Pacific Northwest
NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

Decoupling Street Lighting from Sky Glow

Bruce Kinzey, Pacific Northwest National Laboratory

ALAN 2018

Snowbird, UT

November 12, 2018

Projected Growth, 2017 – 2030

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

Africa in 2017

Source: IEA, Energy Access Outlook 2017

Projected Growth, 2017 – 2030

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

Africa in 2030

Source: IEA, Energy Access Outlook 2017

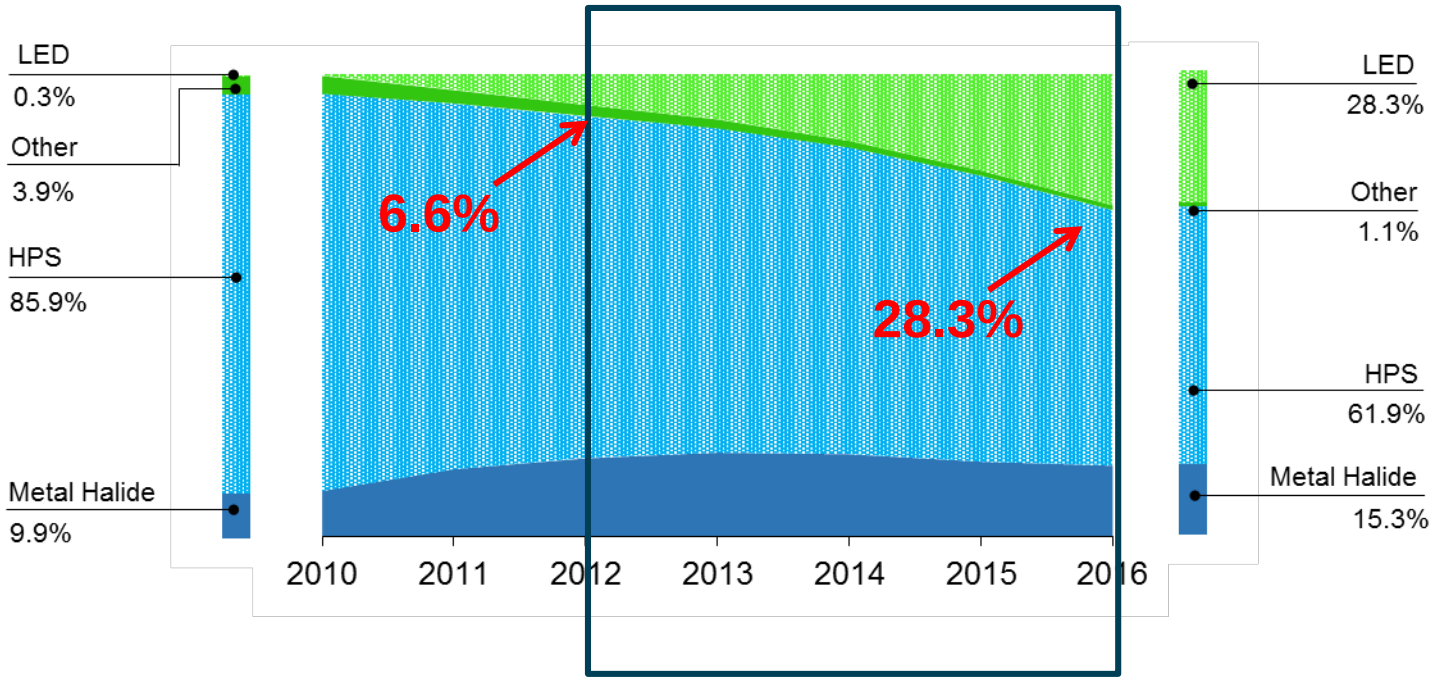
Light in the Night Sky Comes from Many Sources

U.S. Street/Roadway Installed Stock Penetration from 2012 to 2016

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

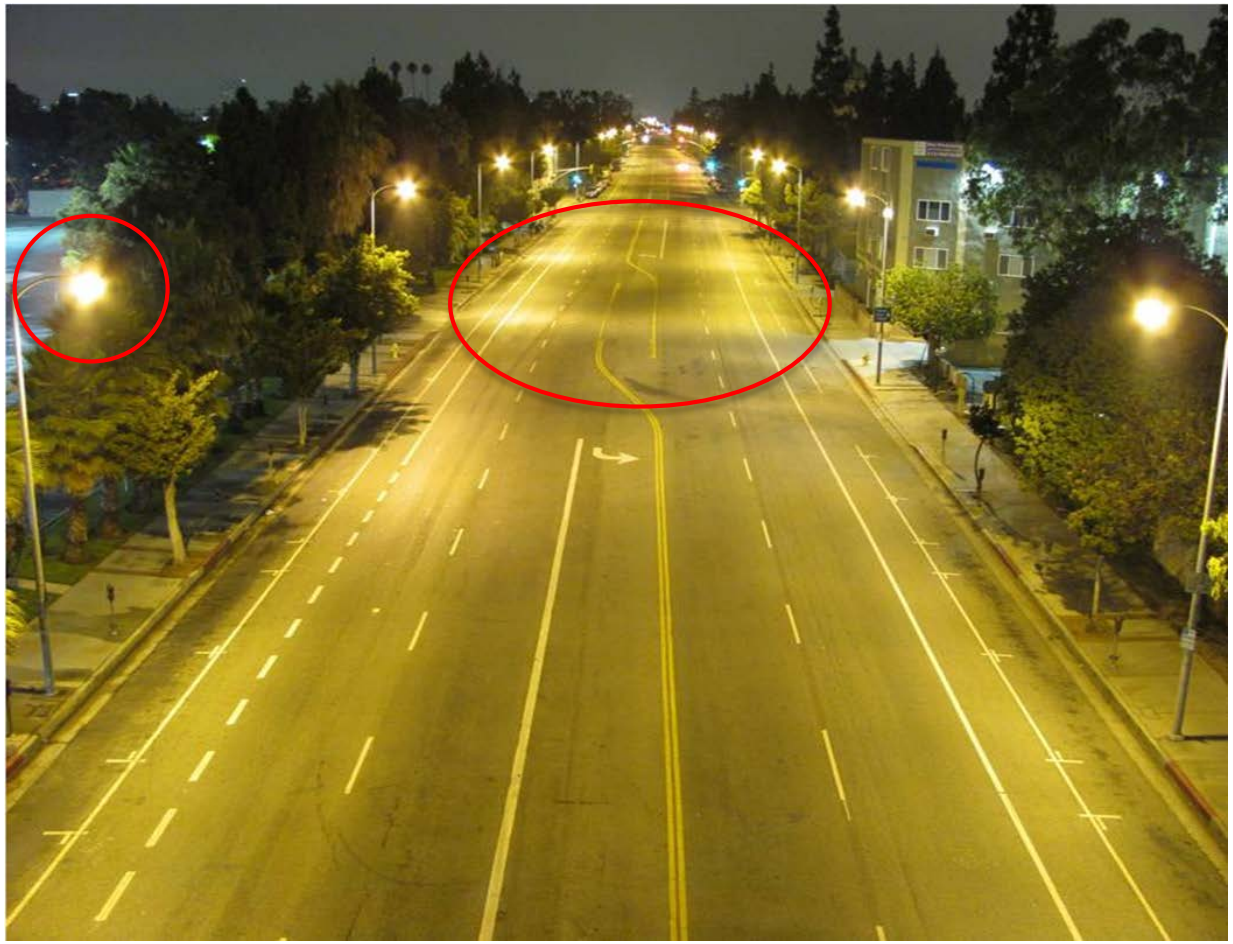
LEDs in the installed stock increased significantly during the period examined in Kyba, et al, 2017, primarily replacing HPS with 4000 K and higher CCT…

…yet U.S. upward radiance was reported as "stable"



Source: Navigant, LED Adoption Report, July 2017

The impact of improved distribution - Los Angeles



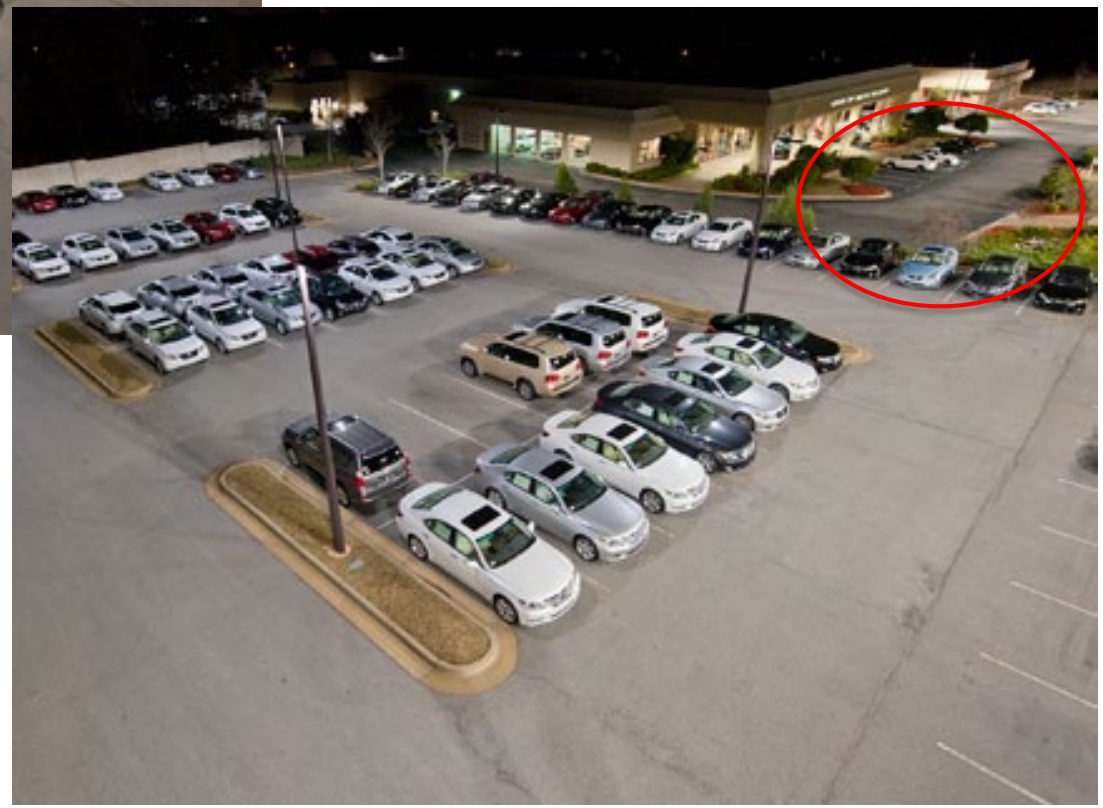
Photos Courtesy: LABSL

Collectively, the improved distribution, elimination of hot spots and uplight, etc., enabled a >50% reduction in fixture output.

Georgia Power Customer - 2013

- Assuming initial efficacies are about the same means an 8:1 reduction in light output
- …and an 87% reduction in wattage

Before with HID: <u>138,000 watts</u>
(138 1000-watt metal halide fixtures)



After LED system: <u>17,584 watts</u>
67 202 - watt fixtures = 13,534 watts
15 270 - watt fixtures = 4,050 watts
Color Temperature: 4000K | CRI: 70

Sky Glow Comparison Tool Outputs

- Comparing the old with the new:
  - HPS, MH and MV products compared with 5 LEDs ranging from 2700 K to 5200 K, distant observer (~25 miles) location
  - This comparison reflects differences in spectral content only
- Effects of spectral content compared to HPS baseline:
  - Range from about 1.3 to 1.5
  - Do not track well with CCT

INPUT CONDITIONS

1. Scenario Parameters

Observer location	distant
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

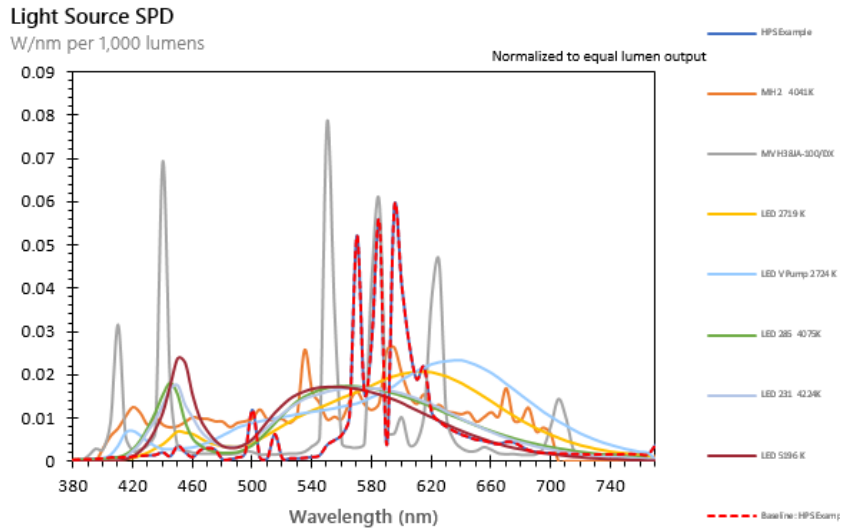
Percent uplight	0%
Lumen output (% of baseline)	100%

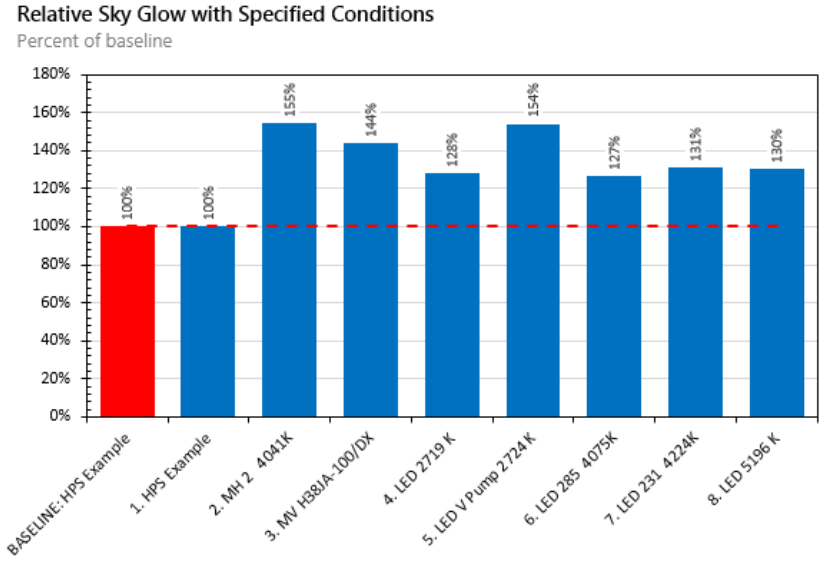
Clear | Calculate

RESULTS

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

Source Label	Relative Sky Glow
BASELINE: HPS Example	1.00
1. HPS Example	1.00
2. MH 2 4041K	1.55
3. MV H38JA-100/DX	1.44
4. LED 2719 K	1.28
5. LED V Pump 2724 K	1.54
6. LED 285 4075K	1.27
7. LED 231 4224K	1.31
8. LED 5196 K	1.30





Sky Glow Comparison Tool Outputs

- A more relevant scenario
  - Lumen package is reduced by 50% relative to baseline HPS (common in U.S. conversions)
  - Can be achieved both by downsizing initial lumen output (most common) and/or by dimming later
- All replacement products reduce sky glow relative to baseline HPS
  - Note that the differences achieved are greater than those between any white light SPDs

INPUT CONDITIONS

1. Scenario Parameters

Observer location	distant
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

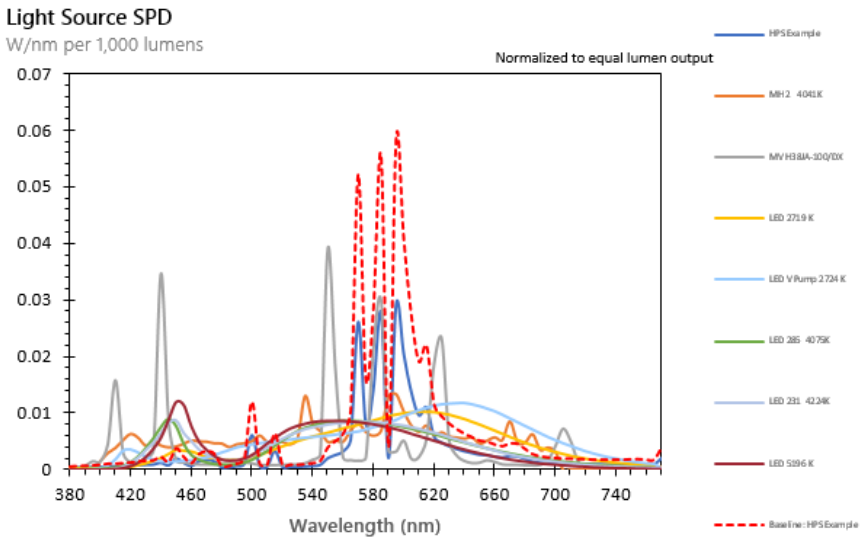
Percent uplight	0%
Lumen output (% of baseline)	50%

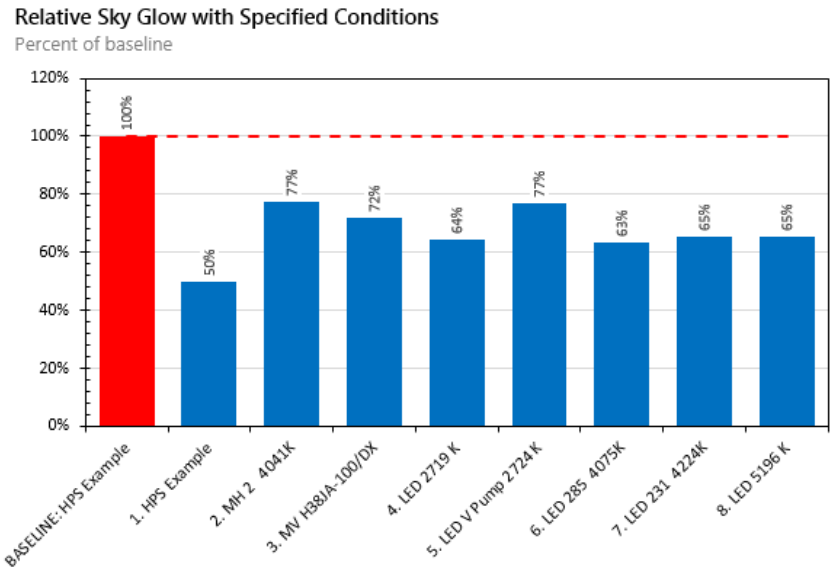
Clear | Calculate

RESULTS

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

Source Label	Relative Sky Glow
BASELINE: HPS Example	1.00
1. HPS Example	0.50
2. MH 2 4041K	0.77
3. MV H38JA-100/DX	0.72
4. LED 2719 K	0.64
5. LED V Pump 2724 K	0.77
6. LED 285 4075K	0.63
7. LED 231 4224K	0.65
8. LED 5196 K	0.65





Sky Glow Comparison Tool Outputs

- The effect of uplight overwhelms all else
  - A modest 2% uplight is added to the baseline; replacement products remain at 0%
  - Sky glow reduced by >90% at this location across the board
  - These kinds of changes are occurring in most U.S. street lighting conversions
- Such contributions potentially come from all other sources of uplight as well, e.g., buildings, signage

INPUT CONDITIONS

1. Scenario Parameters

Observer location	distant
Atmospheric condition	clear low particulate
Weighting function	unweighted

2. Baseline Light Source Characteristics

Percent uplight	2%
Baseline source	1. HPS Example

3. Comparison Light Source(s) Characteristics

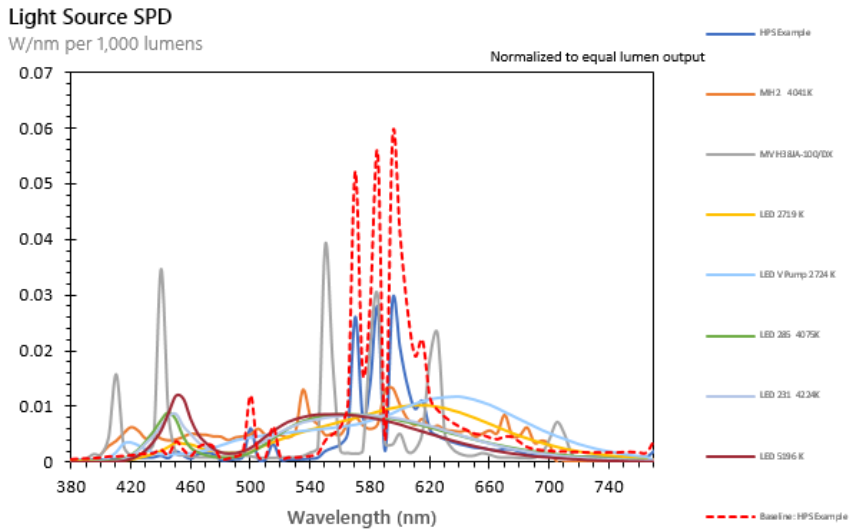
Percent uplight	0%
Lumen output (% of baseline)	50%

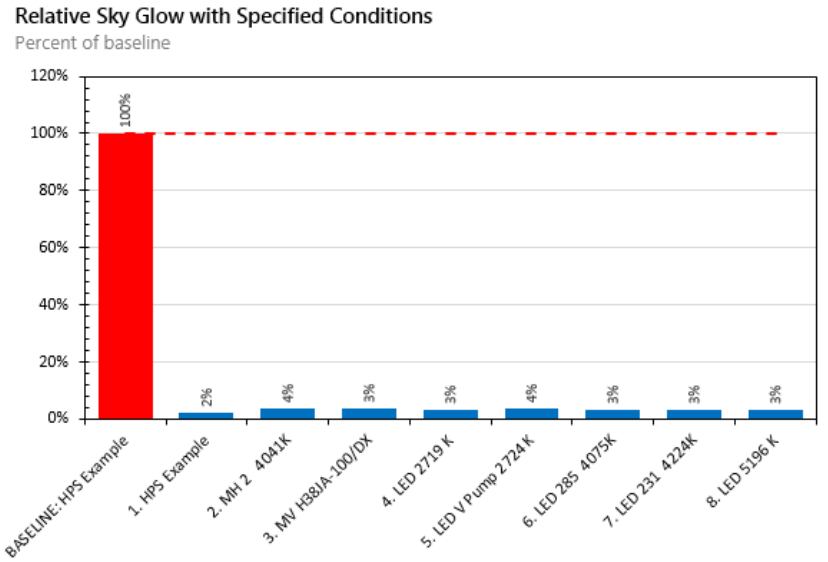
Clear | Calculate

RESULTS

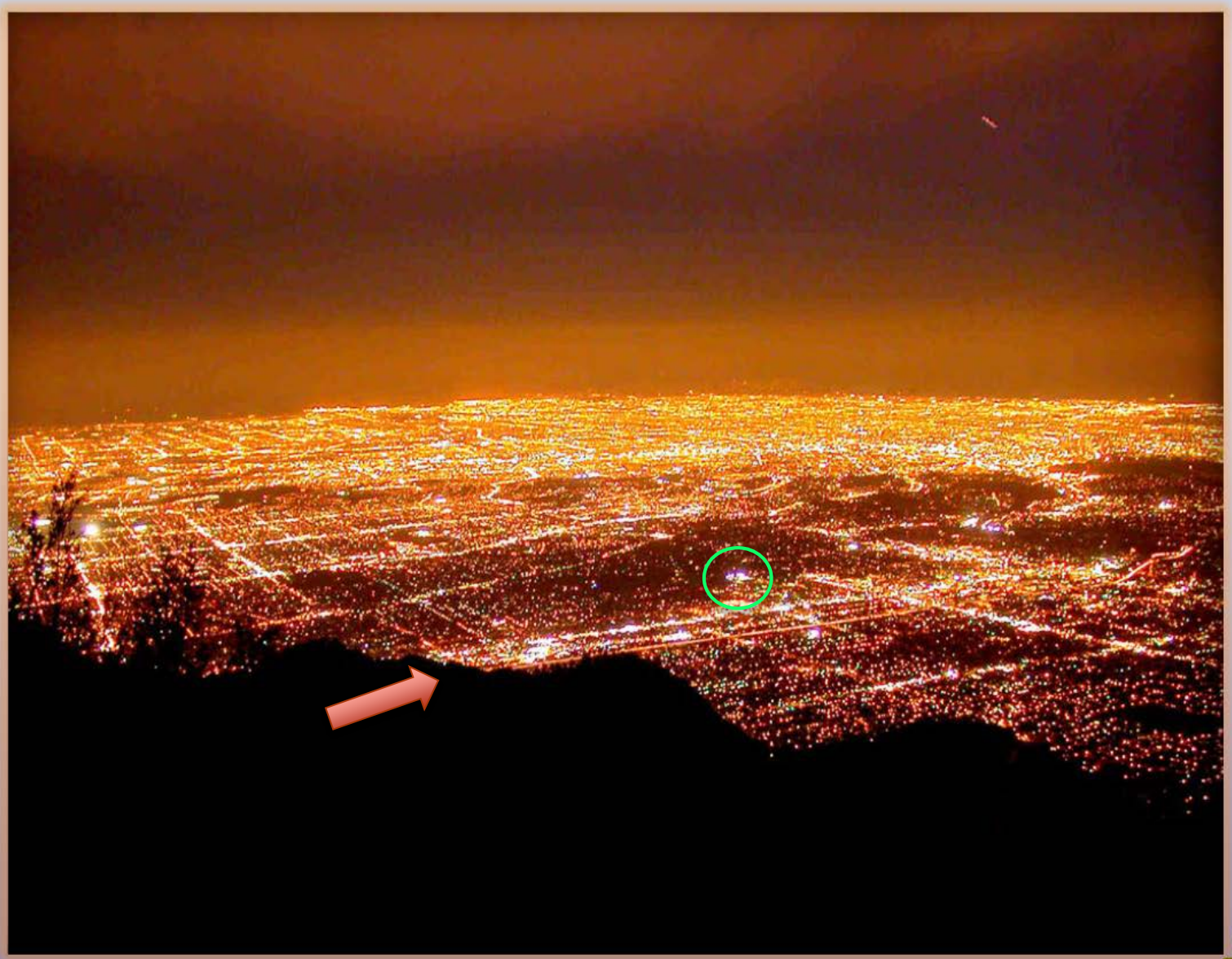
[Add new SPDs using the "SPD Input" sheet]

Source Label	Relative Sky Glow
BASELINE: HPS Example	1.00
1. HPS Example	0.02
2. MH 2 4041K	0.04
3. MV H38JA-100/DX	0.03
4. LED 2719 K	0.03
5. LED V Pump 2724 K	0.04
6. LED 285 4075K	0.03
7. LED 231 4224K	0.03
8. LED 5196 K	0.03



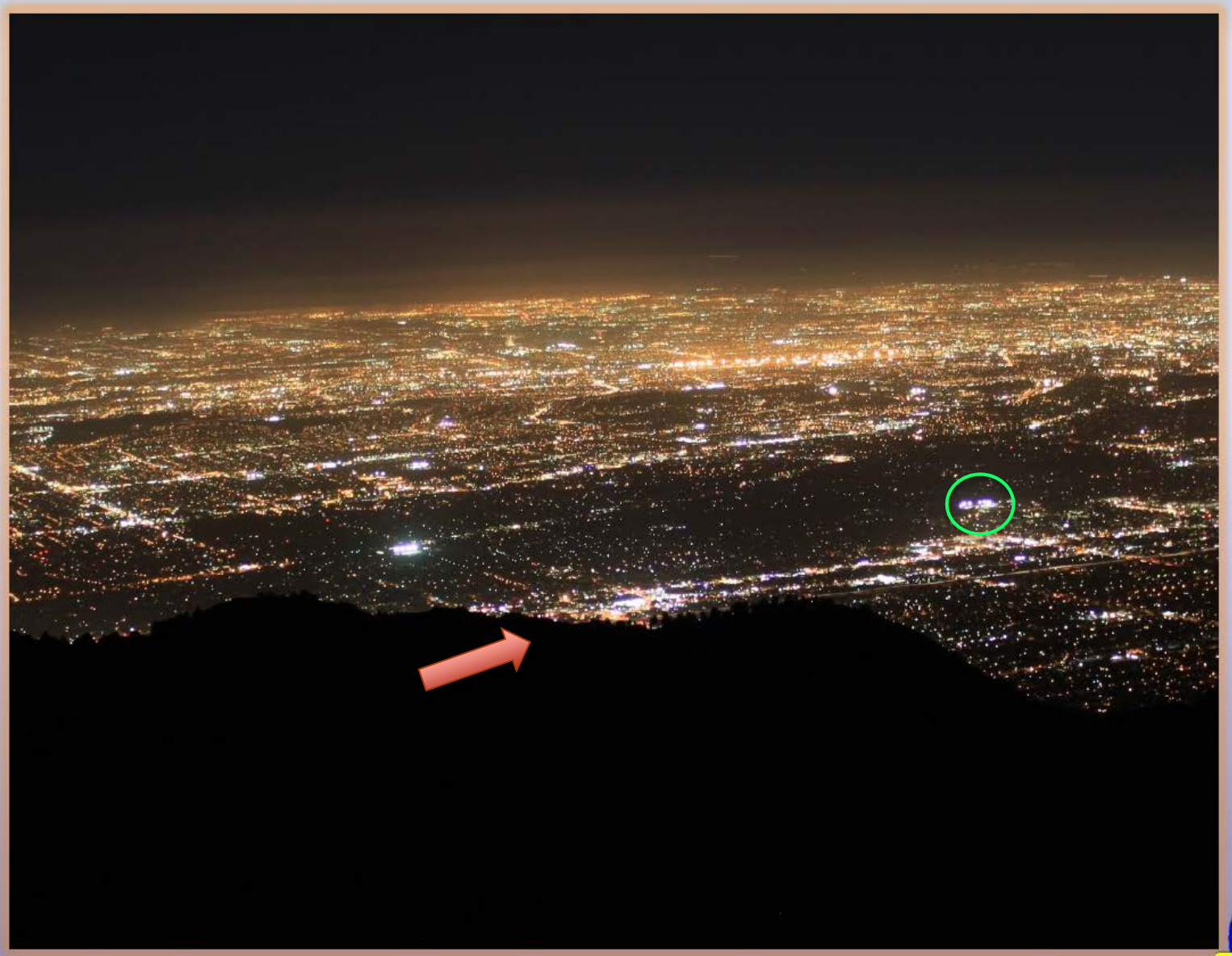


Los Angeles Basin – View from Mt. Wilson
Before LED Retrofit Project – 2008



BUREAU OF STREET LIGHTING
DEPARTMENT OF PUBLIC WORKS
CITY OF LOS ANGELES

Los Angeles Basin – View from Mt. Wilson
After LED Retrofit Project – 2012

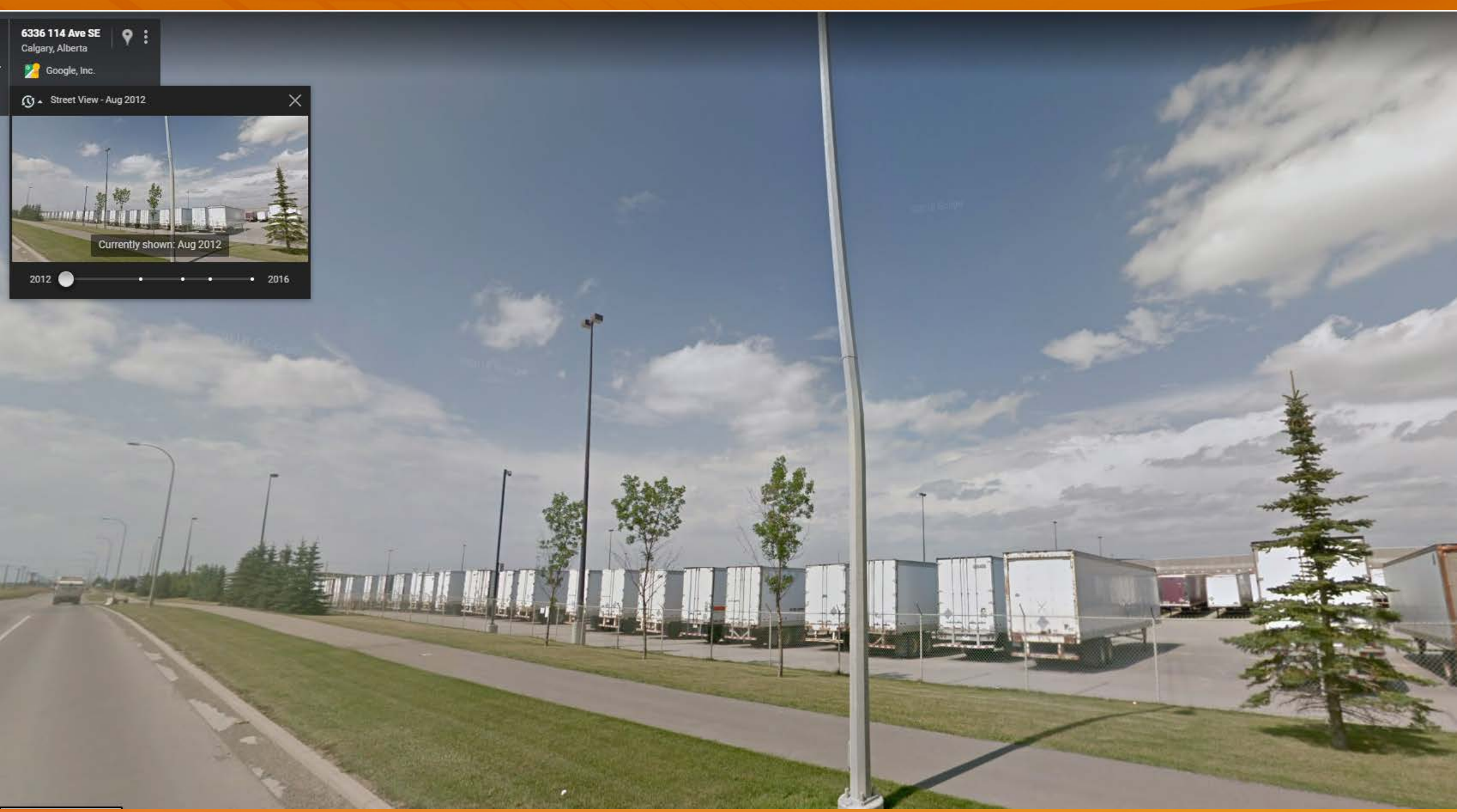


BUREAU OF STREET LIGHTING
DEPARTMENT OF PUBLIC WORKS
CITY OF LOS ANGELES

ISS Observations of Calgary

Calgary, 2010

Calgary, 2015


6336 114 Ave SE
Calgary, Alberta
Google, Inc.
Street View - Aug 2012
Currently shown: Aug 2012
2012
2016


6336 114 Ave SE
Calgary, Alberta
Google, Inc.
Street View - May 2016
Currently shown: May 2016
2012
2016

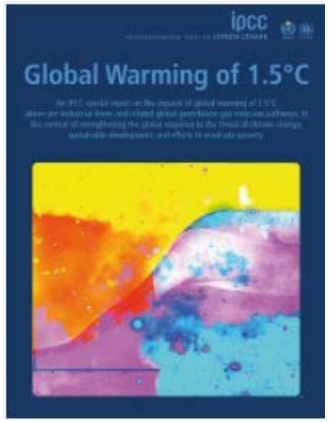
What else do we care about?

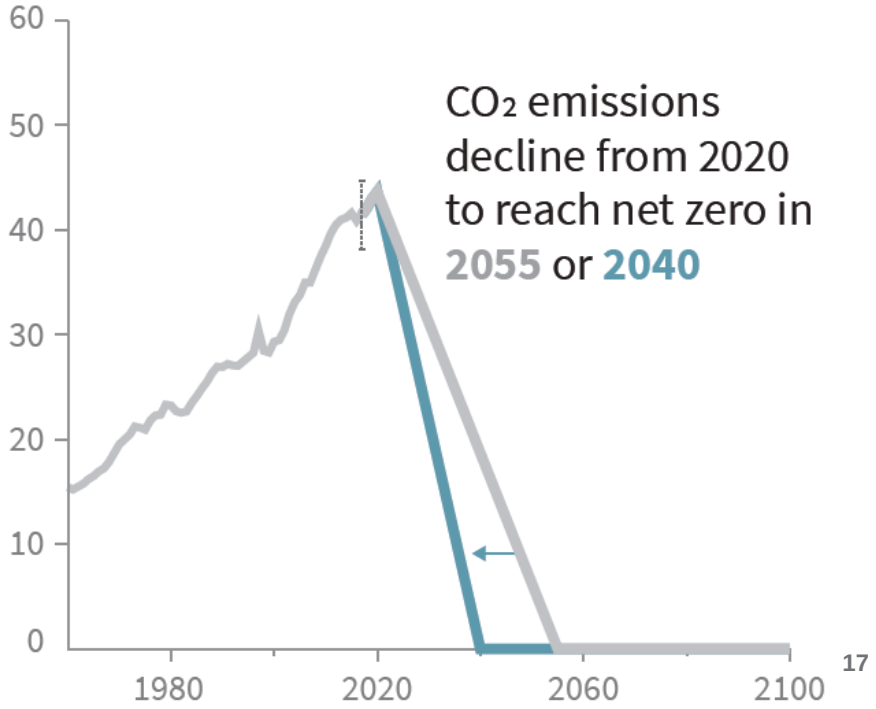
- Q: Why does DOE continue to focus on energy efficiency in LED lighting?
- A1: We still have a long ways to go before exhausting LED potential.
- A2 Lighting comprises 15-20% of global energy use.
- A3: Projections are that energy used in lighting worldwide is going to grow significantly over the next few decades.
- A4: In the U.S., half the carbon dioxide emissions reductions achieved in the electric utility sector since 2005 (half of 28%) have come from slowed growth in demand (the remainder from fuel switching including renewables)

IPCC Report Released October 8, 2018 - Excerpts

- A3.1. Impacts on natural and human systems from global warming have already been observed. Many land and ocean ecosystems and some of the services they provide have already changed due to global warming.
- B3.1. Of 105,000 species studied, 6% of insects, 8% of plants and 4% of vertebrates are projected to ***lose over half of their climatically determined geographic range*** for global warming of 1.5°C,…

…compared with 18% of insects, 16% of plants and 8% of vertebrates for global warming of 2°C.





Stylized net global CO_2 emission pathways
Billion tonnes CO_2 per year ($GtCO_2$/yr)

Source: Intergovernmental Panel on Climate Change, http://www.ipcc.ch/report/sr15/

Effective measures that most everyone can agree to

- Encourage the ongoing transition to LED
  - Focusing on containing the appropriate level of light within the intended space
- Encourage the accompanying installation and use of dimming controls
  - Serves multiple objectives simultaneously
  - Municipalities need backup
- Encourage the development of municipal lighting ordinances that include all sources, e.g., commercial buildings and offices (interior lighting that escapes through windows as well as façade lighting), signage, sports fields, horticultural hothouses
  - Uplight has greatest influence on propagating light's effects outside the intended space, by far
- Discourage the sale of old, obsolete lighting equipment to others
  - Transporting problems elsewhere does not resolve any of these issues

Thank You

Bruce Kinzey
Pacific Northwest National Lab
Bruce[dot]Kinzey[at]pnnl[dot]gov

Graphic Courtesy Musco Lighting