U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

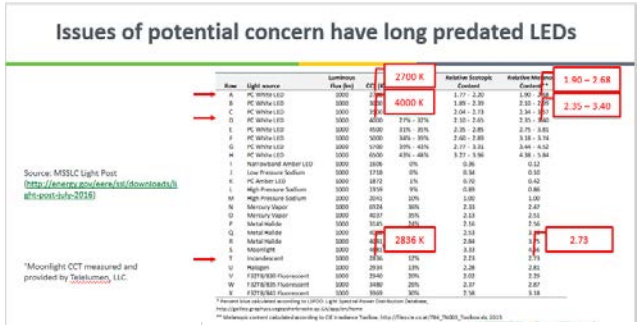
Blue Light & Sky Glow Activity Update

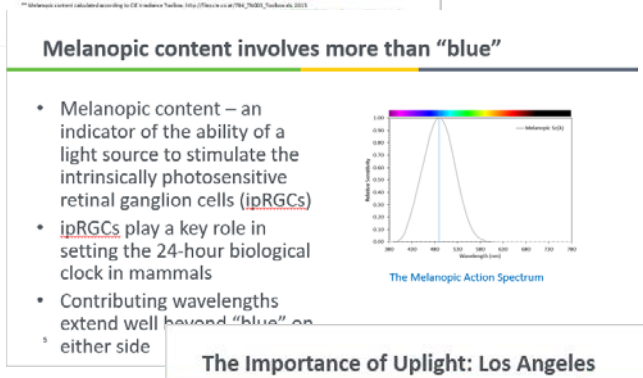
Bruce Kinzey – Pacific Northwest National Laboratory

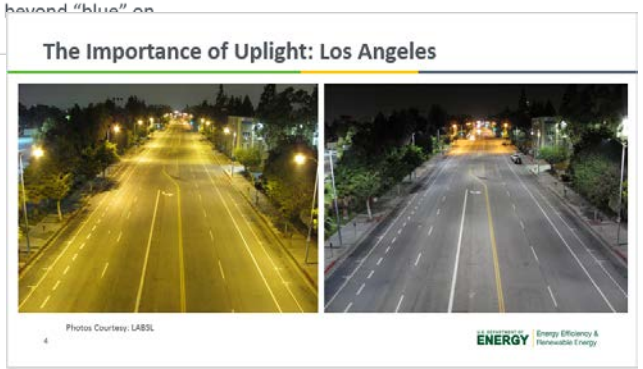
2017 DOE SSL Technology R&D Workshop

Street lighting and blue light

- American Medical Association public release of June 2016 kicked off a host of issues pertaining to LEDs
- Selective assumptions, frequent mischaracterizations motivated significant response from the lighting community, including DOE
- Lots of webinars, reports and other information on the SSL website: https://energy.gov/eere/ssl/street-lighting-and-blue-light

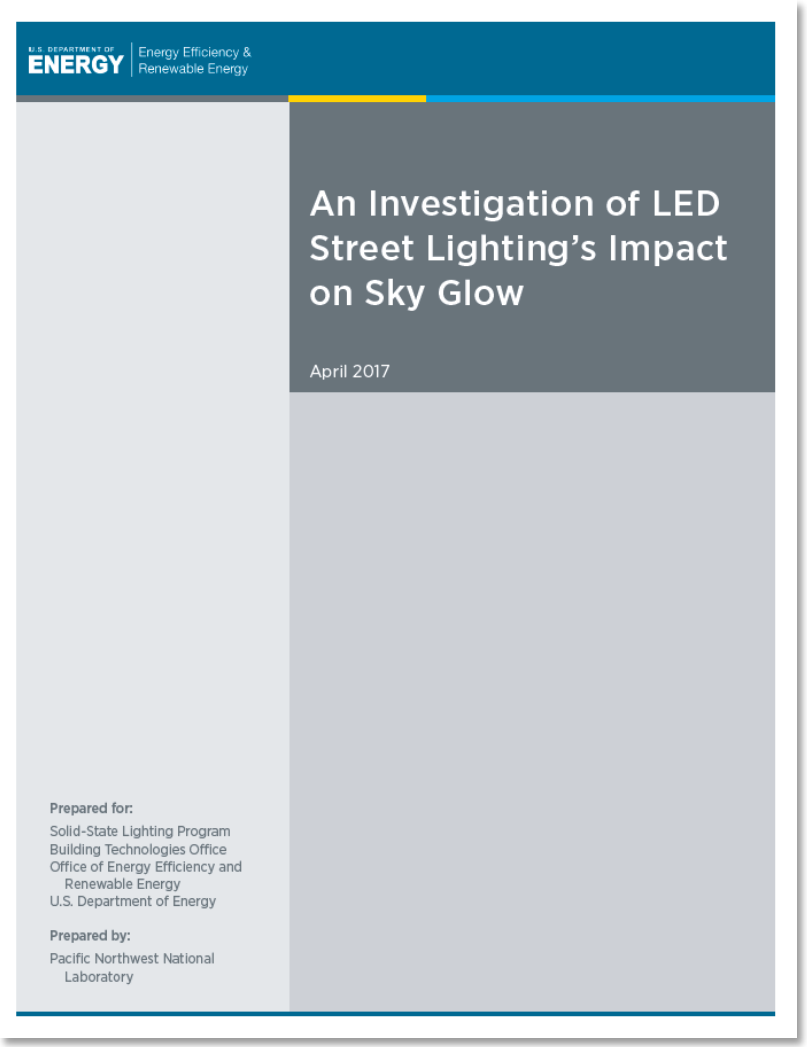






DOE sky glow investigation

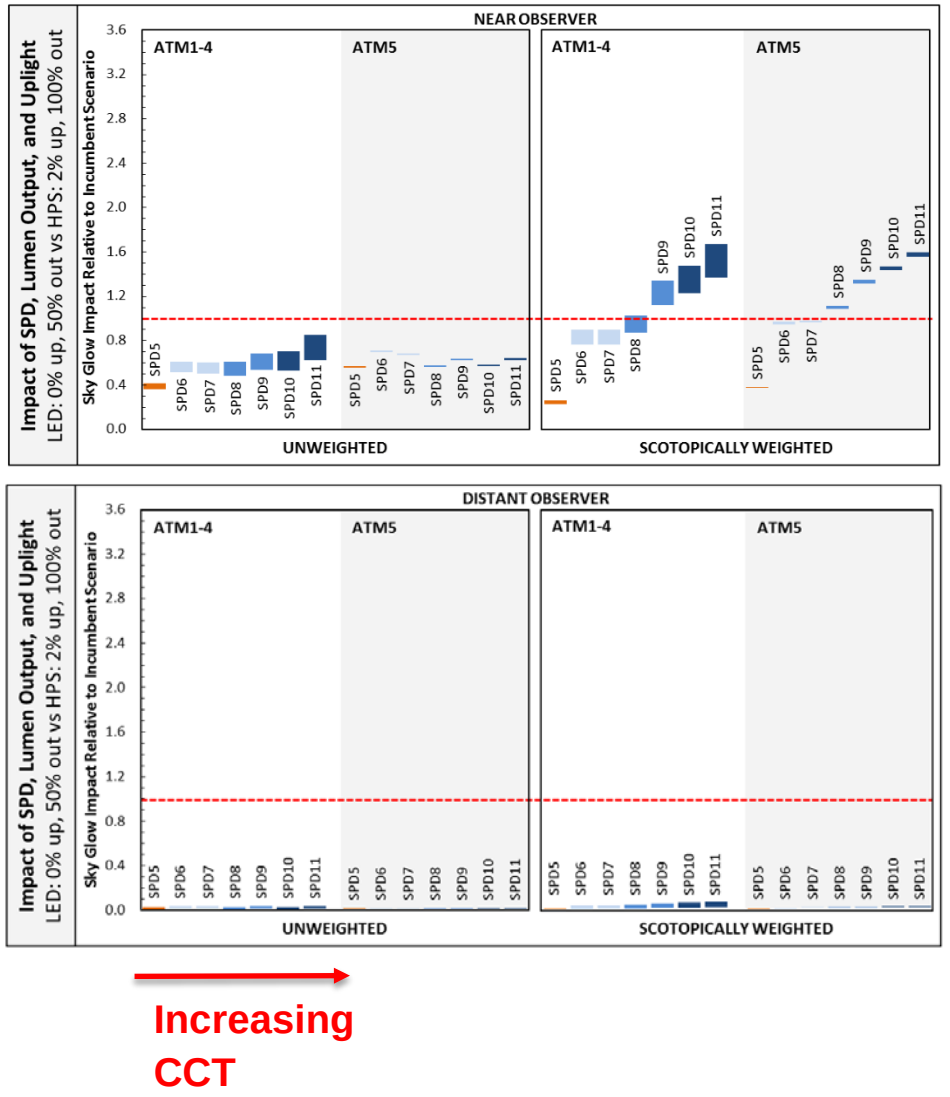
- Report authors:
  - Bruce Kinzey
  - Tess E. Perrin
  - Naomi J. Miller
  - Miroslav Kocifaj
  - Martin Aubé
  - Héctor S. Lamphar
- Sky Glow Report: https://energy.gov/eere/ssl/downloads/investigation-led-street-lighting-s-impact-sky-glow



Sky glow investigation results

- Broader spectral content does augment impact to sky glow compared to incumbent HPS refractor cobra heads, but is attenuated by reduced output (esp. for near locations) and by eliminating uplight (for distant locations)

Impact of SPD, 50% reduction in output, and 0% uplight



Near Observer Location

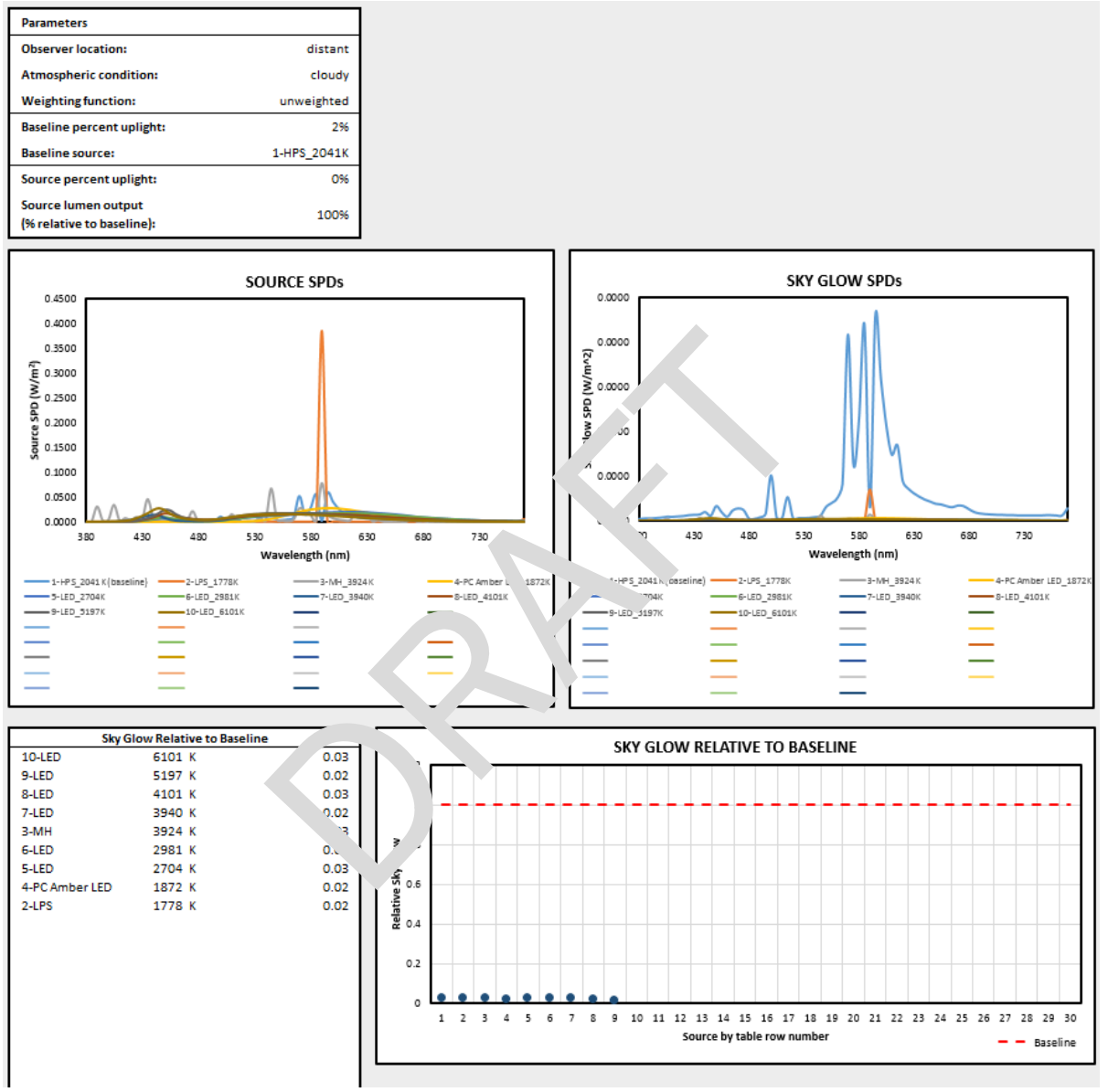
Distant Observer Location

The deadly details

Photo Credit: Acuity Brands

Sky glow calculation tool (under development)

- A straight spreadsheet calculation, not a model
- Created from the “universe” of results provided by the 200,000+ runs of the sky glow model
- Intended to enable first-order analysis by the lighting community, such as basic A-B comparison of sky glow impacts among products being considered



Parameters	
Observer location:	distant
Atmospheric condition:	cloudy
Weighting function:	unweighted
Baseline percent uplight:	2%
Baseline source:	1-HPS_2041K
Source percent uplight:	0%
Source lumen output (% relative to baseline):	100%

Sky Glow Relative to Baseline		
10-LED	6101 K	0.03
9-LED	5197 K	0.02
8-LED	4101 K	0.03
7-LED	3940 K	0.02
3-MH	3924 K	[illegible]
6-LED	2981 K	[illegible]
5-LED	2704 K	0.03
4-PC Amber LED	1872 K	0.02
2-LPS	1778 K	0.02

The IES Sky Glow Calculations Committee

- **Newly formed activity; no existing document.**
- **Recruited a "Who's Who" in this arena:**
  - Ian Ashdown, byHeart Consultants
  - Chris Bailey, Hubbell Lighting
  - Robert Clear, Retired Lawrence Berkeley National Laboratory
  - Dan Duriscoe, Retired U.S. National Park Service
  - Fabio Falchi, Istituto di Scienza e Tecnologia dell'Inquinamento Luminoso
  - Mike Grather, LightLab Allentown
  - Miroslav Kocifaj, University of Slovakia
  - Chris Luginbuhl, Retired U.S. Naval Observatory
  - Brad Schlesselman, Musco Lighting
  - Richard Wainscoat, University of Hawaii, Institute for Astronomy
  - Connie Walker, National Optical Astronomy Observatory

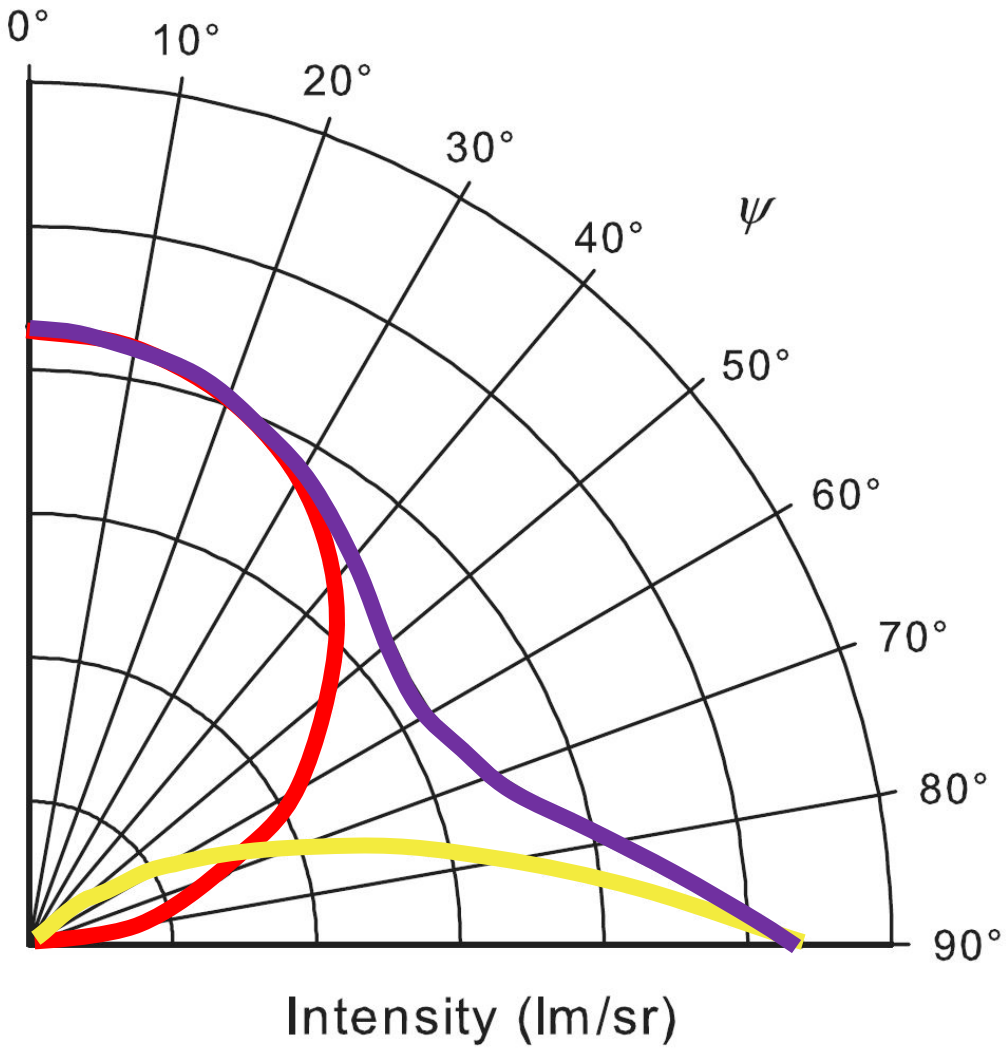
SGCC topics of discussion

- Purpose – to provide impartial recommendations/guidance for estimating quantifiable contributions of light at night to sky glow
- Scope – expanding the usual focus on street lighting to include other important end uses that fall under IES purview
- Audience – city planners, lighting designers, and virtually all other interested parties
- Anticipated outputs – Recommended best practices for minimizing contributions to sky glow; equations/methodologies for estimating contributions to sky glow; tools for conducting assessments of sky glow

Lighting end-use “modules”

- **Committee presently considering three end-uses:**
  - Street and area lighting
  - Building internal lighting spilling from windows
  - Sports lighting
- **Three basic properties characterize a light source’s contribution to sky glow: its emission function, spectral properties, and output/geographic density.**
- **Emission function for e.g., street lighting is a combination of reflected light (cosine distribution) and low-angle uplight.**

Emission function – street lighting



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- Fraction of light emitted downward and isotropically reflected (assuming a 15% ground reflectance)
- Fraction of light radiated directly upward, proportional to ψ^4 (above 90°)
  - 0%: "full cut-off" fixtures
  - 2% and 5%: typical and relatively poor drop-lens cobra heads
  - 10%: good quality acorn top, assumed in other sky glow models
- Combined product of downward-reflected and upward-emitted quantities

Garstang's City Emission function:

$$B(Q, q, z_0) = 2\boldsymbol{Q}(1 - \boldsymbol{q}) \cos z_0 + 0.554\boldsymbol{q} z_0^4$$

15% ground reflectance

downlight quantity

uplight quantity

Buildings

- Emissions from vertically-oriented surfaces require a different function
- Interior building light escapes through a ? distribution
- Typically 4000+ K CCT for commercial office space

Sports

- Extremely high intensity
- Very directional, but much horizontal emission plus reflected component
- Spectrum reflected from grass (or other vegetation) is different from the source spectrum.

Thank you

Contact

- Bruce [dot] Kinzey [at] pnnl.gov
- https://energy.gov/eere/ssl/street-lighting-and-blue-light