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Addressing the Concerns Over Blue Light

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Pacific Northwest National Laboratory

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U.S. DEPARTMENT OF ENERGY

Why does the SSL Program continue to respond to claims about blue light?

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1. Public concerns about LED lighting typically focus on the color appearance of the light, with corresponding pressure to employ lower CCT sources.
2. Due to inherent losses in the phosphor optical conversion process, warmer CCT LED sources carry an energy penalty compared to their cooler CCT siblings, all else equal. Energy penalties can easily exceed 20% depending on circumstances.
3. Current evidence suggests that the issues related to “blue light” exposure are more greatly influenced by intensity, duration and timing than by variations in spectral content; any of these other properties can be effectively used to mitigate the expected causes for concern, while incurring lower (or no) energy penalty.
4. An exclusive focus on spectral content (or even more so, CCT) may lead to higher energy use while diverting attention from more ultimately effective measures.

Where does Blue Light Risk fall in the big picture?

We don't know yet for certain.

Outdoor Light at Night and Breast Cancer Incidence in the Nurses' Health Study II

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RESULTS: Over 2,187,425 person-years, we identified 3,549 incident breast cancer cases. Based on a fully adjusted model, the estimated HR for incident breast cancer with an interquartile range (IQR) (31:6 nW=cm2=sr) increase in cumulative average outdoor LAN was 1.05 (95% CI: 1.00, 1.11). An association between LAN and breast cancer appeared to be limited to women who were premenopausal at the time of a case [HR = 1:07 (95% CI: 1.01, 1.14) based on 1,973 cases vs. HR = 1:00 (95% CI: 0.91, 1.09) based on 1,172 cases in postmenopausal women; p-interaction = 0:08]. The LAN–breast cancer association was observed only in past and current smokers at the end of follow-up [HR = 1:00 (95% CI: 0.94, 1.07) based on 2,215 cases in never smokers; HR = 1:10 (95% CI: 1.01, 1.19) based on 1,034 cases in past smokers vs. HR = 1:21 (95% CI: 1.07, 1.37) for 300 cases in current smokers; p-interaction = 0:08].
CONCLUSIONS: Although further work is required to confirm our results and to clarify potential mechanisms, our findings suggest that exposure to residential outdoor light at night may contribute to invasive breast cancer risk.

Assuming the risk is real, how do the various sources of exposure compare?

Every time we flip the switch we expose ourselves to broad spectrum sources containing blue wavelengths.

Blue light is common to all broad spectrum sources

LED ranges shown are based on a total of more than 450 real product SPDs

Row	Light source	Luminous Flux (lm)	CCT (K)	% Blue*	Relative Scotopic Potential	Relative Melanopic Potential**
A	PC White LED	1000	2700	15% - 21%	1.74 - 2.33	1.90 - 2.82
B	PC White LED	1000	3000	18% - 25%	1.88 - 2.46	2.09 - 3.06
C	PC White LED	1000	3500	22% - 28%	2.04 - 2.54	2.34 - 3.25
D	PC White LED	1000	4000	26% - 33%	2.11 - 2.77	2.36 - 3.64
E	PC White LED	1000	4500	32% - 35%	2.39 - 2.94	2.83 - 3.95
F	PC White LED	1000	5000	35% - 40%	2.61 - 3.43	3.22 - 4.69
G	PC White LED	1000	5700	39% - 45%	2.75 - 3.39	3.42 - 4.62
H	PC White LED	1000	6500	43% - 48%	3.12 - 3.97	4.10 - 5.87
I	Narrowband Amber LED	1000	1606	0%	0.36	0.12
J	Low Pressure Sodium	1000	1718	0%	0.34	0.10
K	PC Amber LED	1000	1872	1%	0.70	0.42
L	High Pressure Sodium	1000	1959	9%	0.89	0.86
M	**High Pressure Sodium**	**1000**	**2041**	**10%**	**1.00**	**1.00**
N	Mercury Vapor	1000	6924	36%	2.33	2.47
O	Mercury Vapor	1000	4037	35%	2.13	2.51
P	Metal Halide	1000	3145	24%	2.16	2.56
Q	Metal Halide	1000	4002	33%	2.53	3.16
R	Metal Halide	1000	4041	35%	2.84	3.75
S	Moonlight †	1000	4681	29%	3.33	4.56
T	Incandescent	1000	2812	11%	2.21	2.72
U	Halogen	1000	2934	13%	2.28	2.81
V	F32T8/830 Fluorescent	1000	2940	20%	2.02	2.29
W	F32T8/835 Fluorescent	1000	3480	26%	2.37	2.87
X	F32T8/841 Fluorescent	1000	3969	30%	2.58	3.18

1.90 – 2.82

2.36 – 3.64

3.16

2.72

3.18

*Percent blue calculated according to LSPDD: Light Spectral Power Distribution Database, http://galileo.graphycs.cegepsherbrooke.qc.CA/app/en/home

**Melanopic content calculated according to CIE Irradiance Toolbox, http://files.cie.co.at/784_TN003_Toolbox.xls, 2015

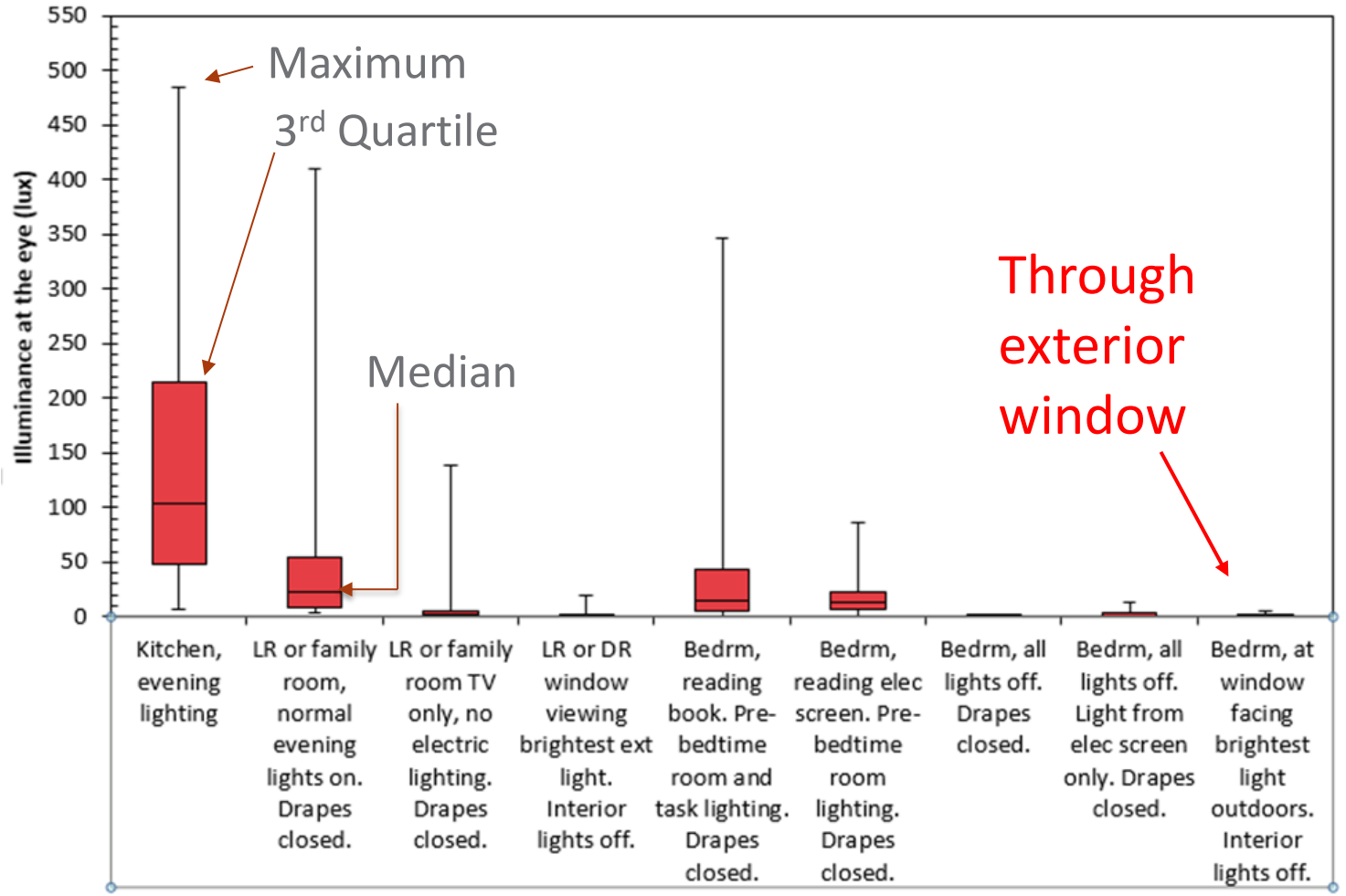
† Moonlight CCT provided by Telelumen, LLC.

Sources: IES and CIE Product Databases (Table updated June 2017)

How much exposure are we getting?

Our informal investigation of interior exposures showed much higher levels presented by interior than exterior sources.

Light Meter readings taken by 30 IALD and IES members



How we typically manage risk

- Reduce or avoid the activity as much as possible
- Minimize exposure to risk during the activity
- Engage in other separate activities to offset the risk
- What are the specific measures we have available in lighting?
  - Eliminating exposure to light or to certain wavelengths at the critical times
  - Reducing the intensity of that exposure
  - Reducing the duration of that exposure
  - Other means to help reduce the impact, such as getting sufficient exposure to natural light during the day, or other habits of maintaining a healthy lifestyle

Light trespass is not caused by spectral content

LED Streetlights Are Giving Neighborhoods the Blues

Early adopters of LED street lighting are struggling with glare and light pollution

Photo: Bob O'Connor

Blue content may increase the perception of brightness, but a warmer CCT source will not address the issue being emphasized here

Uplight / stray light is not caused by spectral content

Nor here

Photo: Chris Kyba

Glare can be an issue with any spectral content

Glary installations have been around since lighting was invented

Over-lighting is not caused by spectral content

As has over-lighting

Image: Portland Archives and Records Center

New lighting capabilities are key to addressing concerns

- Modern LED lighting products offer more control over distribution and output than anything that has come before.

Photo: Chris Kyba

Photo: LABSL

Modeling suggests distribution and output have greater influence than spectral content

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- Based on the DOE Sky Glow Investigation published April 2017, the most effective measures we have (if we are to benefit from supplemental, broad spectrum light) are, in order:
  - Eliminating uplight
  - Reducing light output (either during initial selection or via dimming later)
  - Altering the spectral content (while still retaining a broad spectrum source)
- All of which are easier to do with LEDs than any other mainstream light source technology yet invented.

Modeled Sky Glow Impact Comparisons

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The "Sky Glow Comparison Tool"

In this example, four samples each of 2700, 3000 and 4000 K products with HPS baseline

Displayed with scotopic weighting and equal lumen output, all 0% uplight

Sky Glow Comparison Tool

INPUT CONDITIONS

1. Scenario Parameters

Observer location	distant
Atmospheric Condition	clear high particulate
Weighting function	scotopic

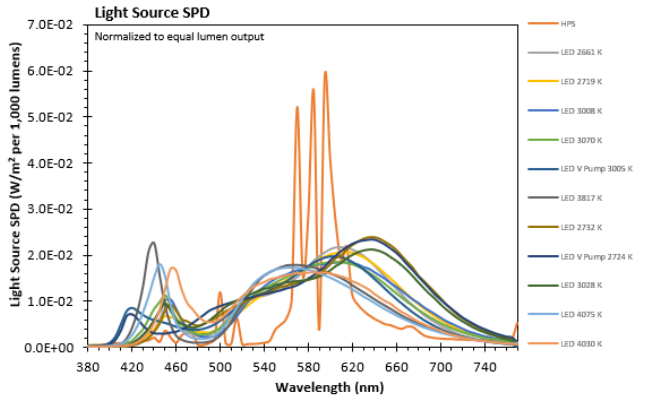
2. Baseline Light Source Characteristics

Percent uplight	0%
Baseline source	1. HPS

3. Comparison Light Source(s) Characteristics

Percent uplight	0%
Lumen output (% of baseline)	100%

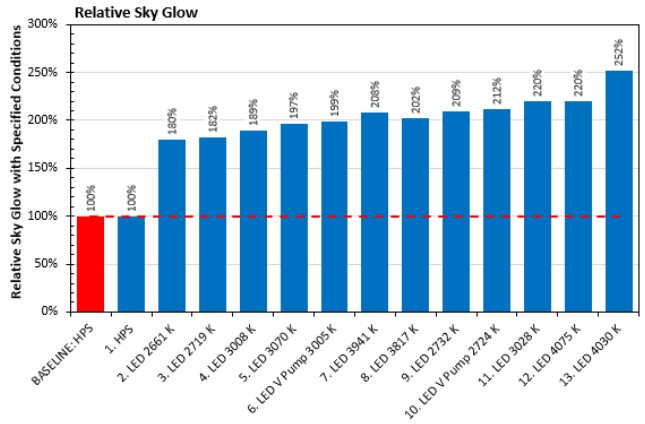
Clear | Calculate



RESULTS

[Add new SPDs using the "SPD Input" sheet]

Source Label	Relative Sky Glow
BASELINE: HPS	1.00
1. HPS	1.00
2. LED 2661 K	1.80
3. LED 2719 K	1.82
4. LED 3008 K	1.89
5. LED 3070 K	1.97
6. LED V Pump 3005 K	1.99
7. LED 3941 K	2.08
8. LED 3817 K	2.02
9. LED 2732 K	2.09
10. LED V Pump 2724 K	2.12
11. LED 3028 K	2.20
12. LED 4075 K	2.20
13. LED 4030 K	2.52



LEDs show 1.8 to 2.5x the relative sky glow impact

Modeled Sky Glow Impact Comparisons

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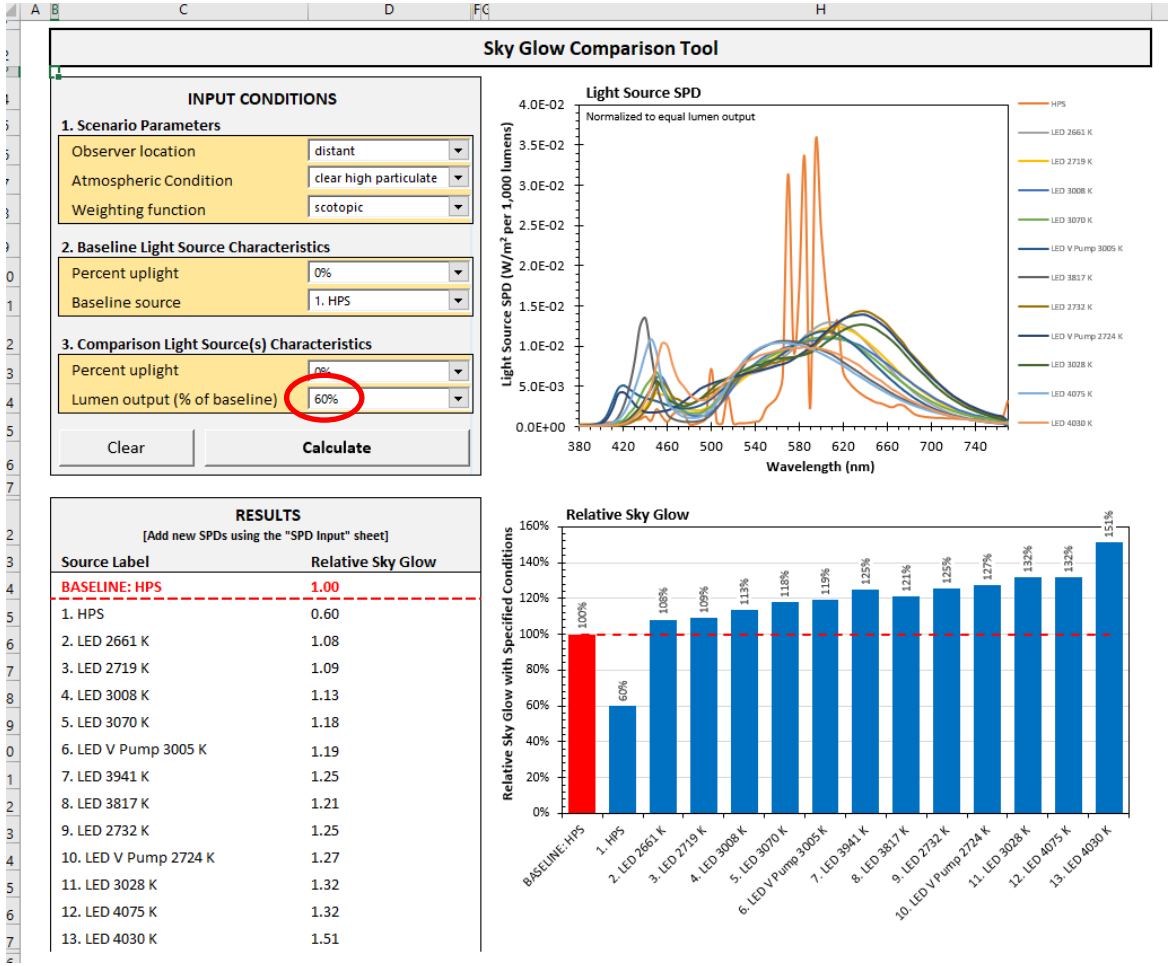
But total lumen output of LED replacement products is almost never 100% of the incumbent!



Now LED relative impact is reduced to 1.1 to 1.5x that of the HPS baseline

Modeled Sky Glow Impact Comparisons

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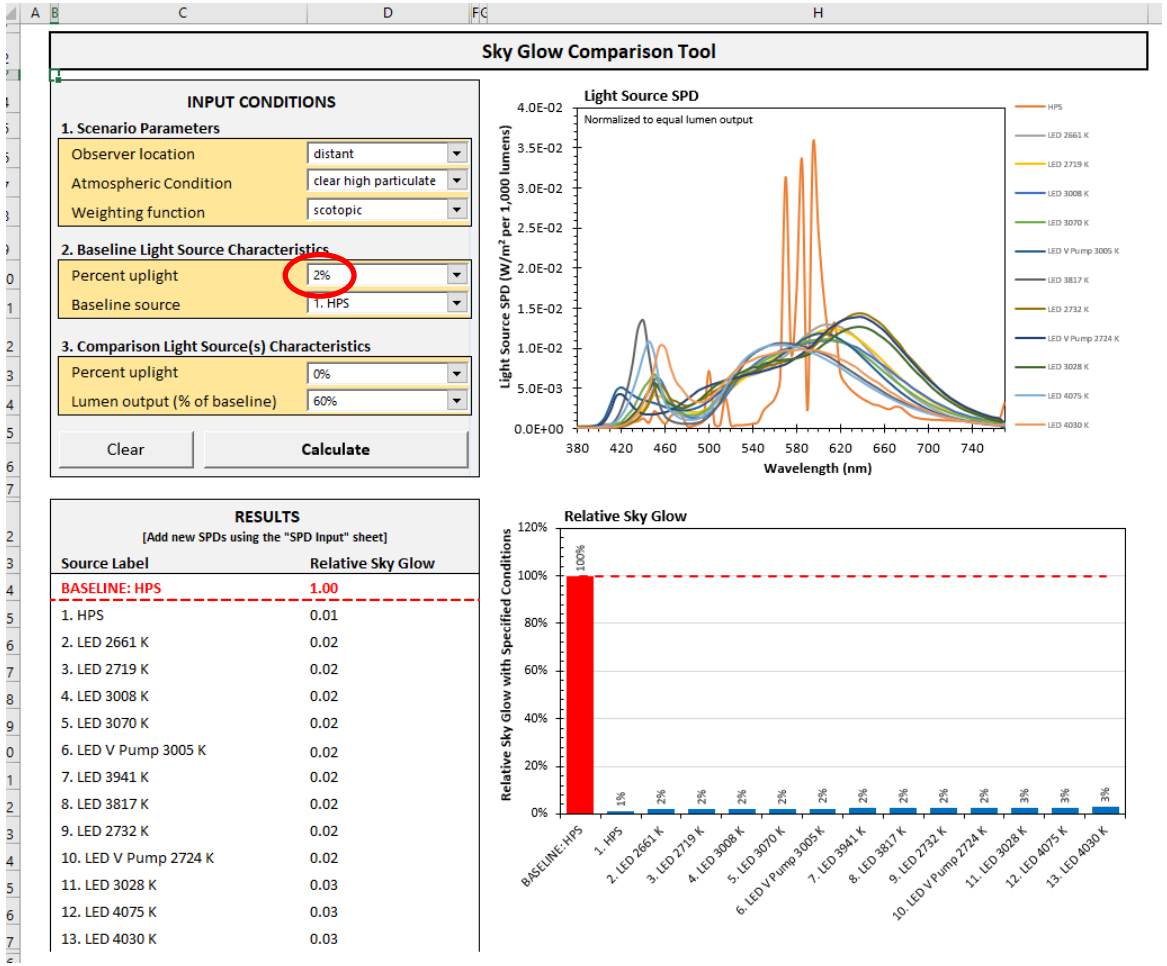
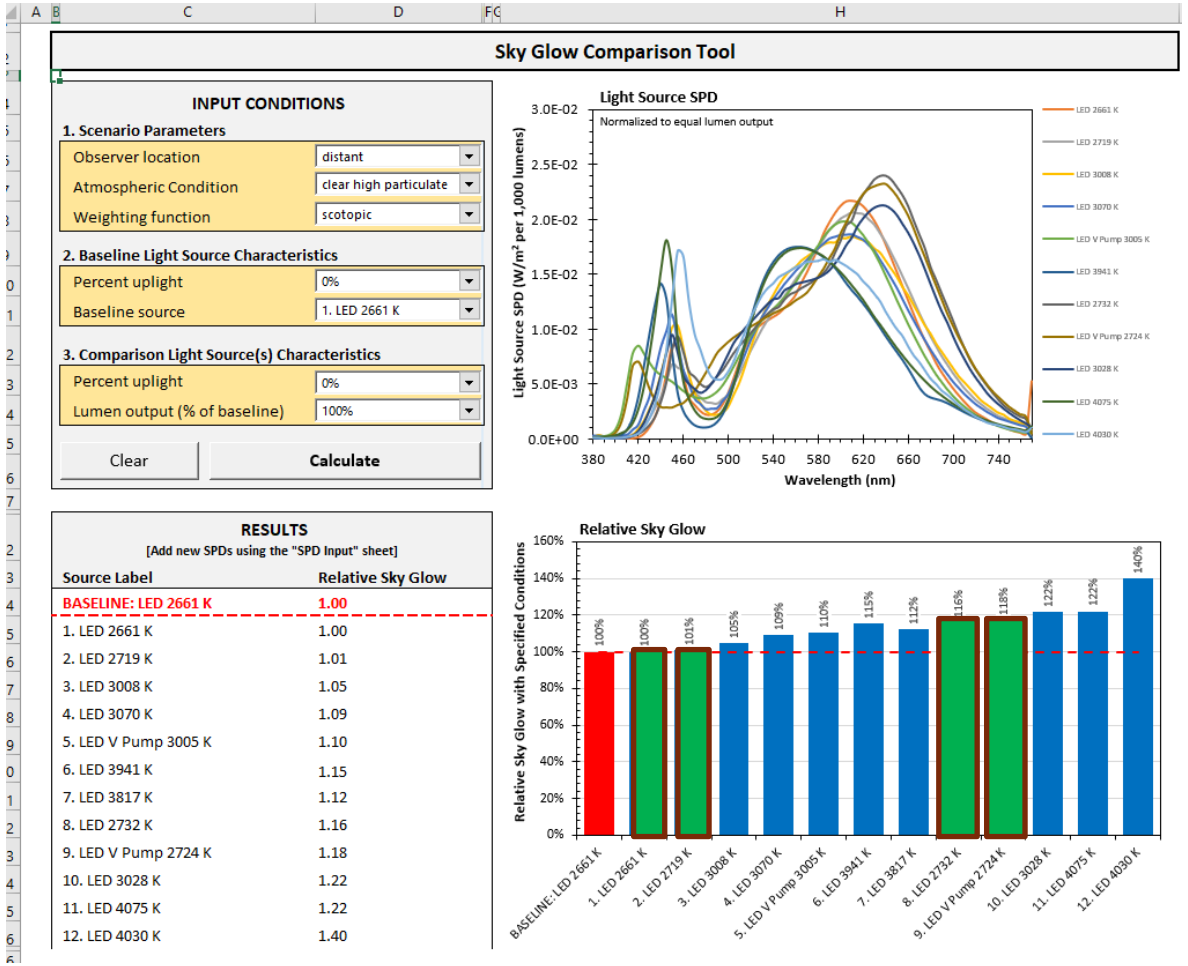
Very often the incumbent HPS is a dropped-lens cobra head, with uplight



These results illustrate the dominating effect of getting rid of uplight to a distant location

Modeled Sky Glow Impact Comparisons

To view the effects of spectral content in isolation, eliminate HPS and put all on equal footing



2700 K SPDs

The range of impact in this sample ranges from 1.0 to 1.4, with a mean of 1.14.

Note these are not in direct order of CCT and illustrate its weakness as a control mechanism

Summing Up

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- The present emphasis on CCT to control “blue light” is misguided and a weak approach to achieving the intended result
- Control over light distribution and intensity appear to have much greater ability to impact the issues of concern than minor variations in spectral content
- Interior sources on average appear to be much more significant in terms of likely human exposure than exterior sources
- Much uninformed perspective is currently confusing lighting effects due to spectrum with others that are not, but don’t you fall for it!
- Based on our research, efforts promoting the use of controls and dimming will be much more effective than limiting CCT in terms of both addressing the concerns being raised and reducing energy use

Questions?

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Street light pole in St. Croix, USVI after hurricane Maria

Course L18SM18
The Sky Glow Comparison Tool
Thursday, May 10 11:30-12:30
Room S501BCD