Philips Lumec	CMH		0.285	0.290		-1.90%
F	GE Lighting Solutions	HPS		1.282	1.257		1.95%
F	GE Lighting Solutions	HPS		1.311	1.294		1.28%
					Mean:	**4.74%**	**-0.72%**

1. Accuracy is relative to metered value.

Table B3. **Apparent Power of the demonstration luminaires.** Apparent power could not be determined for some luminaire types based on the limited information provided by the manufacturer.

Type	Manufacturer	Lamp Type	Measurement (VA)			Accuracy[1]	
			Nominal	Control	Metered	Nominal	Control
A	Philips Hadco	LED	79	84.5	84.2	-6.18%	0.36%
A	Philips Hadco	LED	79	79.1	79.6	-0.75%	-0.63%
B	GE Lighting Solutions	Induction		101.3	102.9		-1.52%
B	GE Lighting Solutions	Induction		100.6	101.4		-0.77%
C	Cooper Lumark	LED	84.8	80.4	82.1	3.29%	-2.03%
C	Cooper Lumark	LED	84.8	78.7	81.0	4.69%	-2.81%
D	GE Lighting Solutions	LED	72.2	70.0	72.8	-0.79%	-3.85%
D	GE Lighting Solutions	LED	72.2	68.8	69.4	4.07%	-0.86%
E	Philips Lumec	CMH		68.0	69.6		-2.24%
E	Philips Lumec	CMH		68.3	70.3		-2.87%
F	GE Lighting Solutions	HPS		307.6	312.0		-1.42%
F	GE Lighting Solutions	HPS		314.5	320.7		-1.93%
					Mean:	**0.72%**	**-1.71%**

1. Accuracy is relative to metered value.

Table B4. **Active power of the demonstration luminaires.** Neither active power nor power factor data were available from the control system.

Type	Manufacturer	Lamp Type	Measurement (W)			Accuracy[1]	
			Nominal	Control	Metered	Nominal	Control
A	Philips Hadco	LED	77.4		81.9	-5.49%	
A	Philips Hadco	LED	77.4		76.7	0.91%	
B	GE Lighting Solutions	Induction	107.0		101.5	5.42%	
B	GE Lighting Solutions	Induction	107.0		99.9	7.11%	
C	Cooper Lumark	LED	76.3		79.6	-4.15%	
C	Cooper Lumark	LED	76.3		77.7	-1.80%	
D	GE Lighting Solutions	LED	65.0		69.7	-6.74%	
D	GE Lighting Solutions	LED	65.0		66.0	-1.52%	
E	Philips Lumec	CMH	67.3		68.3	-1.46%	
E	Philips Lumec	CMH	67.3		69.2	-2.75%	
F	GE Lighting Solutions	HPS	125.0		140.9	-11.28%	
F	GE Lighting Solutions	HPS	125.0		142.9	-12.53%	
					Mean:	**-2.86%**	

1. Accuracy is relative to metered value.

Appendix C: Calculation Results

The demonstration area was modeled using two different sets of calculation points:

1. *Method One* – Illuminance was calculated using the original engineering drawing, with each type of luminaire used for the entire span of the demonstration area. This method provided a uniform basis for comparison of the products, negating the effects of the substantial difference in pole spacing between sites. Calculation grids were centered on the width of the vehicle lanes, bicycle lanes, and sidewalks according to RP-8-00, with longitudinal spacing at 11 feet throughout the demonstration area. The results are shown in Table C1 and Table C3.

2. *Method Two* – Illuminance was calculated using grids designated to match the physical measurement points. The calculations were for the specific area that was evaluated in the field, with the pole spacing adjusted to match field measurements (rather than the engineering drawing). This method allows for a direct comparison of the calculated and measured results. The results are shown in Table C2 and Table C4.

Table C1. Calculated initial horizontal illuminance, method one. Red values fail to meet PBOT criteria.

	PBOT Criteria	IES RP-8-00 Criteria	Area / Luminaire Type					
			A	B	C	D	E	F
Car Lanes								
Maximum			0.89	1.83	0.91	1.50	2.70	2.48
Minimum			0.22	0.19	0.57	0.26	0.28	0.39
Average	**0.5**	**0.6**	0.49	0.68	0.73	0.61	1.02	0.80
Avg:Min	**3.0**	**4.0**	2.23	3.58	1.28	2.35	3.64	2.05
Max:Min	**9.0**		4.05	9.63	1.60	5.77	9.64	6.36
Bicycle Lanes								
Maximum			0.88	1.82	0.89	1.50	2.62	2.95
Minimum			0.19	0.15	0.40	0.16	0.11	0.24
Average	**0.5**	**0.3**	0.42	0.69	0.67	0.42	0.60	0.83
Avg:Min	**3.0**	**6.0**	2.21	4.60	1.68	2.63	5.45	3.46
Max:Min	**9.0**		4.63	12.13	2.23	9.38	23.82	12.29
Sidewalk								
Maximum			0.57	1.36	0.73	0.21	0.68	1.65
Minimum			0.11	0.10	0.24	0.09	0.05	0.10
Average	**0.2**	**0.3**	0.23	0.50	0.48	0.14	0.25	0.48
Avg:Min		**6.0**	2.09	5.00	2.00	1.56	5.00	4.80
Max:Min			5.18	13.60	3.04	2.33	13.60	16.50

Table C2. Calculated initial horizontal illuminance, method two. Red values fail to meet PBOT criteria.

	PBOT Criteria	IES RP-8-00 Criteria	Area / Luminaire Type					
			A	B	C	D	E	F
Car Lanes								
Maximum			0.84	1.45	0.95	1.38	2.49	1.90
Minimum			0.30	0.26	0.69	0.37	0.30	0.47
Average	**0.5**	**0.6**	0.50	0.63	0.86	0.61	0.87	0.78
Avg:Min	**3.0**	**4.0**	1.67	2.42	1.25	1.65	2.90	1.66
Max:Min	**9.0**		2.80	5.58	1.38	3.73	8.30	4.04
Bicycle Lanes								
Maximum			0.78	1.64	0.94	0.76	2.40	2.81
Minimum			0.26	0.24	0.69	0.17	0.16	0.27
Average	**0.5**	**0.3**	0.41	0.66	0.85	0.34	0.71	0.78
Avg:Min	**3.0**	**6.0**	1.58	2.75	1.23	2.00	4.44	2.89
Max:Min	**9.0**		3.00	6.83	1.36	4.47	15.00	10.41
Sidewalk								
Maximum			0.57	1.39	0.70	0.17	0.69	1.61
Minimum			0.14	0.12	0.47	0.11	0.05	0.13
Average	**0.2**	**0.3**	0.25	0.48	0.62	0.14	0.22	0.49
Avg:Min		**6.0**	1.79	4.00	1.32	1.27	4.40	3.77
Max:Min			4.07	11.58	1.49	1.55	13.80	12.38

Table C3. **Calculated maintained horizontal illuminance, method one.** Red values fail to meet PBOT criteria. Maintained values are 70% of initial values.

	PBOT Criteria	IES RP-8-00 Criteria	Area / Luminaire Type A	B	C	D	E	F
Car Lanes								
Maximum			0.62	1.28	0.64	1.05	1.89	1.74
Minimum			0.15	0.13	0.40	0.18	0.20	0.27
Average	**0.5**	**0.6**	0.34	0.48	0.51	0.43	0.71	0.56
Avg:Min	**3.0**	**4.0**	2.23	3.58	1.28	2.35	3.64	2.05
Max:Min	**9.0**		4.05	9.63	1.60	5.77	9.64	6.36
Bicycle Lanes								
Maximum			0.62	1.27	0.62	1.05	1.83	2.07
Minimum			0.13	0.11	0.28	0.11	0.08	0.17
Average	**0.5**	**0.3**	0.29	0.48	0.47	0.29	0.42	0.58
Avg:Min	**3.0**	**6.0**	2.21	4.60	1.68	2.63	5.45	3.46
Max:Min	**9.0**		4.63	12.13	2.23	9.38	23.82	12.29
Sidewalk								
Maximum			0.40	0.95	0.51	0.15	0.48	1.16
Minimum			0.08	0.07	0.17	0.06	0.04	0.07
Average	**0.2**	**0.3**	0.16	0.35	0.34	0.10	0.18	0.34
Avg:Min		**6.0**	2.09	5.00	2.00	1.56	5.00	4.80
Max:Min			5.18	13.60	3.04	2.33	13.60	16.50

Table C4. **Calculated <u>maintained</u> horizontal illuminance, method two.** Red values fail to meet PBOT criteria. Maintained values are 70% of initial values.

	PBOT Criteria	IES RP-8-00 Criteria	Area / Luminaire Type					
			A	B	C	D	E	F
Car Lanes								
Maximum			0.59	1.02	0.67	0.97	1.74	1.33
Minimum			0.21	0.18	0.48	0.26	0.21	0.33
Average	**0.5**	**0.6**	0.35	0.44	0.60	0.43	0.61	0.55
Avg:Min	**3.0**	**4.0**	1.67	2.42	1.25	1.65	2.90	1.66
Max:Min	**9.0**		2.80	5.58	1.38	3.73	8.30	4.04
Bicycle Lanes								
Maximum			0.55	1.15	0.66	0.53	1.68	1.97
Minimum			0.18	0.17	0.48	0.12	0.11	0.19
Average	**0.5**	**0.3**	0.29	0.46	0.60	0.24	0.50	0.55
Avg:Min	**3.0**	**6.0**	1.58	2.75	1.23	2.00	4.44	2.89
Max:Min	**9.0**		3.00	6.83	1.36	4.47	15.00	10.41
Sidewalk								
Maximum			0.40	0.97	0.49	0.12	0.48	1.13
Minimum			0.10	0.08	0.33	0.08	0.04	0.09
Average	**0.2**	**0.3**	0.18	0.34	0.43	0.10	0.15	0.34
Avg:Min		**6.0**	1.79	4.00	1.32	1.27	4.40	3.77
Max:Min			4.07	11.58	1.49	1.55	13.80	12.38

Table C5. Comparison of calculated and measured illuminance for the bicycle lanes of NE Cully Boulevard. Red values fail to meet PBOT criteria. Maintained values are 70% of initial values.

			Average Illuminance			Avg:Min Ratio		
			Calc. 1	Calc. 2	Measured	Calc. 1	Calc. 2	Measured
PBOT Criteria		**Maintained**	**≥ 0.5**	**≥ 0.5**	**≥ 0.5**	**≤ 3**	**≤ 3**	**≤ 3**
IES RP-8-00 Criteria		**Maintained**	**≥ 0.6**	**≥ 0.6**	**≥ 0.6**	**≤ 4**	**≤ 4**	**≤ 4**
Area / Luminaire Type	**A**	Initial	0.42	0.41	0.27	2.21	1.58	1.27
		Maintained	0.29	0.29				
	B	Initial	0.69	0.66	0.58	4.60	2.75	2.73
		Maintained	0.48	0.46				
	C	Initial	0.67	0.85	1.01	1.68	1.23	1.24
		Maintained	0.47	0.60				
	D	Initial	0.42	0.34	0.35	2.63	2.00	1.52
		Maintained	0.29	0.24				
	E	Initial	0.60	0.71	0.53	5.45	4.44	2.86
		Maintained	0.42	0.50				
	F	Initial	0.83	0.78	0.75	3.46	2.89	2.88
		Maintained	0.58	0.55				

Table C6. Comparison of calculated and measured illuminance for the sidewalks of NE Cully Boulevard. Red values fail to meet PBOT criteria. Maintained values are 70% of initial values.

			Average Illuminance			Avg:Min Ratio		
			Calc. 1	Calc. 2	Measured	Calc. 1	Calc. 2	Measured
PBOT Criteria		**Maintained**	**≥ 0.2**	**≥ 0.2**	**≥ 0.2**			
IES RP-8-00 Criteria		**Maintained**	**≥ 0.3**	**≥ 0.3**	**≥ 0.3**	**≤ 6**	**≤ 6**	**≤ 6**
Area / Luminaire Type	**A**	Initial	0.23	0.25	0.17	2.09	1.79	1.28
		Maintained	0.16	0.18				
	B	Initial	0.50	0.48	0.41	5.00	4.00	3.42
		Maintained	0.35	0.34				
	C	Initial	0.48	0.62	0.75	2.00	1.32	1.33
		Maintained	0.34	0.43				
	D	Initial	0.14	0.14	0.18	1.56	1.27	1.24
		Maintained	0.10	0.10				
	E	Initial	0.25	0.22	0.24	5.00	4.40	2.53
		Maintained	0.18	0.15				
	F	Initial	0.48	0.49	0.45	4.80	3.77	3.04
		Maintained	0.34	0.34				

Appendix D: Measurements Results

Table D1. Measured horizontal illuminance. Red values fail to meet PBOT criteria.

	PBOT Criteria	IES RP-8-00 Criteria	Area / Luminaire Type A	B	C	D	E	F
Car Lanes								
Maximum			0.72	1.29	1.16	1.79	2.70	2.15
Minimum			0.35	0.23	0.80	0.43	0.33	0.41
Average	**0.5**	**0.6**	0.55	0.57	1.01	0.77	0.98	0.75
Avg:Min	**3.0**	**4.0**	1.57	2.43	1.26	1.79	2.93	1.83
Max:Min	**9.0**		2.03	5.56	1.45	4.20	8.06	5.25
Bicycle Lanes								
Maximum			0.44	1.45	1.15	0.57	1.33	2.64
Minimum			0.21	0.21	0.82	0.23	0.19	0.26
Average	**0.5**	**0.3**	0.27	0.58	1.01	0.35	0.53	0.75
Avg:Min	**3.0**	**6.0**	1.27	2.73	1.24	1.52	2.86	2.88
Max:Min	**9.0**		2.04	6.78	1.41	2.44	7.15	10.14
Sidewalk								
Maximum			0.30	1.13	0.90	0.21	0.74	1.37
Minimum			0.13	0.12	0.57	0.15	0.09	0.15
Average	**0.2**	**0.3**	0.17	0.41	0.75	0.18	0.24	0.45
Avg:Min		**6.0**	1.28	3.42	1.33	1.24	2.53	3.04
Max:Min			2.29	9.38	1.59	1.44	8.00	9.19

Appendix E: Demonstration Area Photographs

Figure E1. Demonstration area A.

Figure E2. Demonstration area B.

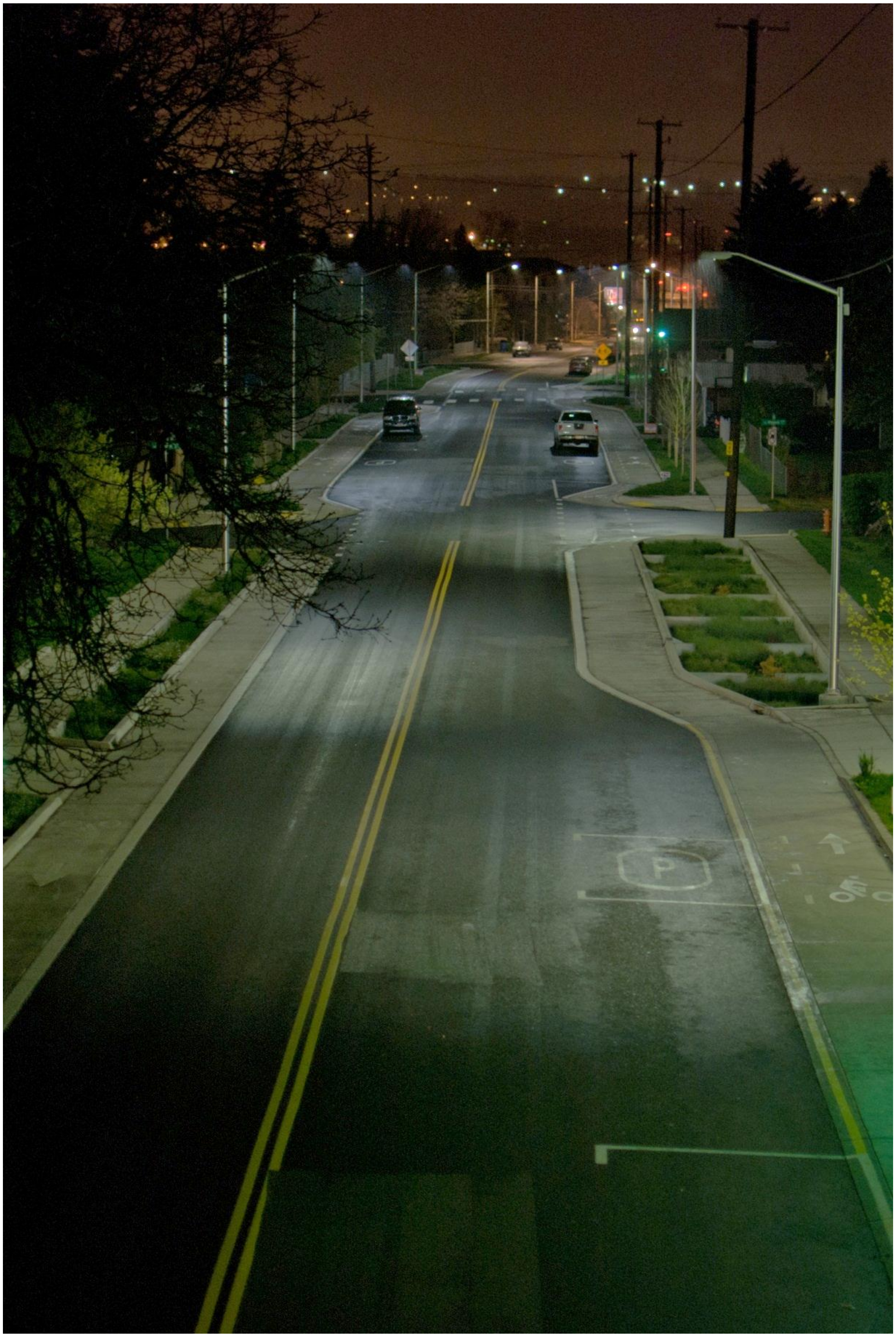


Figure E3. Demonstration area C.

Figure E4. **Demonstration area D.**

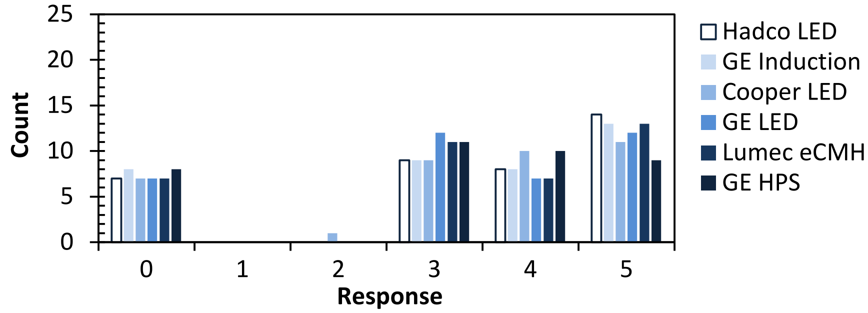
Figure E5. Demonstration area E.

Figure E6. Demonstration area F.

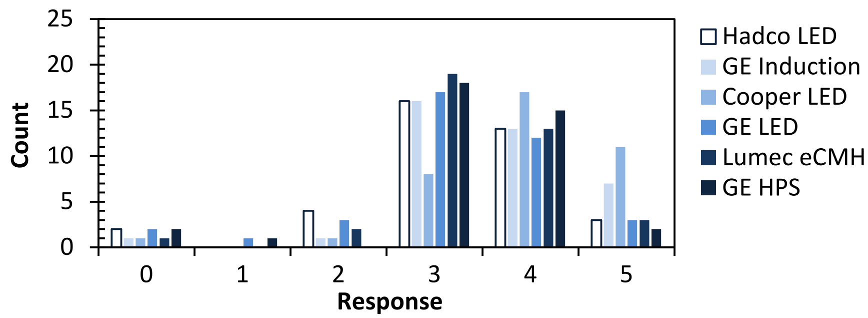
Appendix F: Summary of Questionnaire Responses

The twelve statements were evaluated on a scale of one to five, with one indicating strong disagreement, three being neutral, and five indicating strong agreement. The question, *how does the lighting in this area compare with the lighting of similar Portland city streets at night,* had five possible answers: much worse, worse, about the same, better, or much better—these correspond to one through five in the histogram provided here. In these charts, zero indicates either a non-response or a response of "don't know."

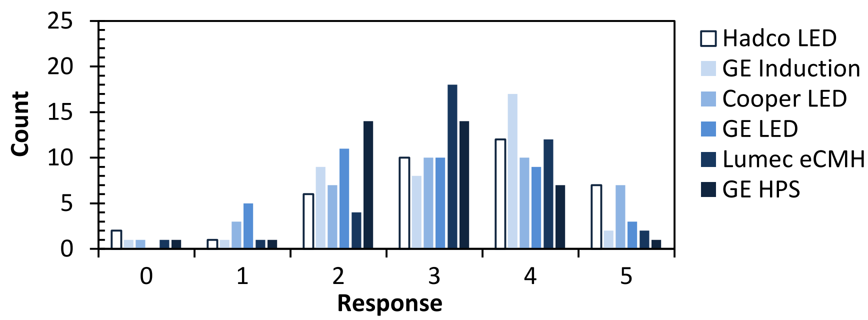
1. It would be safe to walk here, alone, during daylight hours.



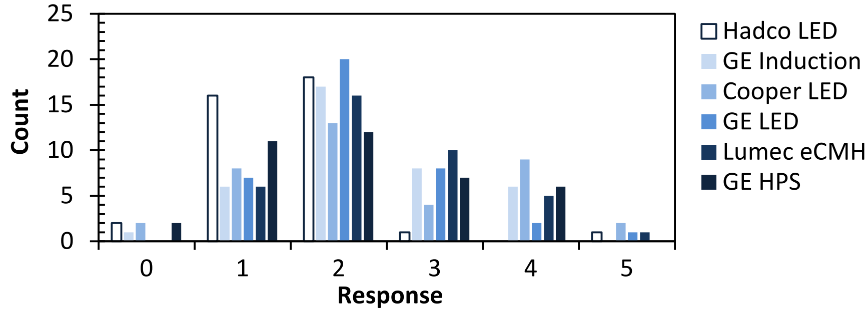
2. It would be safe to walk here, alone, during darkness hours.



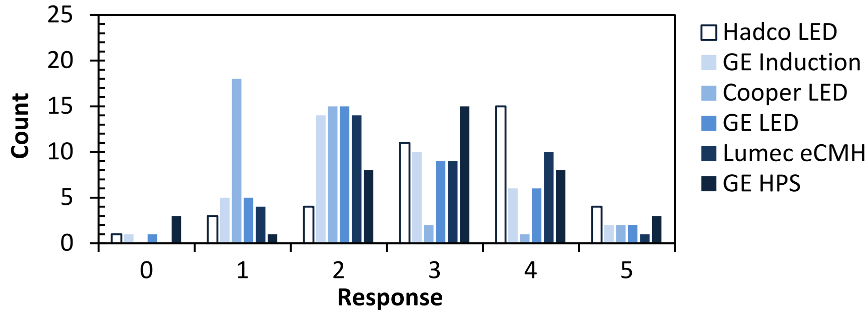
3. The lighting is comfortable.



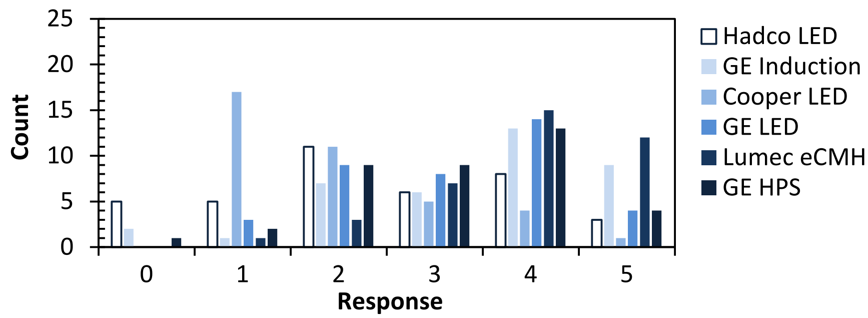
4. There is too much light on the street.



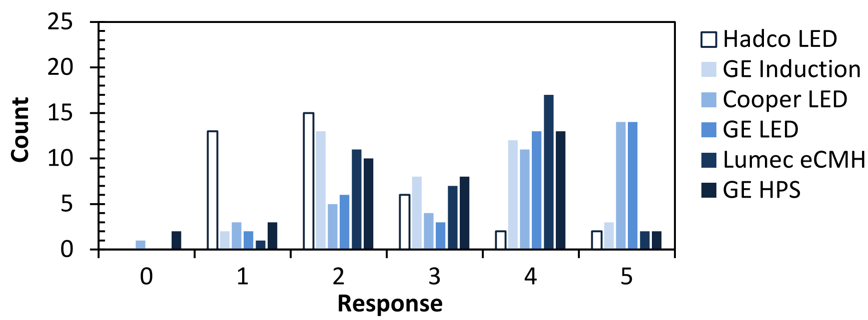
5. There is not enough light on the street.



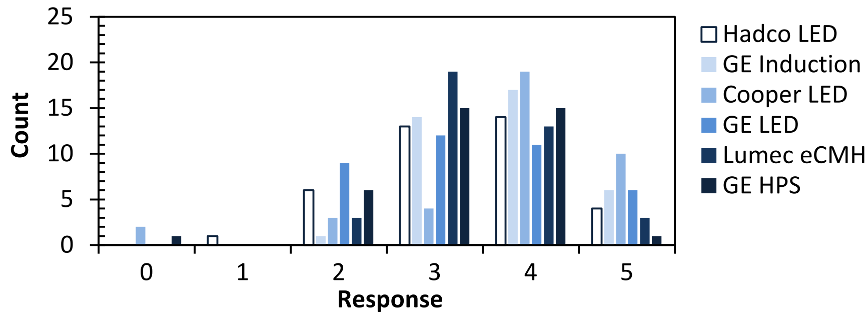
6. The light is uneven (patchy).



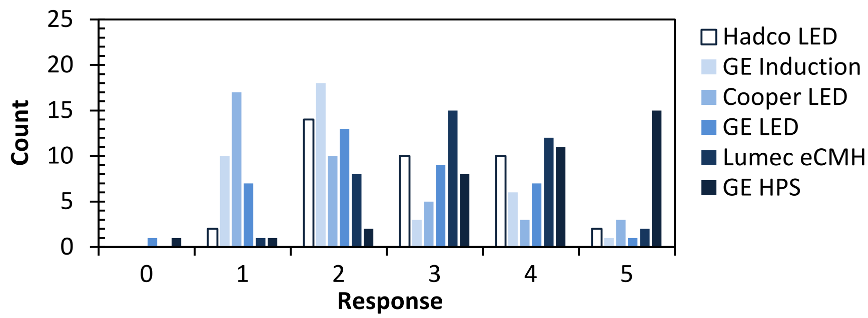
7. The light sources are glaring.



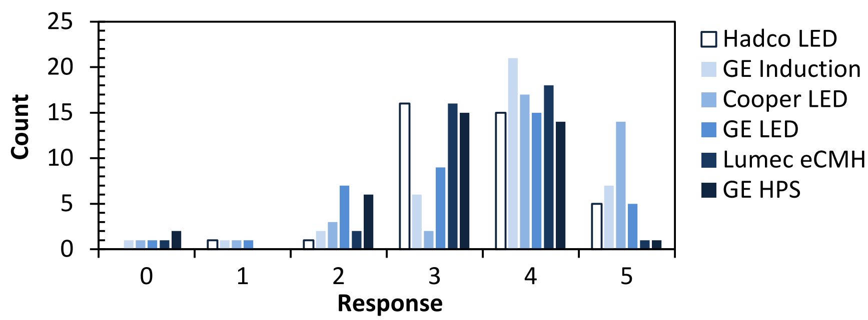
8. It would be safe to walk on the sidewalk here at night.



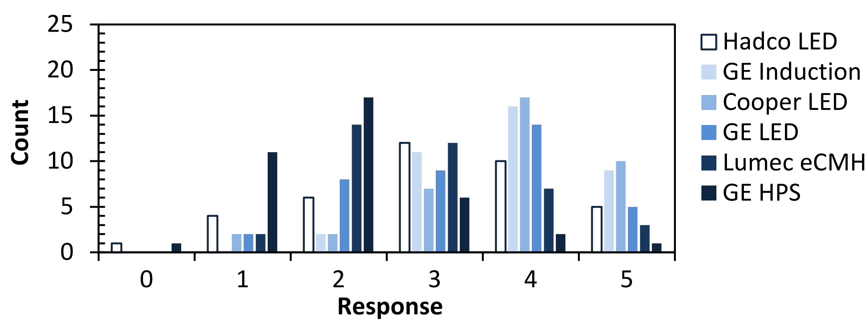
9. I cannot tell the colors of things due to the lighting.



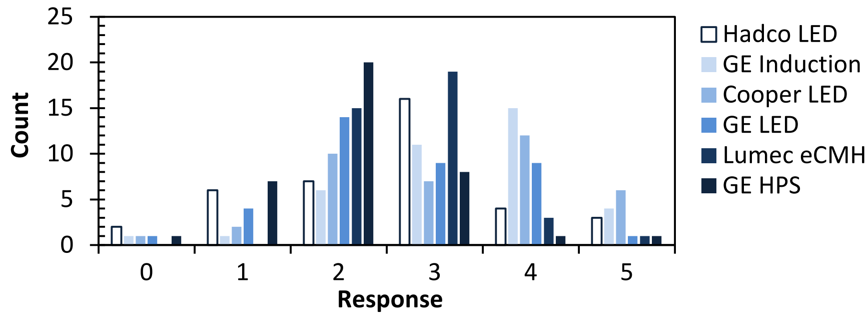
10. The lighting enables safe vehicular navigation.



11. I like the color of the light.



12. I would like this style lighting on my city streets.



13. How does the lighting in this area compare with the lighting of similar Portland city

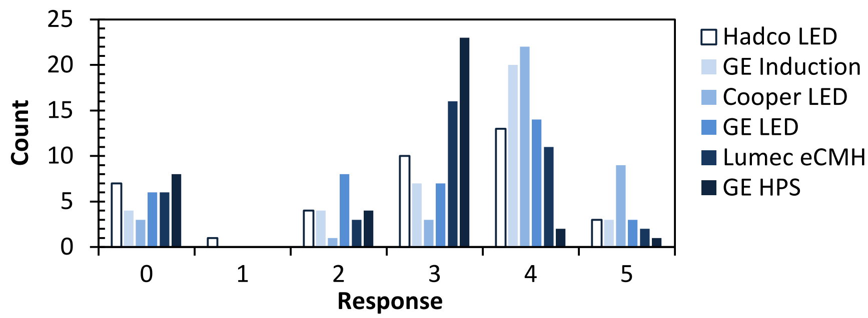


Table F1. **Mean responses to the questionnaire items.** The scale of one to five corresponded to "strongly disagree" to "strongly agree."

Area / Luminaire Type: Source Type:	A LED	B Induction	C LED	D LED	E CMH	F HPS
1. It would be safe to walk here, alone, during daylight hours.	4.2	4.1	4.0	4.0	4.1	3.9
2. It would be safe to walk here, alone, during darkness hours.	3.4	3.7	4.0	3.4	3.5	3.5
3. The lighting is comfortable.	3.5	3.3	3.3	2.8	3.3	2.8
4. There is too much light on the street.	1.7	2.4	2.6	2.2	2.4	2.2
5. There is not enough light on the street.	3.4	2.6	1.8	2.6	2.7	3.1
6. The light is uneven (patchy).	2.8	3.6	2.0	3.2	3.9	3.2
7. The light sources are glaring.	2.1	3.0	3.8	3.8	3.2	3.0
8. It would be safe to walk on the sidewalk here at night.	3.4	3.7	4.0	3.4	3.4	3.3
9. I cannot tell the colors of things due to the lighting.	2.9	2.2	2.1	2.5	3.2	4.0
10. The lighting enables safe vehicular navigation.	3.6	3.8	4.1	3.4	3.5	3.3
11. I like the color of the light.	3.2	3.8	3.8	3.3	2.9	2.1
12. I would like this style lighting on my city streets.	2.8	3.4	3.3	2.7	2.7	2.2
13. How does the lighting in this area compare with the lighting of similar Portland city streets at night?	3.4	3.6	4.1	3.4	3.4	3.0

Table F2. **Mode (most frequent) responses to the questionnaire items.** The scale of one to five corresponded to "strongly disagree" to "strongly agree."

Area / Luminaire Type: Source Type:	A LED	B Induction	C LED	D LED	E CMH	F HPS
1. It would be safe to walk here, alone, during daylight hours.	5	5	5	3	5	3
2. It would be safe to walk here, alone, during darkness hours.	3	3	4	3	3	3
3. The lighting is comfortable.	4	4	4	2	3	2
4. There is too much light on the street.	2	2	2	2	2	2
5. There is not enough light on the street.	4	2	1	2	2	3
6. The light is uneven (patchy).	2	4	1	4	4	4
7. The light sources are glaring.	2	2	5	5	4	4
8. It would be safe to walk on the sidewalk here at night.	4	4	4	3	3	3
9. I cannot tell the colors of things due to the lighting.	2	2	1	2	3	5
10. The lighting enables safe vehicular navigation.	3	4	4	4	4	3
11. I like the color of the light.	3	4	4	4	2	2
12. I would like this style lighting on my city streets.	3	4	4	2	3	2
13. How does the lighting in this area compare with the lighting of similar Portland city streets at night?	4	4	4	4	3	3