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The Sky Glow Comparison Tool

BRUCE KINZEY

Pacific Northwest National Laboratory

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Introduction

- ▶ Much concern raised in recent years regarding LED street lighting conversions and perceived increases in sky glow and associated effects.
- ▶ Most projections not based on realistic assumptions for U.S. conversion projects, vis-à-vis field experience to date.
- ▶ The commonly proposed remedy of limiting CCT involves a potentially significant energy penalty among other possible tradeoffs, while being of limited or no effectiveness.
- ▶ The DOE SSL Program therefore conducted its own investigation of street lighting and sky glow in 2016-2017.
- ▶ The investigation created a limited “universe” of results from 215,000+ runs of a well-known sky glow model.
- ▶ Those results in turn led to the development of this simple tool.




Purpose of the Sky Glow Comparison Tool

- ▶ Up to now the outdoor lighting community has had:
 - No simple means of evaluating their impact on sky glow, positive or negative.
 - No way to test the validity of assertions by others.
 - No real means of working with SPD.
- ▶ The sky glow tool is a first-order approach to addressing these gaps, using standard inputs and outputs familiar to a lighting audience.
- ▶ The tool enables relative comparisons between impacts of different lighting system characteristics, specifically: upright, lumen output, and spectral content (SPD), under a limited set of input conditions.
- ▶ Intended to help identify the most effective means for addressing sky glow associated with an individual system or design.
- ▶ The outputs are provided in terms relative to the selected baseline, and are *not absolute*.



Derived from 215,000+ runs of *Skyglow Simulator*

- ▶ Variable parameters investigated include:
 - 3 cities of varying population (3,500 to 500,000)
 - 2 lumen output levels
 - 2 emission functions (Garstang or cosine)
 - 5 atmospheric conditions (4 clear with increased loading, 1 cloudy)
 - 11 SPDs
 - 4 uplight percentages (0%, 2%, 5%, 10%)
 - 2 observer locations
 - 2 output types (non-weighted irradiance or scotopic illuminance)
 - full visible spectrum in 80 increments (5 nm each) 
 - => **~215,000 runs**



Scattering functions drive the spreadsheet

- ▶ 48 separate scattering functions were derived from the results, one for each of the different possible combinations of input conditions
- ▶ Any SPD can now be input and results are calculated by interpolating among the 5 nm results for the given scattering function (i.e., the selected set of input conditions)

INPUT CONDITIONS	
1. Scenario Parameters	
Observer location	near
Atmospheric condition	clear low particulate
Weighting function	scotopic
2. Baseline Light Source Characteristics	
Percent uplight	0%
Baseline source	1. HPS Example
3. Comparison Light Source(s) Characteristics	
Percent uplight	0%
Lumen output (% of baseline)	100%
Clear	Calculate



The Sky Glow Comparison Tool

- ▶ Simple inputs/outputs familiar to the lighting community.

Different tabs
for different
steps



The screenshot displays the 'Sky Glow Comparison Tool' interface. It is divided into several sections:

- INPUT CONDITIONS:**
 - 1. Scenario Parameters: Observer location (near), Atmospheric condition (clear low particulate), Weighting function (unweighted).
 - 2. Baseline Light Source Characteristics: Percent uplight (0%), Baseline source (1. HPS Example).
 - 3. Comparison Light Source(s) Characteristics: Percent uplight (0%), Lumen output (% of baseline) (100%).
- RESULTS:** A table showing the relative sky glow for various sources compared to a baseline HPS Example.
- Light Source SPD:** A line graph showing the spectral power distribution (SPD) for various light sources, normalized to equal lumen output. The x-axis is Wavelength (nm) from 380 to 740, and the y-axis is W/nm per 1,000 lumens from 0 to 0.09.
- Relative Sky Glow with Specified Conditions:** A bar chart showing the relative sky glow as a percentage of the baseline for each source.
- Sky Glow SPD:** A line graph showing the sky glow SPD for the same sources, normalized to equal lumen output. The x-axis is Wavelength (nm) from 380 to 740, and the y-axis is W/nm per 1,000 source lumens from 0 to 1.2E-08.

Source Label	Relative Sky Glow
BASELINE: HPS Example	1.00
1. HPS Example	1.00
2. MH 2 4041K	1.79
3. MV H38JA-100/DX	1.74
4. LED 2719 K	1.30
5. LED V Pump 2724 K	1.58
6. LED 285 4075K	1.41
7. LED 231 4224K	1.47
8. LED Example 5	1.50



Procedure

1. Select or input Spectral Power Distributions (SPDs) of products to be compared

“SPD Input” Tab

Add a New SPD
Paste values in shaded cells and click "Add Pasted SPD", or use the dropdown to add a saved SPD

Add Pasted SPD (You will be prompted for a label)

Add to Calculation from Saved: LED Example 5

Paste Values Paste Values

SPDs for Calculation
SPDs require normalization to equal lumen output. Do not paste SPDs directly. All SPDs loaded here will be included in the calculation (see "Calculate" sheet) Clearing SPDs cannot be undone. If needed for future calculations, click the Save button to copy an SPD to the Saved SPDs sheet.

Clear All SPDs

SPD No.	1	2	3	4	5	6
Calculated CCT	CCT = 2661 K	CCT = 2719 K	CCT = 3008 K	CCT = 3070 K	CCT = 3005 K	CCT = 3941 K
Wavelength (nm)	LED 2661 K	LED 2719 K	LED 3008 K	LED 3070 K	LED V Pump 3005 K	LED 3941 K
380	0.0000	0.0003	0.0002	0.0003	0.0002	0.0000
385	0.0000	0.0003	0.0004	0.0003	0.0003	0.0000
390	0.0000	0.0003	0.0002	0.0003	0.0003	0.0001
395	0.0000	0.0003	0.0002	0.0003	0.0005	0.0001
400	0.0000	0.0003	0.0002	0.0003	0.0010	0.0002
405	0.0000	0.0003	0.0002	0.0003	0.0024	0.0004
410	0.0000	0.0003	0.0002	0.0004	0.0051	0.0009
415	0.0001	0.0005	0.0004	0.0008	0.0078	0.0019
420	0.0002	0.0007	0.0009	0.0013	0.0085	0.0038
425	0.0005	0.0013	0.0017	0.0026	0.0078	0.0066
430	0.0011	0.0019	0.0028	0.0039	0.0070	0.0096
435	0.0021	0.0029	0.0041	0.0061	0.0063	0.0123
440	0.0037	0.0039	0.0059	0.0083	0.0059	0.0141
445	0.0060	0.0053	0.0079	0.0098	0.0056	0.0128
450	0.0085	0.0068	0.0101	0.0113	0.0052	0.0080
455	0.0083	0.0065	0.0103	0.0088	0.0048	0.0042

← CCT Calculator

Input Wavelength & Value in any increments

The tool interpolates/averages to 5 nm increments and then normalizes to 1000 lumens

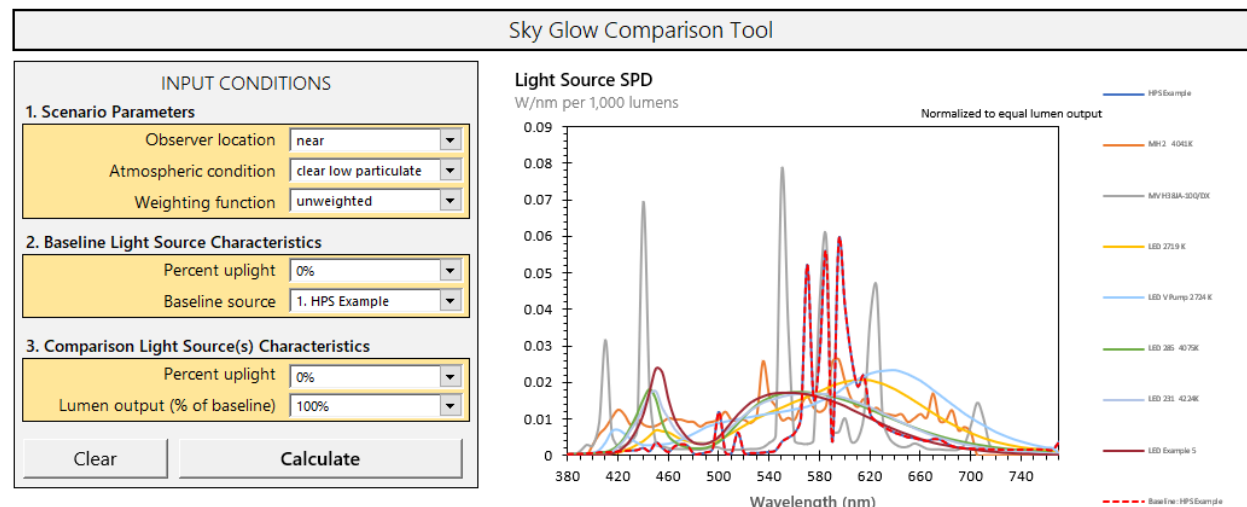
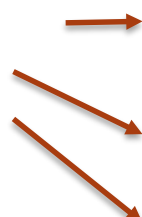


Procedure

2. Choose parameters / characteristics and click “Calculate”

“Calculate” Tab

Drop-down menus

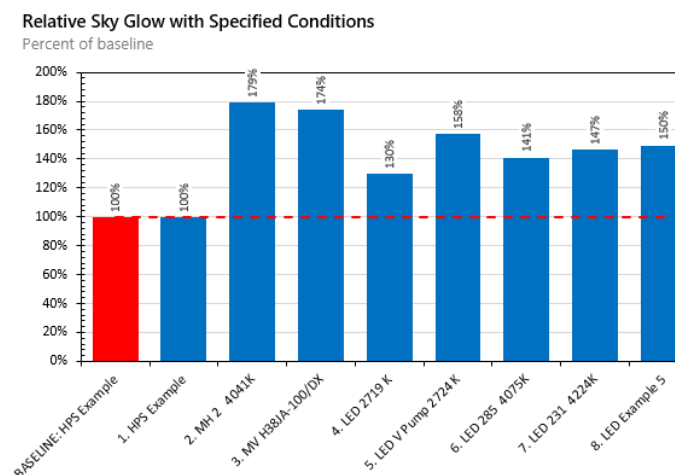


Graphs of Source SPDs

The SPDs being compared show a relative sky glow “score,” compared to the baseline

RESULTS
[Add new SPDs using the “SPD Input” sheet]

Source Label	Relative Sky Glow
BASELINE: HPS Example	1.00
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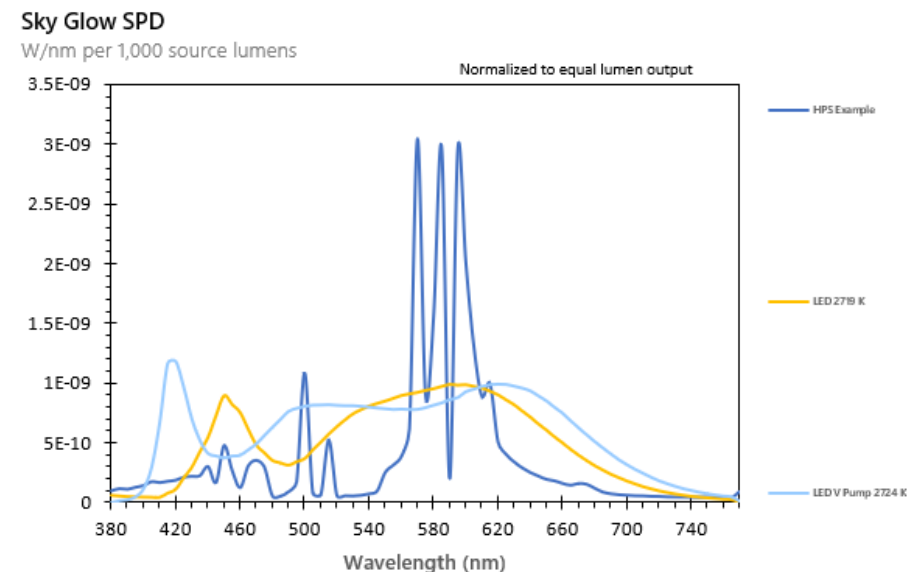
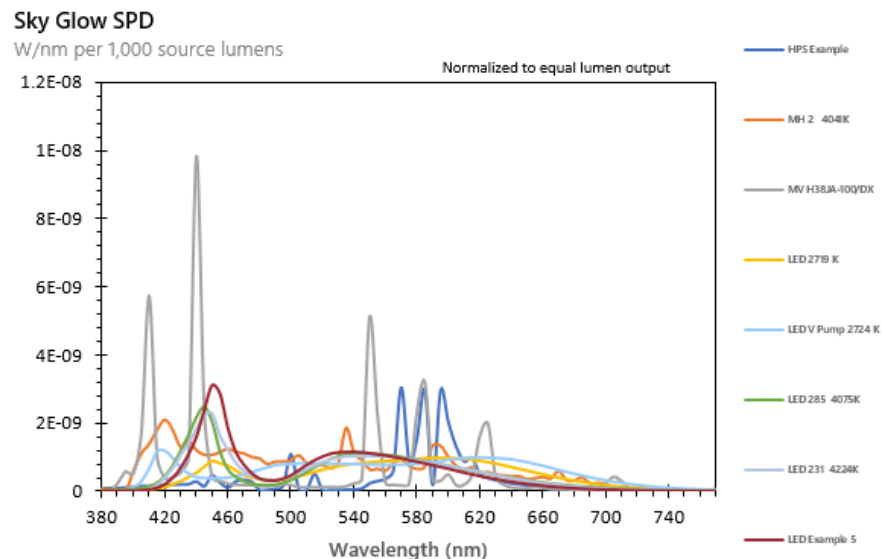
Relative sky glow score displayed graphically



Procedure

- ▶ Graphics of both Source SPDs and Sky Glow SPDs are displayed

Calculate Tab



All SPDs that were evaluated
in this run



Can be filtered to only display
selected sources of interest (click
on chart, then press “Filter” button,
make selections and press “Apply”)

Live Demo



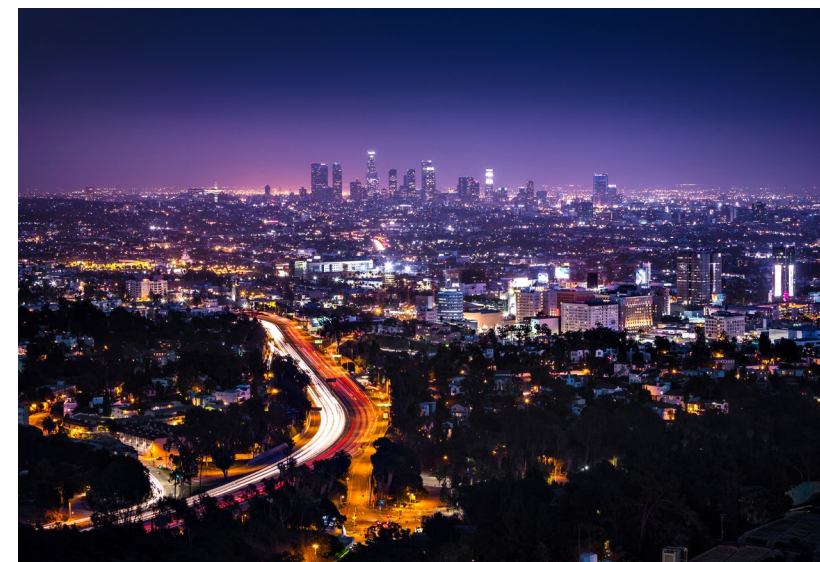
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Inherent Limitations of the Comparison Tool

- ▶ The universe of results is “fixed,” e.g.,
 - 3 sets of atmospheric conditions are substituting for virtually infinite variability in reality
 - Results only modeled at two observer locations, at edge of city and 40 km distant from city center
 - Light output characteristics of luminaires are only approximate, e.g., 0%, 2%, 5%, 10% uplight
 - *It's not a model!* Best used for comparison between scenarios to investigate relative effects rather than absolute
- ▶ Original investigation focused on street and area lighting; other significant contributors to sky glow (e.g., buildings, signage) are probably not represented
- ▶ The results reflect the state of the model in early 2017; ongoing updates are continuous





Thank you

- ▶ The Sky Glow Comparison Tool can be requested from the DOE Solid-State Lighting Website (<https://www.energy.gov/eere/ssl/potential-impacts-led-street-lighting-sky-glow>)
- ▶ Questions, bug reports, etc. can be sent to skyglowtool@pnnl.gov

