Successful Selection of LED Streetlight Luminaires
Optimizing Illumination and Economic Performance
DOE Solid-State Lighting Webinar | Date: March 6, 2013

Chad Stalker
Regional Marketing Manager, Americas
Philips Lumileds Lighting

Eric Haugaard
Director of Product Technology
Cree Lighting

Moderated by:
Edward Smalley
Director, Municipal Solid-State Street Lighting Consortium
Seattle City Light
About The Consortium - Background

• Created by the U.S. Department of Energy (DOE) in March 2010 using American Recovery and Reinvestment Act (ARRA) funding

• Supported by the DOE GATEWAY program

• Intended to be an educational resource on Solid-State street lighting and associated technology for those involved in lighting streets and other outdoor public areas.

  As an independent resource, the Consortium is available to help those unfamiliar with LED technology identify important issues and how to begin the evaluation process

• ...and to help accelerate adoption of SSL technology in the nations street lighting systems
Our Vision

• Accelerate the adoption of high performance solid-state street and area lighting by leading end-user collaboration in the areas of performance, evaluation, application, and standardization.
Mission

- Increase **KNOWLEDGE** around the performance, quality, and application of SS Street Lighting.
- Develop a national **STRUCTURE** to provide oversight and guidance on the evaluation of SSL for public areas.
- Influence national **STANDARDIZATION** of benchmarks, classification, design, and performance criteria. Set standard benchmarks.
Membership

Primary Type Organizations Participating

373

- Municipality, 218
- Utility, 63
- Non-municipal Government, 46
- Municipally Owned Utility, 46
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Today’s Goal…

Define a Process for Developing an LED Streetlight Specification
Enabling the Required Performance Expectations to be Met
Meeting the Illumination Performance Requirements

Meeting the Economic Performance Requirements

Justification Based on 2 Major Criteria
Looking Back…

Example:

Outdoor HID Luminaire Technology

– Optical Distribution Choices for a Given Luminaire Configuration
  • ~ 1 – 5

– Lamp Choices 70W, 100W, 175W, 250W, 400W, Etc…
  – Large Increments of Luminous Intensity & Associated Energy Consumption

– Lumen Maintenance
  • Fixed Value (common rules… generally)
    – Hours/Start
    – Power Supply

– Rated Lamp Life → Lamp Service Requirements
Pulse Start Metal Halide (PSMH) = 0.75
Relamp at 25% Lumen Depreciation

400W PSMH Rated Life = 20,000 Hours
Requires Relamping at 40% of Rated Life = 8,000 Hours

Lumen Maintenance

New Possibilities With LED Luminaire Technology

Application “Fine Tuning”

- Many More Optical Distribution Choice Possibilities

- More/Smaller Luminous Intensity Increments
  - Number of LEDs
  - Power vs. Output Options

Enabling Dramatic Improvements in Application Level Performance Optimization
Optimizing the Process...
Summer 2007
**Municipal Solid-State**

**STREET LIGHTING**

**CONSORTIUM**

**U.S. Department of Energy**

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**HPS Spec Sheet Info**

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**Lighting Sciences Inc.**

**Certified Test Report No. LSI 10246**

**Candlpower distribution curve of 250W HPS**

**Area Cutoff Floodlight without backlight shield.**

<table>
<thead>
<tr>
<th>Catalog #</th>
<th>Lamp Type</th>
<th>Lamp Lumens</th>
</tr>
</thead>
<tbody>
<tr>
<td>WAC2592-M</td>
<td>250W HPS</td>
<td>28,500</td>
</tr>
<tr>
<td></td>
<td>HPS</td>
<td>LED</td>
</tr>
<tr>
<td>----------------</td>
<td>----------------</td>
<td>----------------</td>
</tr>
<tr>
<td>Total System Wattage</td>
<td>300W</td>
<td>141W</td>
</tr>
<tr>
<td>Average Delivered Lumens</td>
<td>20,520</td>
<td>8,040 (61% less Light)</td>
</tr>
<tr>
<td>Luminaire Efficacy (Lumens/Watt)</td>
<td>68</td>
<td>57</td>
</tr>
<tr>
<td>Maintained Average Footcandles</td>
<td>1.96fc</td>
<td>1.01fc</td>
</tr>
<tr>
<td>Maintained Minimum Footcandle</td>
<td>0.30fc</td>
<td>0.30fc</td>
</tr>
<tr>
<td>Energy Savings</td>
<td>-</td>
<td>53%</td>
</tr>
</tbody>
</table>
A Specification Development Process that:

1. Defines the Required Sustainable Illumination Performance

Example:

Illumination Performance Requirements

- 1 fc Minimum Illuminance
- 10:1 Max/Min Uniformity
- 50,000 Hour Application Duration
Municipal Solid-State
STREET LIGHTING
CONSORTIUM
Lighting Design
System Power Comparison

LED – ~19 kW
Spec Grade HID – ~31 kW
2. Defines the Required Sustainable (Risk Managed) Economic Performance

- **Life Cycle Cost Analysis Elements/Variables**
  - Evaluation Timeframe / Desired Application Life
  - Product Durability Performance Requirements
  - Standards Compliance / Reliability / Warranty
  - Etc.

Note: Proportions are Relative
Step #1

Always!

Establish the Required **Maintained** Illumination Performance Requirements

– Lighting Performance Specification
  • Vertical and Horizontal Illumination Requirements
  • Uniformity
  • Color Quality
  • Light trespass
  • Glare Metrics…
  • Etc.
Define the Variables:

– Define the Lighting Application Geometric Target(s)
  • Boundaries

– Luminaire Position Constraints
  • New vs. Upgrade

– Service Life (i.e. Application Life)
  • Years of Expected Near Maintenance Free Operation
    (i.e. Hours of Operation)
  • Required Economic Assessment Period (5 -15yrs...?)

Lumen Maintenance Factors Must Be Applied!
The Value of Lighting Design

Requires Complete and Comprehensive Product Performance Data!!!
If an Exact Application Description Can Not Be Reasonably Established

Then Create a Representative “Model” Application
Essential Data
LED Luminaire Photometric Performance Measurement

- Used for lay-out design & planning
  - Initial Photometric Performance
- IESNA LM-79-08 Testing Standard (early 2008)
  - Approved Method: Electrical and Photometric Measurements of Solid-State Lighting Products
    - Requires Absolute Photometry Methods
    - SSL products dominantly have the light source, power and optics integrated into a single system
  - Generates industry standard IES Data File
LM-79-08 Validates Many Performance Characteristics

- **“Bundles”** the Effects of Many Luminaire System Variables
  - Thermal Management
  - The Effectiveness of the Heat Sink
  - Optical Control
  - Optical Precision
  - Optical Efficiency
  - Electrical Power Efficiency (Driver Efficiency)
  - Etc…

New Possibilities

Application “Fine Tuning”

- Many More Optical Distribution Choice Possibilities
- More/Smaller Luminous Intensity Increments
  - Number of LEDs
  - Power vs. Output Options
- Thousands of Possible Luminaire Configurations (SKUs)...
- How can anyone keep up with all this???
  - MSSLC Model Specification v1.0, Appendix C
  - Product Family Testing – LM-79 and ISTMT
Product Family Testing

- Represented by test data for another luminaire configuration having:
  - The same intensity distribution (typically only applies to LM-79)
  - The same or lower nominal CCT
  - The same or higher nominal drive current
  - The same or greater number of LED light source(s)
  - The same or lower percentage driver loading and efficiency
  - The same or smaller size luminaire housing

<table>
<thead>
<tr>
<th>Tests</th>
<th>Intensity distribution (IES Type)</th>
<th>CCT (K)</th>
<th>Drive current (mA)</th>
<th># of LEDs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1, 2, 3</td>
<td>II, III, IV</td>
<td>4000</td>
<td>700</td>
<td>80</td>
</tr>
<tr>
<td>4, 5</td>
<td>IV</td>
<td>5000, 6000</td>
<td>700</td>
<td>80</td>
</tr>
<tr>
<td>6, 7</td>
<td>IV</td>
<td>4000</td>
<td>325, 525</td>
<td>80</td>
</tr>
<tr>
<td>8, 9, 10</td>
<td>IV</td>
<td>4000</td>
<td>700</td>
<td>20, 40, 60</td>
</tr>
</tbody>
</table>

For example, the manufacturer could detail interpolation as shown in Table C.2, applying the following multipliers to the base test #2 to model a configuration with Type III intensity distribution, 5000K CCT, 525 mA drive current, and 40 LEDs:

- Ratio of test #4 lumens to test #3 lumens
- Ratio of test #7 lumens to test #3 lumens
- Ratio of test #9 lumens to test #3 lumens

<table>
<thead>
<tr>
<th>Test #</th>
<th>Intensity distribution (IES Type)</th>
<th>CCT (K)</th>
<th>Drive current (mA)</th>
<th># of LEDs</th>
<th>Multiplier (lumens ratio)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>III</td>
<td>4000</td>
<td>700</td>
<td>80</td>
<td>n/a</td>
</tr>
<tr>
<td>3</td>
<td>IV</td>
<td>4000</td>
<td>700</td>
<td>80</td>
<td>n/a</td>
</tr>
<tr>
<td>4</td>
<td>IV</td>
<td>5000</td>
<td>700</td>
<td>80</td>
<td>#4 / #3</td>
</tr>
<tr>
<td>7</td>
<td>IV</td>
<td>4000</td>
<td>525</td>
<td>80</td>
<td>#7 / #3</td>
</tr>
<tr>
<td>9</td>
<td>IV</td>
<td>4000</td>
<td>700</td>
<td>40</td>
<td>#9 / #3</td>
</tr>
</tbody>
</table>
Accounting for LED Luminaire Lumen Depreciation
LED Component
Lumen Depreciation

Lumen Maintenance Performance Testing Standard

- IESNA LM-80-08 (released late 2008)
  
  Approved Method: Measuring Lumen Maintenance of LED Light Sources
  
  - Covers the Measurement of Lumen Depreciation for LED Based Packages, Arrays and Modules Only
    
    - Not LED Luminaires
  
    - Does Not Provide Methods or Guidelines for Incorporating LM-80 Test Data for Luminaire Level Lumen Depreciation Extrapolation and/or Prediction.
  
    - HOWEVER luminaire manufactures can accurately correlate to “in-situ” luminaire performance from LED device manufacturers data
Test Details: LM-80 for Packaged LEDs

☐ A Specific LED Drive Current Must Be Identified and Maintained
☐ A Temperature Measurement Point (Case Temperature ($T_S$)) is Defined by the LED Chip Package Manufacturer (typically the solder pad)
☐ **Maintained $T_S$ of 55°C, 85°C and One Additional Temperature** (typically higher) is Required (test environment incorporates active thermal management/control)
☐ Requires a Minimum 6000 Hour Test Duration
☐ Data is Collected Every 1000 Hours (minimum)

Additional “Interpolated” data sets are typically available from LED Chip Package manufacturers
Test Configuration Per IESNA LM-80-2008

- During test, the temperature of the solder pad of the lamps and the air around the lamps is the same
- Per LM-80,
  - For 55°C testing, the $T_{sp}$ of the LED lamps and air are both at 55°C
  - For 85°C testing, the $T_{sp}$ of the LED lamps and air are both at 85°C
LED Device
Lumen Maintenance
Critical Parameters

1. Device Drive Current

2. $T_{\text{AIR}}$
   Ambient Air Temperature

3. $T_{\text{SP}} / T_{\text{C}} / T_{\text{S}}$
   Solder-Point Temperature / Case Temperature
What An LM-80 Report Looks Like
• Technical Memorandum Defining Extrapolation Methods and Other Criteria for Using LM-80-08 Data for the Purpose of LED Lumen Maintenance Prediction
  • Released September 2011

IESNA TM-21 Committee included Representatives from Cree, Philips Lumileds, Nichia, OSRAM, U.S. Dept Of Energy, NIST & PNNL
Lumen Maintenance Projections Times (in hours) Limited to No More Than 6X the LM-80 Test Duration (6000 hours Min)

• “Reported Values”
  – Derived From the Three LM-80 Required Test Conditions (i.e. 55C, 85C and One Other Tₚ) – Lumen Maintenance times limited to 6X LM-80 test duration
    • For Example: 10,000 hour testing…allows for 60,000 hour reported lumen maintenance

• “Projected Values”
  – Derived From Other Tₛ Conditions Using Prescribed Interpolation Methods Outlined in TM-21

• “Calculated Values”
  – Same as Projected Values for Times Greater Than 6X LM-80 Test Duration
Why Is This Important?

Excerpt from MSSLC Model Specification…

1.6 REQUIRED SUBMITTALS FOR EACH LUMINAIRE TYPE DEFINED IN APPENDIX A

A. General submittal content shall include…

B. LM-79 luminaire photometric report(s) shall be produced by the test laboratory and include…

C. Calculations and supporting test data per Appendix B indicating a lumen maintenance life of not less than 36,000 operating hours

D. Computer-generated point-by-point photometric analysis of maintained photopic light levels as per Appendix A

A. Calculations shall be for maintained values, i.e. Light Loss Factor (LLF) < 1.0, where LLF = LLD x LDD x LATF
For Luminaire Model XX.XXX…

**LED Luminaire Lumen Maintenance Factors Example**

Here is a table showing maintenance factors for different zones and drive currents:

<table>
<thead>
<tr>
<th>Zone°C</th>
<th>Drive Current (mA)</th>
<th>Initial LMF</th>
<th>25K hr LMF (Projected)</th>
<th>50K hr LMF (Projected)</th>
<th>100K hr LMF (Calculated)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-20°C (-4°F)</td>
<td>350mA</td>
<td>1.11</td>
<td>1.07</td>
<td>1.03</td>
<td>0.95</td>
</tr>
<tr>
<td></td>
<td>525mA</td>
<td>1.11</td>
<td>1.07</td>
<td>1.02</td>
<td>0.93</td>
</tr>
<tr>
<td></td>
<td>700mA</td>
<td>1.11</td>
<td>1.06</td>
<td>1.01</td>
<td>0.91</td>
</tr>
<tr>
<td>-10°C (14°F)</td>
<td>350mA</td>
<td>1.09</td>
<td>1.05</td>
<td>1.00</td>
<td>0.92</td>
</tr>
<tr>
<td></td>
<td>525mA</td>
<td>1.09</td>
<td>1.04</td>
<td>0.99</td>
<td>0.89</td>
</tr>
<tr>
<td></td>
<td>700mA</td>
<td>1.09</td>
<td>1.03</td>
<td>0.98</td>
<td>0.87</td>
</tr>
<tr>
<td>0°C (32°F)</td>
<td>350mA</td>
<td>1.05</td>
<td>1.01</td>
<td>0.96</td>
<td>0.87</td>
</tr>
<tr>
<td></td>
<td>525mA</td>
<td>1.05</td>
<td>1.00</td>
<td>0.95</td>
<td>0.84</td>
</tr>
<tr>
<td></td>
<td>700mA</td>
<td>1.05</td>
<td>0.99</td>
<td>0.93</td>
<td>0.81</td>
</tr>
<tr>
<td>10°C (50°F)</td>
<td>350mA</td>
<td>1.04</td>
<td>0.99</td>
<td>0.95</td>
<td>0.86</td>
</tr>
<tr>
<td></td>
<td>525mA</td>
<td>1.04</td>
<td>0.98</td>
<td>0.93</td>
<td>0.83</td>
</tr>
<tr>
<td></td>
<td>700mA</td>
<td>1.04</td>
<td>0.98</td>
<td>0.92</td>
<td>0.80</td>
</tr>
<tr>
<td>15°C (59°F)</td>
<td>350mA</td>
<td>1.03</td>
<td>0.98</td>
<td>0.93</td>
<td>0.84</td>
</tr>
<tr>
<td></td>
<td>525mA</td>
<td>1.03</td>
<td>0.97</td>
<td>0.92</td>
<td>0.81</td>
</tr>
<tr>
<td></td>
<td>700mA</td>
<td>1.03</td>
<td>0.96</td>
<td>0.90</td>
<td>0.78</td>
</tr>
<tr>
<td>20°C (68°F)</td>
<td>350mA</td>
<td>1.01</td>
<td>0.97</td>
<td>0.92</td>
<td>0.82</td>
</tr>
<tr>
<td></td>
<td>525mA</td>
<td>1.01</td>
<td>0.96</td>
<td>0.90</td>
<td>0.79</td>
</tr>
<tr>
<td></td>
<td>700mA</td>
<td>1.01</td>
<td>0.95</td>
<td>0.88</td>
<td>0.76</td>
</tr>
<tr>
<td>25°C (77°F)</td>
<td>350mA</td>
<td>1.00</td>
<td>0.95</td>
<td>0.90</td>
<td>0.81</td>
</tr>
<tr>
<td></td>
<td>525mA</td>
<td>1.00</td>
<td>0.94</td>
<td>0.89</td>
<td>0.77</td>
</tr>
<tr>
<td></td>
<td>700mA</td>
<td>1.00</td>
<td>0.93</td>
<td>0.87</td>
<td>0.77</td>
</tr>
<tr>
<td>30°C (86°F)</td>
<td>350mA</td>
<td>0.96</td>
<td>0.91</td>
<td>0.86</td>
<td>0.76</td>
</tr>
<tr>
<td></td>
<td>525mA</td>
<td>0.96</td>
<td>0.90</td>
<td>0.84</td>
<td>0.72</td>
</tr>
<tr>
<td></td>
<td>700mA</td>
<td>0.96</td>
<td>0.89</td>
<td>0.82</td>
<td>0.67</td>
</tr>
<tr>
<td>40°C (104°F)</td>
<td>350mA</td>
<td>0.96</td>
<td>0.91</td>
<td>0.86</td>
<td>0.76</td>
</tr>
<tr>
<td></td>
<td>525mA</td>
<td>0.96</td>
<td>0.90</td>
<td>0.84</td>
<td>0.72</td>
</tr>
<tr>
<td></td>
<td>700mA</td>
<td>0.96</td>
<td>0.89</td>
<td>0.82</td>
<td>0.67</td>
</tr>
</tbody>
</table>
Estimating LED Lumen Maintenance

…The TM-21 methodology shall be used by the manufacturer to determine lamp lumen depreciation (LLD) at end of lumen maintenance life per section 1.6-C...The applicant may estimate lumen maintenance in one of two ways:

Option 1: Component Performance

…the applicant must submit calculations per TM-21 predicting lumen maintenance at the luminaire level using In Situ Temperature Measurement Testing (ISTMT) and LM-80 data…

**BOTTOM LINE:** Can/Should be provided by the manufacturer…LM-80 is available from most any LED supplier…

Option 2: Luminaire Performance

…the applicant must submit TM-21 calculations based on LM-79 photometric test data for no less than three samples of the entire luminaire…

**BOTTOM LINE:** This compliance path poses a greater testing burden to luminaire manufacturers but incorporates long-term testing of other components in the system, such as drivers.
Essential Data:

IES Photometric File
✅ LM-79 Report
✅ LM-80 Report
✅ (w/ TM-21 Derived Values at the Luminaire Level)
MSSLC’s Model Specification for LED Roadway Luminaires
Model Luminaire Spec – Timeline

- September 2010 – Concept introduced at inaugural meeting
- November 2010 – “Beta release” used by Kansas City, MO
- April 2011 – Public review of first draft
- June 2011 – Manufacturer workshop #1
- August 2011 – Manufacturer workshop #2
- September 2011 – Manufacturer meetings at IES SALC (www.ies.org/salc)
- Released, October 2011 – Version 1.0
Purpose

- Developed in response to demand from Consortium members and others
  - To compile experience gained by members
  - To establish a common language and framework
  - To serve as a living document, undergoing continual revision
  - To allow for customization by each adopting entity
  - To serve as a checklist to minimize errors and omissions

Risk Mitigation!
Scope

Strong Focus on Maintained Illumination Quality and Performance

- Addresses
  - Streets, roadways, and nearby pedestrian ways
  - Pole-mounted luminaires
  - Warranty details
  - Input power, electrical immunity and emission, housing finish, mechanical vibration, etc.
  - Drivers, including lighting controls interface
  - Photocontrol functionality
  - Etc.

- Doesn’t address
  - Lamp/ballast retrofit products
  - Lighting control systems
  - Detailed guidance for proper usage of the model specification
    - Limited guidance is provided in hidden text
Enabling application-specific photometric performance evaluation(s)

Maintained Illumination performance rather than matching lumens

Intended to be used as a template, customized by each adopter to meet unique requirements

Adopter to choose between two means of specification

Application-dependent (greatly preferred!)

Requires application specific details to be developed

Model applications can be developed to cover a range of application variables

Application-independent

Specific application details are not incorporated

Compromise in illumination quality and economic value
Application-dependent – GREATLY PREFERRED!

### APPENDIX A

**APPLICATION-BASED SYSTEM SPECIFICATION**

**LUMINAIRE TYPE “A”**

<table>
<thead>
<tr>
<th>SITE PARAMETERS</th>
<th>ROADWAY DATA:</th>
<th>SIDEWALK DATA:</th>
<th>LIGHT POLE DATA:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lane width</td>
<td>Sidewalk width</td>
<td>Luminaire mounting height</td>
</tr>
<tr>
<td></td>
<td>13.5 ft</td>
<td>5 ft</td>
<td>27 ft</td>
</tr>
<tr>
<td></td>
<td>Number of lanes, total on both sides of median</td>
<td>Edge of sidewalk to edge of roadway pavement</td>
<td>Arm length, horizontal</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>6 ft</td>
<td>6 ft</td>
</tr>
<tr>
<td></td>
<td>Shoulder width, drivelane to edge of pavement</td>
<td></td>
<td>Luminaires per pole</td>
</tr>
<tr>
<td></td>
<td>4 ft</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Median width</td>
<td></td>
<td>Pole set-back from edge of pavement</td>
</tr>
<tr>
<td></td>
<td>0 ft</td>
<td></td>
<td>2 ft</td>
</tr>
<tr>
<td></td>
<td>IES pavement class.</td>
<td></td>
<td>In-line pole spacing (one pole cycle)</td>
</tr>
<tr>
<td></td>
<td>☐ R1 ☐ R2 ☑ R3 ☐ R4</td>
<td></td>
<td>150 ft</td>
</tr>
<tr>
<td></td>
<td>Posted speed limit</td>
<td></td>
<td>Layout</td>
</tr>
<tr>
<td></td>
<td>☐ ≤ 25 mph ☑ &gt; 25 mph</td>
<td></td>
<td>☑ One side ☐ Opposite ☐ Staggered ☐ Median</td>
</tr>
</tbody>
</table>

**PERFORMANCE CRITERIA: APPLICATION ROADWAY**
Application-dependent – GREATLY PREFERRED!

**Photometric Performance Requirements**

<table>
<thead>
<tr>
<th>Layout</th>
<th>One side</th>
<th>Opposite</th>
<th>Staggered</th>
<th>Median</th>
</tr>
</thead>
</table>

**PERFORMANCE CRITERIA: APPLICATION**

<table>
<thead>
<tr>
<th>Roadway</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Photopic</td>
<td>Maintained average horizontal at pavement</td>
</tr>
<tr>
<td>ILLUMINANCE:</td>
<td>Avg:min uniformity ratio</td>
</tr>
<tr>
<td>Photopic</td>
<td>Maintained average luminance</td>
</tr>
<tr>
<td>Luminance:</td>
<td>Avg:min uniformity ratio</td>
</tr>
<tr>
<td>Max:min uniformity ratio</td>
<td></td>
</tr>
<tr>
<td>Veiling Luminance:</td>
<td>Max. veiling luminance ratio</td>
</tr>
<tr>
<td>4.0 lux (0.4 fc)</td>
<td>6.0 : 1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sidewalks</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Photopic</td>
<td>Maintained average horizontal at pavement</td>
</tr>
<tr>
<td>ILLUMINANCE:</td>
<td>Avg:min uniformity ratio (horizontal)</td>
</tr>
<tr>
<td>Maintained min. vertical illum. at 4.9 ft, in directions of travel</td>
<td></td>
</tr>
<tr>
<td>2.0 lux (0.2 fc)</td>
<td>4.0 : 1</td>
</tr>
</tbody>
</table>

**PERFORMANCE CRITERIA: LED LUMINAIRE**

<table>
<thead>
<tr>
<th>Input Power:</th>
<th>Max. nominal luminaire input power</th>
</tr>
</thead>
<tbody>
<tr>
<td>103 W</td>
<td></td>
</tr>
</tbody>
</table>
Application-dependent – GREATLY PREFERED!

### Luminaire Functionality Requirements

<table>
<thead>
<tr>
<th>Metric</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input Power</td>
<td>Max. nominal luminaire input power</td>
</tr>
<tr>
<td>Nominal CCT</td>
<td>Rated correlated color temperature</td>
</tr>
<tr>
<td>Bug¹ Rating</td>
<td>Max. nominal backlight-uplight-glare ratings</td>
</tr>
<tr>
<td>Voltage</td>
<td>Nominal luminaire input voltage</td>
</tr>
<tr>
<td>Finish</td>
<td>Luminaire housing finish color</td>
</tr>
<tr>
<td>Weight</td>
<td>Maximum luminaire weight</td>
</tr>
<tr>
<td>EPA</td>
<td>Maximum effective projected area</td>
</tr>
<tr>
<td>Mounting</td>
<td>Mtg. method</td>
</tr>
<tr>
<td></td>
<td>Tenon nominal pipe size (NPS)</td>
</tr>
<tr>
<td>Vibration</td>
<td>ANSI test level</td>
</tr>
<tr>
<td>Driver</td>
<td>Control signal interface</td>
</tr>
</tbody>
</table>

¹ The deprecated “cutoff” classification system cannot be accurately applied to LED luminaires.
Addressing application variability?

- In practice, pole spacing varies along any given street
- Defining representative “typical” scenario(s) for each type is critical

Create model applications to define and solidify application variables
- Vital for fair evaluation of various solutions being evaluated
- Be aware of the resulting range of application performance variation
If an Exact Application Description Can Not Be Reasonably Established

Then Create a Representative “Model” Application
Examples
Defined Illumination Performance: IESNA RP-8-00
Collector - Medium Pedestrian Conflict Area

<table>
<thead>
<tr>
<th>Application</th>
<th>Pavement Classification</th>
<th>Uniformity Illuminance</th>
<th>Veiling Luminance Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roadway Type</td>
<td>Pedestrian Conflict Area</td>
<td>R1</td>
<td>R2/R3</td>
</tr>
<tr>
<td>Collector</td>
<td>High</td>
<td>8.0 (0.8)</td>
<td>12.0 (1.2)</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>6.0 (0.6)</td>
<td>9.0 (0.9)</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>4.0 (0.4)</td>
<td>6.0 (0.6)</td>
</tr>
</tbody>
</table>

Table per IESNA RP-8-00

Defined Application Geometric Target and Constraints
Luminaire Mounting Height, Spacing and Positioning:
30.5’ AFG, 152.5’ single spacing (non-staggered), 2’ set back, 8’ arm
Roadway: 4 lanes (44’ width)

 Ambient Environment: 10° C (Average Nighttime Temperature)
Required Hours of Operation: 50,000 Hours (approximately 12 years)
Required CCT (Correlated Color Temperature): 4000K

0.9 fc Average
4 to 1 avg./min. (or less…)
**Defined Illumination Performance: IESNA RP-8-00**

**Optimized Luminaire Selection**

<table>
<thead>
<tr>
<th># of LEDs</th>
<th>初始输出流明 - Type II Short @ 6000K</th>
<th>B</th>
<th>U</th>
<th>G</th>
<th>初始输出流明 - Type II Short @ 4300K</th>
<th>B</th>
<th>U</th>
<th>G</th>
<th>系统瓦特 @ 120V</th>
<th>总电流 @ 120V</th>
<th>总电流 @ 240V</th>
<th>总电流 @ 277V</th>
<th>系统瓦特 @ 347-480V</th>
<th>总电流 @ 347V</th>
<th>总电流 @ 480V</th>
<th>L&lt;sub&gt;h&lt;/sub&gt;小时 @ 25°C (77°F)</th>
<th>50K小时 Lumen Maintenance @ 15°C (59°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>7,294 (04)</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>6,722 (04)</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>92</td>
<td>0.78</td>
<td>0.40</td>
<td>0.35</td>
<td>100</td>
<td>0.29</td>
<td>0.23</td>
<td>&gt; 150,000</td>
<td>93%</td>
</tr>
<tr>
<td>50</td>
<td>9,013 (05)</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>8,307 (05)</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>120</td>
<td>1.00</td>
<td>0.52</td>
<td>0.44</td>
<td>128</td>
<td>0.37</td>
<td>0.29</td>
<td>&gt; 150,000</td>
<td>89%</td>
</tr>
<tr>
<td>60</td>
<td>10,752 (06)</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>9,909 (06)</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>139</td>
<td>1.17</td>
<td>0.60</td>
<td>0.51</td>
<td>148</td>
<td>0.43</td>
<td>0.32</td>
<td>149,000</td>
<td>89%</td>
</tr>
</tbody>
</table>
Defined Illumination Performance: IESNA RP-8-00

Results

<table>
<thead>
<tr>
<th>Calculation Summary</th>
<th>CalcType</th>
<th>Units</th>
<th>Avg</th>
<th>Max</th>
<th>Min</th>
<th>Avg/Min</th>
<th>Max/Min</th>
</tr>
</thead>
<tbody>
<tr>
<td>Label</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Road Illum</td>
<td>Illuminance</td>
<td>Fc</td>
<td>0.91</td>
<td>2.07</td>
<td>0.30</td>
<td>3.03</td>
<td>6.90</td>
</tr>
<tr>
<td>Road Luminance</td>
<td>Luminance</td>
<td>Cd/SqM</td>
<td>0.66</td>
<td>1.35</td>
<td>0.23</td>
<td>2.87</td>
<td>5.87</td>
</tr>
</tbody>
</table>

```
1.32 1.27 1.09 0.78 0.52 0.39 0.34 0.30 0.30 0.33 0.38 0.48 0.71 1.02 1.24 1.31
1.71 1.69 1.55 1.10 0.72 0.52 0.44 0.37 0.36 0.42 0.49 0.65 0.98 1.44 1.69 1.70
2.01 1.93 1.54 1.23 0.86 0.63 0.49 0.42 0.41 0.47 0.60 0.78 1.13 1.46 1.86 1.99
1.96 2.00 1.51 1.15 0.91 0.63 0.49 0.45 0.44 0.48 0.58 0.83 1.11 1.36 1.93 1.96
1.78 2.04 1.49 1.07 0.89 0.59 0.47 0.43 0.42 0.46 0.54 0.81 1.06 1.31 2.00 1.81
1.59 2.07 1.45 0.96 0.82 0.56 0.44 0.40 0.39 0.43 0.52 0.76 0.96 1.25 2.04 1.64
1.65 2.04 1.46 0.87 0.73 0.53 0.42 0.38 0.37 0.42 0.49 0.68 0.84 1.26 1.97 1.69
1.51 1.86 1.45 0.84 0.66 0.51 0.41 0.37 0.36 0.40 0.48 0.63 0.77 1.27 1.84 1.57
```

44 Ft

152.5 Ft
Alternate Evaluation

Proposed

IES Type II Short, 4000K
9116 Lumens @ 50,000 Hours and 139 watts

Approx. equivalent

IES Type II Short, 4000K
9053 Lumens @ 50,000 Hours and 119 watts

Additional 20 Watt Energy Savings...

What’s Product Provides the Best Value?
Assuming the More Energy Efficient Product Costs $100.00 More:

- 50,000 Hour (~12 Year) Expected Service Life
  - $60.00 Savings At $0.06/kwh
  - $430.00 Savings At $0.43/kwh
Define the Required Product Functionality and Durability Requirements and/or Limits

- **Electrical**
  - Input Voltage Range…
  - Maximum Power Consumption…?
    - Infrastructure, Rebate Requirements, etc…
  - Power Factor…
  - THD…

- **Mechanical**
  - Vibration Resistance…
  - Corrosion Resistance…

- **Warranty**
- **Etc.**
Examples

*Define the Required Product Functionality and Durability Requirements and/or Limits*
Required Product Characteristics

Possible “Must Haves”

• Designed to mount on 1.25” IP (1.66” O.D.) and/or 2” IP (2.375” O.D.) horizontal tenon
• Adjustable Horizontal tenon mounting capable of (+/- 5 Degrees) in 2.5° vertical increments
• Finish Color shall be silver
• Luminaire EPA shall not exceed 0.90 / maximum weight not to exceed 30 LBS
• UL Listed for Wet Locations
• RoHS Compliant
• ANSI C136.31-2001 Normal Applications Vibration Standards
• ANSI C136.31-2001 Bridge & Overpass Vibration Standards
Required Product Characteristics

Possible “Must Haves”

• Driver: UL Listed, Power Factor > 90% and THD < 20% at full load; Complies with FCC rules and regulations, Title 47 CFR Part 15 Non-Consumer (Class A), 100,000 hours expected life (≤ 0.5% failure at 100,000 hours of operation in 25°C ambient).

• Integral 10kV Surge Protection
  – Tested in Accordance With IEEE/ANSI C62.41
  – Refer to MSSLC Model Specification Appendix D

• Serviceable and upgradable light engine

• Passive thermal management (heat sink)
Required Product Characteristics

Possible “Must Haves”

- International Dark-Sky Association (IDA) approved
- Suitable to operate in -40°C to +40°C ambient environments
- XX year Luminaire Warranty
- Minimum XX year Finish Warranty
- Etc.
**Optional Product Characteristics**

**Possible “Nice Haves”**

- Manufactured in an ISO9001 facility
- Tool-less Entry
- Minimum 70% recyclable content (by weight)
- Adjustable output power
- Leveling Indicator
- Power supply quick disconnect harness(s) suitable for mate-and-break under load on power feed
- Minimum XX years LED luminaire manufacturing experience and XX installed LED projects (XX References Required)
- Etc.
Do **NOT** Specify Product Performance Variables That Directly or Indirectly Affect Illumination Performance

For Example:

- Total Luminaire Efficacy (lumens per watt)
  - Optical Efficiency
  - Thermal Efficiency
  - Electrical Efficiency
- Specific IES Types (Type I, II, III, IV, V)
- Etc.
Type II Medium

1 MOUNTING HEIGHT
1/2 MOUNTING HEIGHT
Other Economic Variables
Outside the Scope of the Spec

- Energy Costs
- Maintenance Costs
- System Operation Options

Financing
Public / Private Partnerships
Etc.
MSSLC’s Retrofit Financial Analysis Tool


- Detailed Analysis Provides Numerous Outputs, Including:
  - Annual Energy and Energy-Cost Savings
  - Annual Maintenance Savings
  - Annual Greenhouse Gas Reductions
  - Simple Payback, IRR
  - Net Present Value
Important Take-Aways for All Applications

• Application based performance evaluations provide the best opportunity for optimizing maintained illumination performance and economic performance

• Requires complete and comprehensive product performance data
  – Disqualify solutions that have incomplete data

• Always use a Lifecycle-Cost-Analysis (LCA) approach when evaluating LED luminaire solutions

• THE GOAL…
  – **Sustainable illumination performance**
    • Establish the appropriate illumination performance requirements
    • Time based
    • Predictable and risk managed (data!)
  – **Sustainable economic performance**
    • Time based
    • Lowest Total-Cost-of-Ownership objective
Brief Review

How to get the right luminaire…
Supplement or Revise Existing Lighting Specs?

1. Determine which of the following approaches will be more efficient
   - Revise existing specifications (usually based on HID and/or induction) to seamlessly incorporate the various elements of the Model Spec
   - Simply customize the Model Spec as needed to serve as a stand-alone specification for LED luminaires (separate from existing specs)
Customize the Body Text for Your Locality

2. Either customize or incorporate the body text of the Model Spec

☐ Some municipalities or utilities may find very little editing is required (default values are generally appropriate for the locality) but ALL users should review the text before adopting

☐ For example, more stringent salt-spray criteria would likely be appropriate (cost-effective) in coastal regions

(insert owner/utility/esco name here)

Specification for LED Roadway Luminaires

PART 1 – GENERAL

1.1. REFERENCES

The publications listed below form a part of this specification to the extent referenced. Publications are referenced within the text by their basic designation only. Versions listed shall be superseded by updated versions as they become available.

A. American National Standards Institute (ANSI)

1. C136.2-2004 (or latest), American National Standard for Roadway and Area Lighting
Specifying Photometric Performance

3. Establish “typical” or representative applications for each luminaire type being installed/replaced

   □ For example, if three different HPS luminaires are being replaced, there should be three different luminaire types

   □ More than one application may be defined for each product type since the same luminaire is often used in different situations

4. For each application, establish site geometries and corresponding photometric criteria based on

5. Customize Appendix A of the Model Specification accordingly
Issuing an RFP for Product Evaluation

6. Use the customized specification to issue an RFP, or distribute among manufacturers and their sales reps

- Manufacturers and/or their sales reps will save you a substantial amount of work by identifying their best product(s) for the job
- Low-quality or ill-suited products are effectively excluded
Submittal Review

7. Review product submittals to ensure conformance with the specification
   - Labor-intensive but worth the effort
   - Some less-reputable manufacturers may be counting on inadequate review of incomplete or non-conforming submittals

<table>
<thead>
<tr>
<th>Luminaire Type</th>
<th>Manufacturer</th>
<th>Model number</th>
<th>Housing finish color</th>
<th>Tenon nominal pipe size (inches)</th>
<th>Nominal luminaire weight (lb)</th>
<th>Nominal luminaire EPA (ft²)</th>
<th>Nominal input voltage (V)</th>
<th>ANSI vibration test level</th>
<th>Nominal BUG Ratings</th>
<th>Make/model of LED light source(s)</th>
<th>Make/model of LED driver(s)</th>
<th>Dimmability</th>
<th>Control signal interface</th>
<th>Upon electrical immunity system failure</th>
<th>Thermal management</th>
<th>Lumen maintenance testing duration (hr)</th>
<th>Reported lumen maintenance life (hr)</th>
<th>Warranty period (yr)</th>
<th>Parameter</th>
<th>Nominal value</th>
<th>Tolerance (%)</th>
</tr>
</thead>
</table>
Small-Scale Mock-ups

8. Acquire at least four product samples of each qualifying luminaire for evaluation of
   - Lead time for production and shipment
   - General quality of construction, fit, and finish
   - Ease of installation and maintenance
   - Quantity and quality of illumination when installed in the field
Larger-Scale Demonstrations

9. Continue evaluation of “finalists” on a larger scale
   □ Survey residents before/after installation
   □ Survey design should avoid biasing of results – sample surveys can be found at www.ssl.energy.gov/gatewaydemos_results.html

2. Compared to the standard street lighting on Gertz Road, how would you characterize the lighting on Lija Loop?
   - Number
   - Percentage
   - Extremely different: 8 (72.7%)
   - Somewhat different: 2 (18.2%)
   - Not different: 0
   - No opinion: 1 (9.1%)

3. The quality of street lighting on Lija Loop ________ my ability to see the street and objects that are on it.
   - Number
   - Percentage
   - Greatly enhances: 7 (63.6%)
   - Enhances: 2 (18.2%)
   - Has no effect on: 1 (9.1%)
Finalizing Specifications

10. Update standard specifications
   - Identify pre-approved luminaires (if appropriate)
   - Revise customized Model Specification (if needed) and merge with standard specifications (if appropriate)
Q&A