Western Connecticut Council of Governments

Minimizing Light Pollution

September 12, 2018

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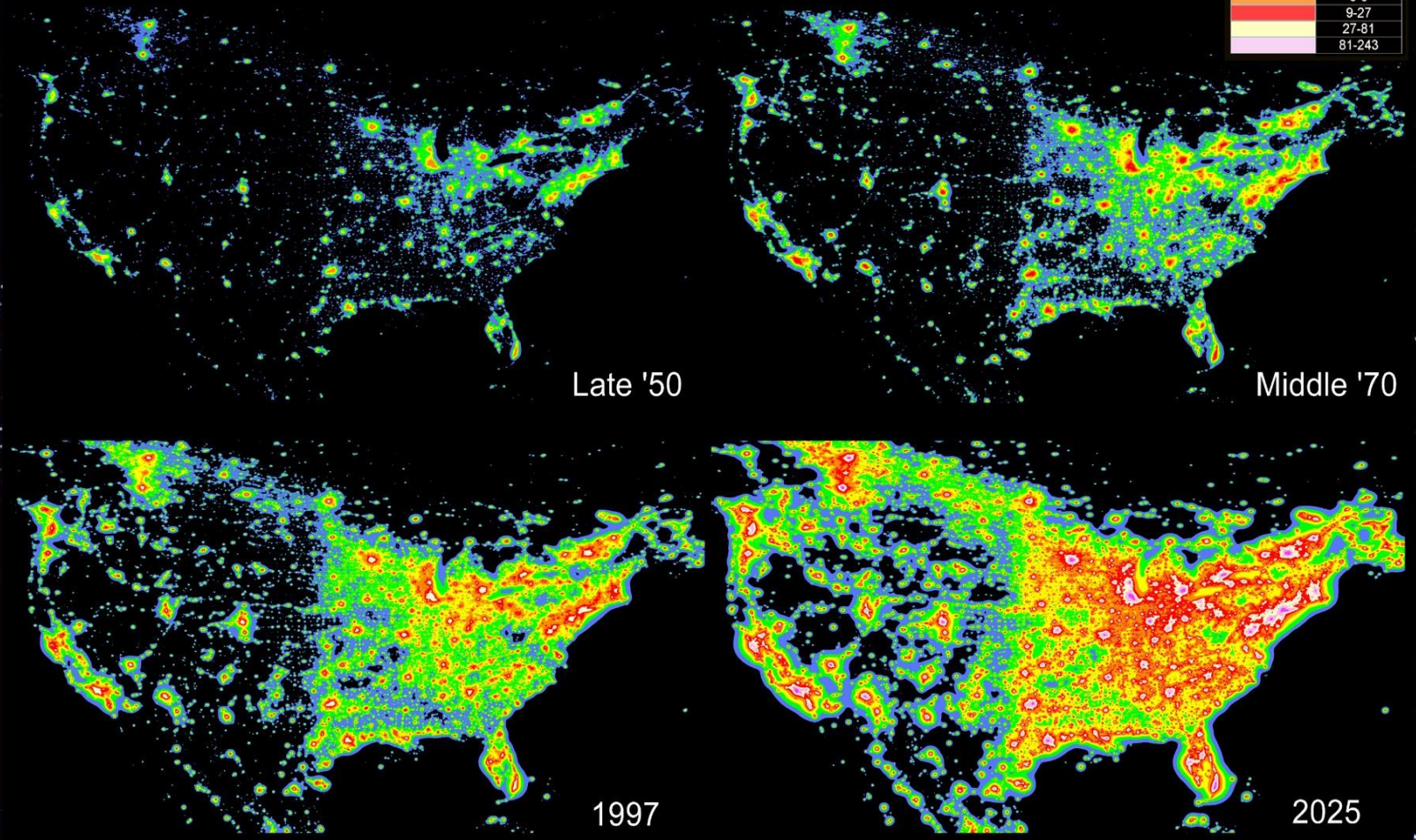
Member, IES Roadway Lighting Committee
Northeast Regional Director - IDA

Light Pollution

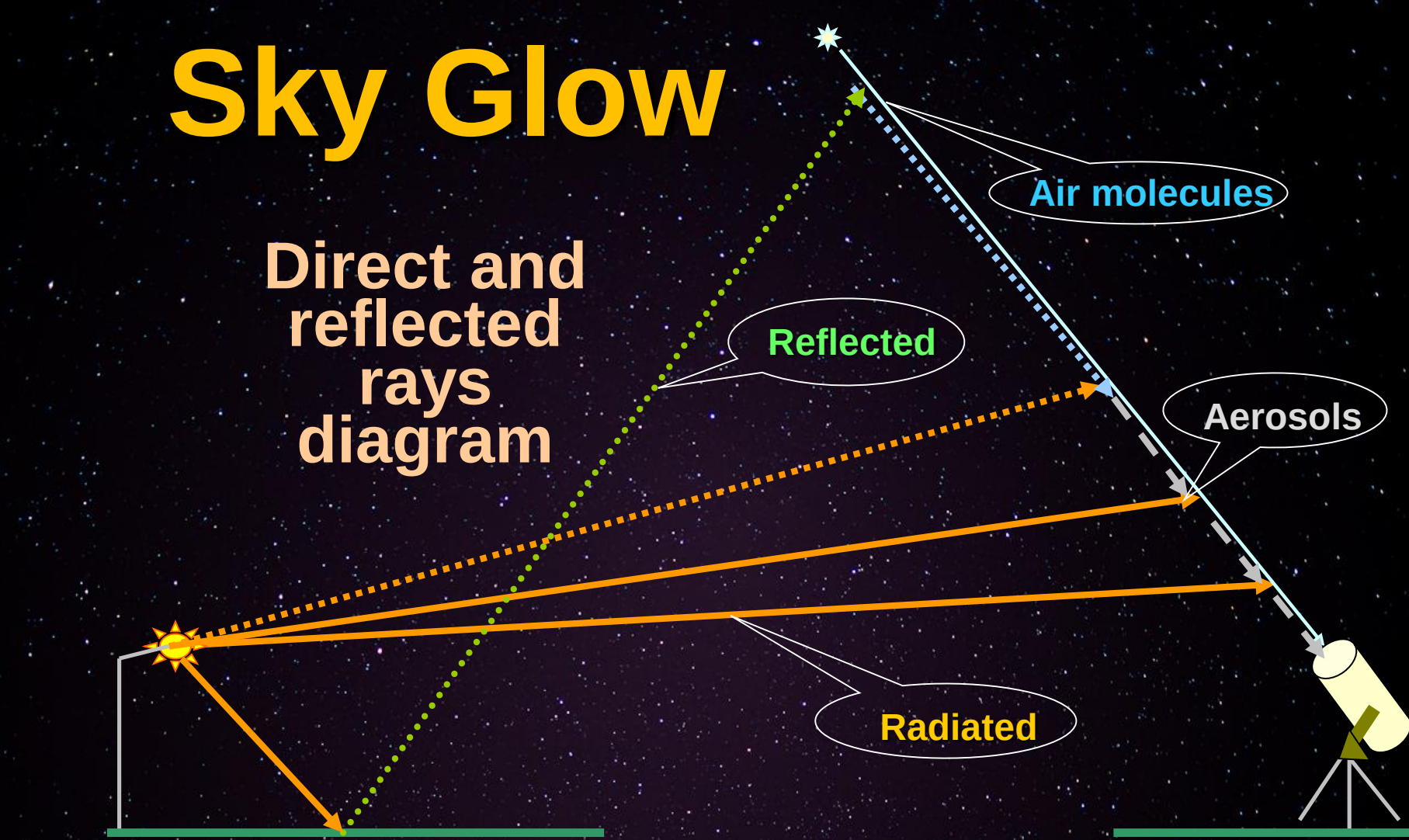
A Brief Overview

Artificial Night Sky Brightness due to Light Pollution in North America
A preliminary picture of the growth from 1950 to 2025



Light Pollution In the Northeast

Sky Glow



Skyglow is caused by the downward scattering of upward light by air molecules and also aerosols, mostly water droplets and dust. The longer the path length through the lowest part of the atmosphere, the more the scattering. Light that goes straight up is mostly reflected, and has shorter paths through the lower scattering layers. The low angle light is mostly directly radiated, and it is this that causes most of the sky glow well away from the source.

2003 blackout in Ontario, Canada

Connecticut Laws & Regulations Addressing Light Pollution

1997 – Connecticut Law Shielding Streetlights on State Highways

2001 – Connecticut Expands Law to Include Municipal Roads for Shielding Streetlights

2003 – Connecticut Law Limiting Light Trespass from Floodlights on State Highways

2006 – Connecticut Law on Outdoor Lighting at State Facilities

2006 – Connecticut Building Code on Exterior Lighting

2009 – 16a-38k- 4 State Law on Building Construction Standards require that a project implement at least two out of 15 site selection and development strategies, which include one to reduce light pollution by doing such things as installing automatic light controls and limiting exterior lighting (Conn. Agencies Regs. §§ 16a-38k-4 and 16a-38k-6).

National Laws & Codes Addressing Light Pollution

2004 – ASHREA 90.1 – Exterior Lighting

2005 - California Title 24 (California Energy Code) Applies to Non Residential Outdoor Lighting

2006 - Model Outdoor Lighting Ordinance (MLO) International Dark-Sky Association and the Illuminating Engineering Society Joint Effort

2006 - International Energy Conservation Code Section on Exterior Lighting – Adopted as part of the Connecticut State Building Code

Partial List of Municipalities with Light Pollution Ordinances in Connecticut

Ashford
Avon
Bloomfield
Branford
Brookfield
Cheshire
Clinton
Colchester
Darien
Derby
East Hartford
East Windsor
Ellington
Farmington
Glastonbury
Greenwich
Guilford
Killingworth
Manchester
Milford
Ridgefield
Somers
Southbury
South Windsor
Stratford
Suffield
Tolland
Wallingford
Watertown
West Hartford
Weston
Wethersfield
Wilton
Windsor

Municipal Exterior Lighting Regulations In Connecticut Often Focus on basics

- Shielding Requirements
- Light Trespass Restrictions across property line
- No Objectionable (?) Glare

Some municipalities have more comprehensive outdoor lighting regulations. Examples:

- Require a Lighting Plan as part of the Site Plan
- No floodlighting
- All building lighting for aesthetics will be full cut- off (Fully shielded – no uplight)

For Exterior Lighting, the U.S. Department of Energy promotes use of

Dimmers
Occupancy Controls
Motion Sensor Controls
Timers

to reduce energy waste

Exterior Lighting Codes & Regulations started around 2000 and are likely to Increase in the coming years

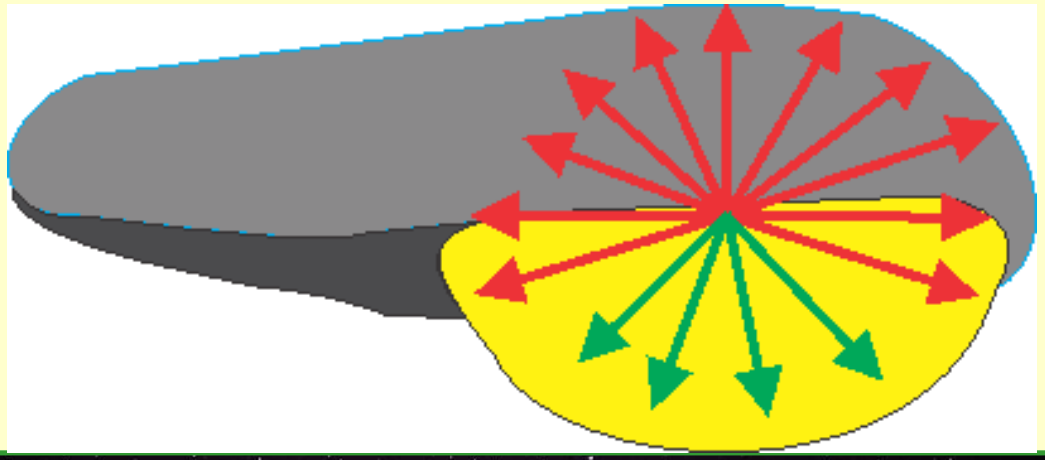
How to Avoid Overlighting When Using LEDs

Achieving Visibility Equivalence

using 1/3 the lumen output of traditional light sources

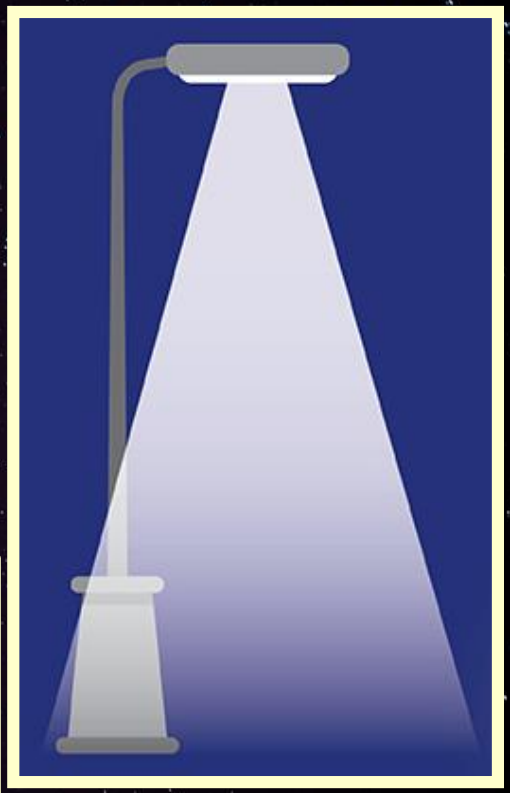
Traditional Lamp Lumen Delivery to the Target Area

Only a fraction of the lumen output reaches the target area – most of the lumens hit inside the fixture shell or are directed at high angles away from the target area.



LED Lighting & Directionality

LED lights are directional - pointed at the target



3000 LED lumens will equal 9000 HPS lumens in terms of Visibility equivalence

LED Blue Wavelength Problem

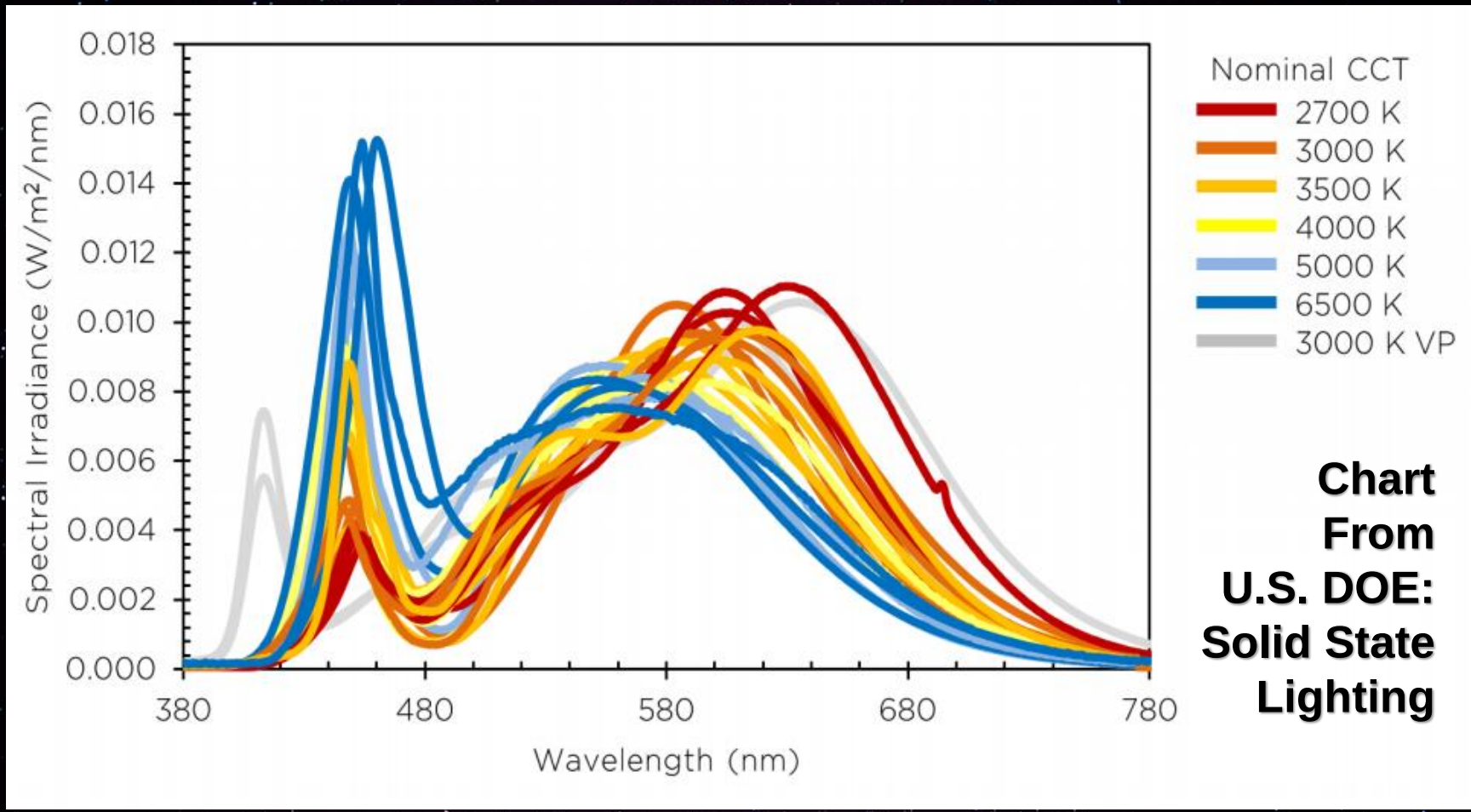
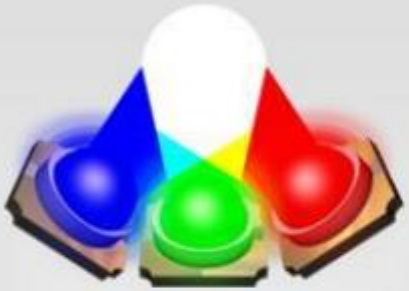
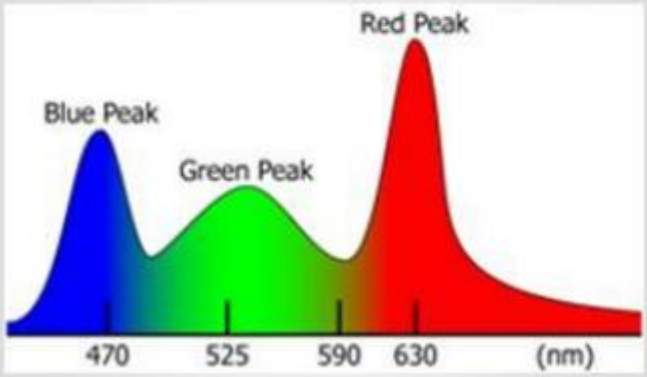


Chart From U.S. DOE: Solid State Lighting

2 ways to produce white light with LEDs

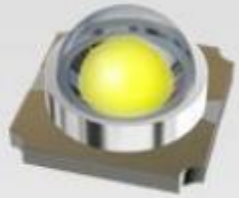
RGB (Red, Green, Blue)

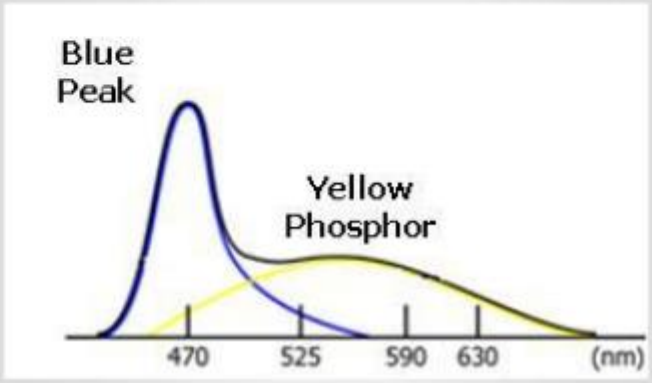




LED Color Mix

Blue + Yellow Phosphor





Blue LED with P

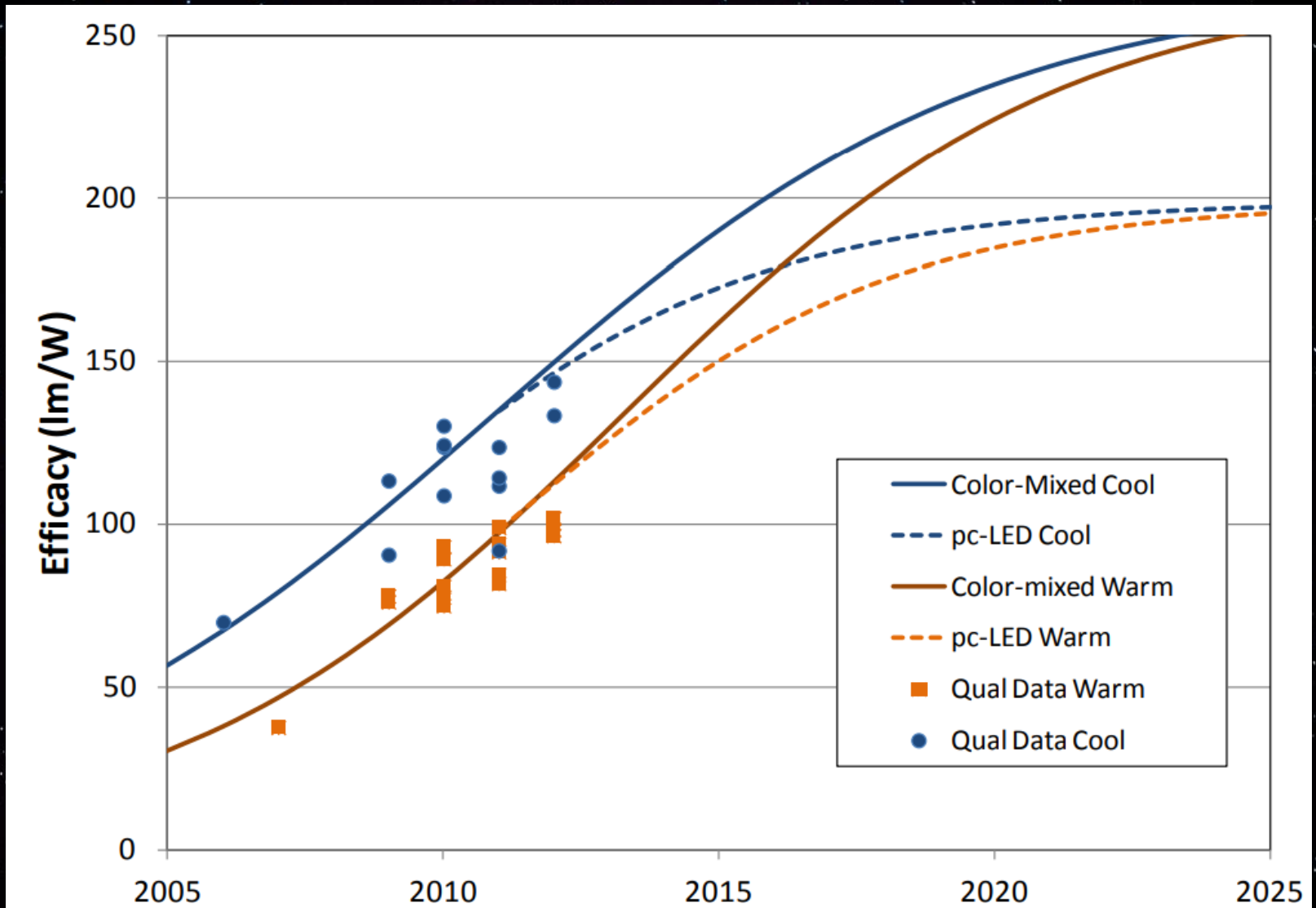
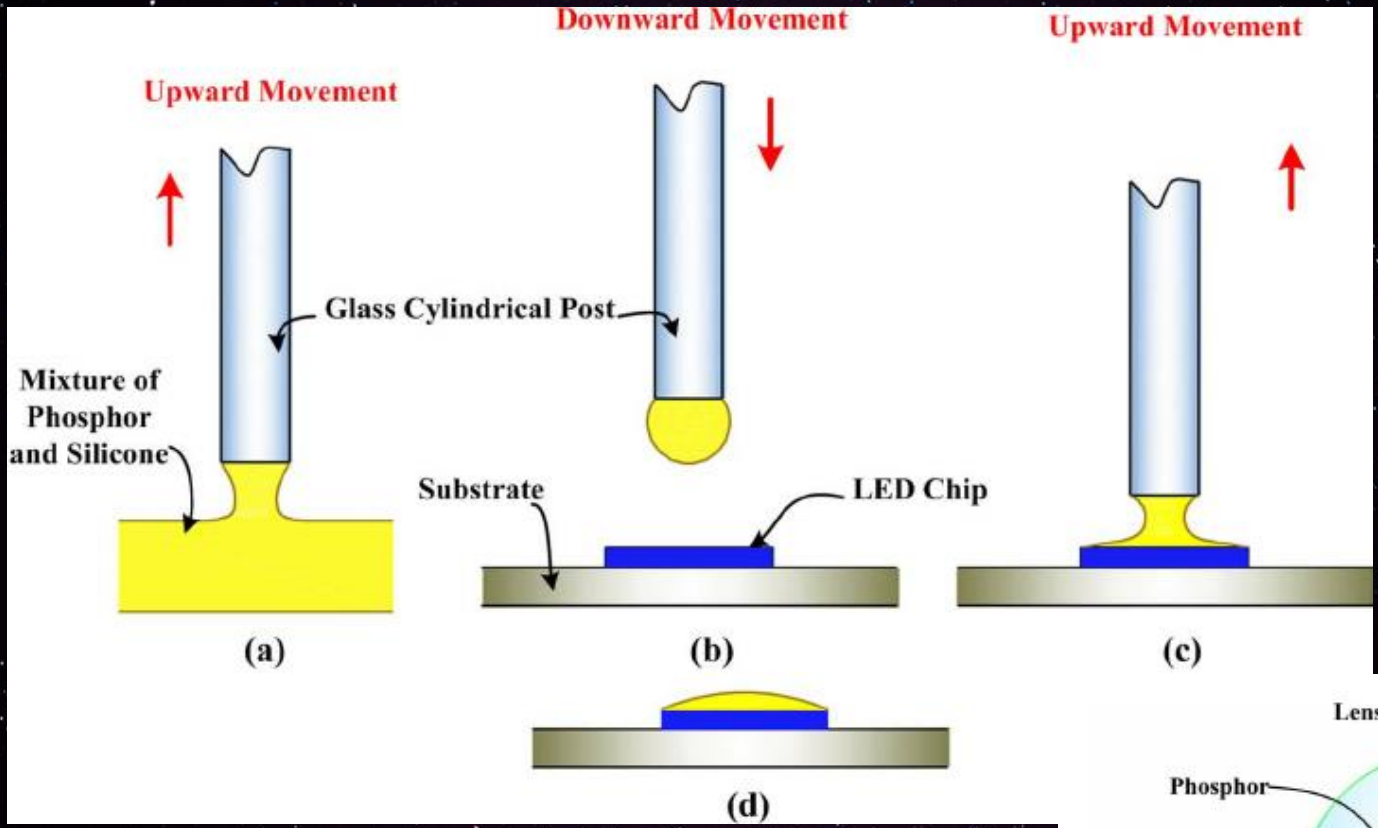


Figure 5.5: White Light LED Package Efficacy Projections for Commercial Product

Most LED Chips have a Phosphor coating. Phosphor mix controls how much Blue Wavelength emission is suppressed



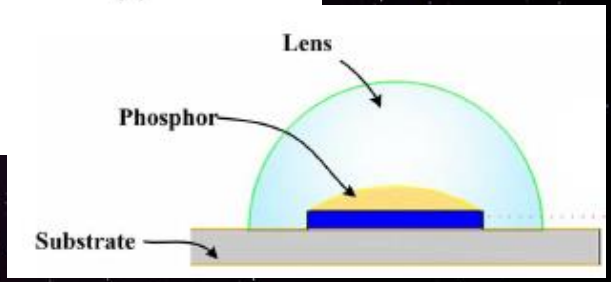


Table 1. Selected blue light characteristics of various outdoor lighting sources at equivalent lumen output.

Row	Light source	CCT (K)	% Blue*	Luminous Flux (lm)	Scotopic content relative to HPS	Melanopic content relative to HPS**
A	PC white LED	2700	17% - 20%	1000	1.77 - 1.82	1.90 - 2.06
B	PC white LED	3000	18% - 25%	1000	1.89 - 2.13	2.10 - 2.51
C	PC white LED	3500	22% - 27%	1000	2.04 - 2.37	2.34 - 2.97
D	PC white LED	4000	27% - 32%	1000	2.10 - 2.65	2.35 - 3.40
E	PC white LED	4500	31% - 35%	1000	2.35 - 2.85	2.75 - 3.81
F	PC white LED	5000	34% - 39%	1000	2.60 - 2.89	3.18 - 3.74
G	PC white LED	5700	39% - 43%	1000	2.77 - 3.31	3.44 - 4.52
H	PC white LED	6500	43% - 48%	1000	3.27 - 3.96	4.38 - 5.84
I	Narrowband amber LED	1606	0%	1000	0.36	0.12
J	Low pressure sodium	1719	0%	1000	0.35	0.10
K	PC amber LED	1872	1%	1000	0.70	0.42
L	High pressure sodium	1959	9%	1000	0.89	0.86
M	**High pressure sodium**	**2041**	**10%**	**1000**	**1.00**	**1.00**

* Percent blue calculated according to LSPDD: Light Spectral Power Distribution Database, http://galileo.graphycs.cegepsherbrooke.qc.CA/app/en/home. The specific calculation, developed for evaluating the potential for affecting sky glow, divides the radiant power contained in the wavelengths between 405 and 530 nm by the total radiant power contained from 380 to 780 nm, for each light source.

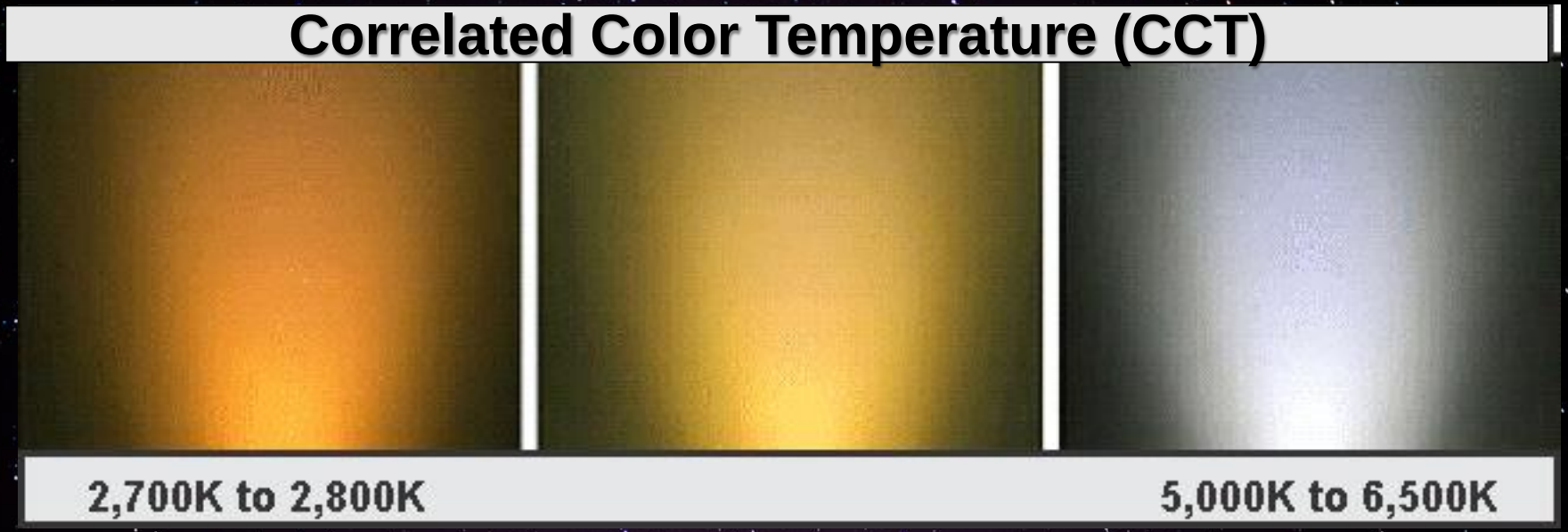
** Melanopic content calculated according to CIE Irradiance Toolbox, http://files.cie.co.at/784_TN003_Toolbox.xls, 2015 as derived from Lucas et al., 2014.

Key: PC -- Phosphor Converted; LED -- Light Emitting Diode

http://energy.gov/sites/prod/files/2016/07/f33/msslc_enews_jul2016.pdf

Controlling Color Temperature - (LED)

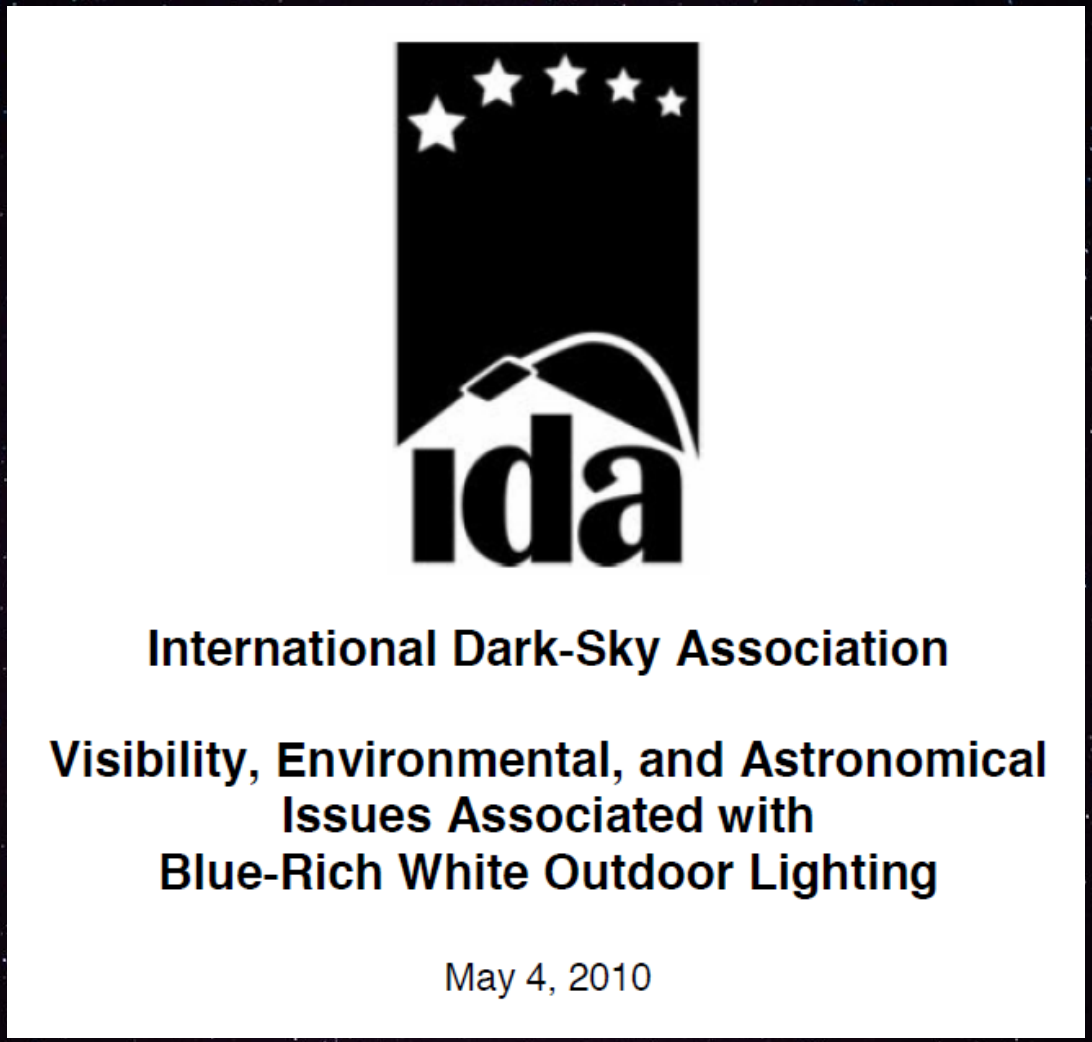
Limit CCT to 2,700K (warm white) to minimize light pollution



2,700K – Warmer – more inviting – less blue

4,000K and above – more bluish – colder – creates more light pollution

Blue-Rich Light Issue Raised in IDA White Paper - 2010



IDA White Paper - Findings

Blue-rich LED lighting will increase scatter, resulting in increased levels of sky glow.

Blue-rich LED light at night is more likely to alter the circadian rhythm and photoperiod in the animal world.

New metrics are needed to better describe the ramifications of shorter wavelength emissions on sky glow, human health and plant & animal life.

“CRI, CCT and the Scotopic/Photopic Ratio are too blunt to model the range of significant impacts”.

American Medical Association 2009

- Advocates that all future outdoor lighting be of energy efficient designs to reduce waste of energy and production of greenhouse gasses that result from this wasted energy use, and be it further

- Develops and enacts a policy that supports light pollution reduction efforts and glare reduction efforts at both the national and state levels; and be it further

- Supports that all future streetlights will be of a fully shielded design or similar non-glare design to improve the safety of our roadways for all, but especially vision impaired and older drivers.

American Medical Association
LED Warning – Issued June 14, 2016

Covers Environmental Effects of Light Emitting Diode (LED) Community Lighting

AMA encourages the use of 3000K color temperature or lower lighting for outdoor installations…(limit blue light)

All LED lighting should be properly shielded to minimize glare and detrimental human and environmental effects

Consideration should be given to dimming LED lighting for off-peak time periods

http://darksky.org/ama-report-affirms-human-health-impacts-from-leds/

Cities with 3000K or lower CCT LEDs

- New York City
- Chicago
- San Francisco
- Los Angeles
- San Diego
- Tucson
- Phoenix
- Toronto
- Montreal
- Davis

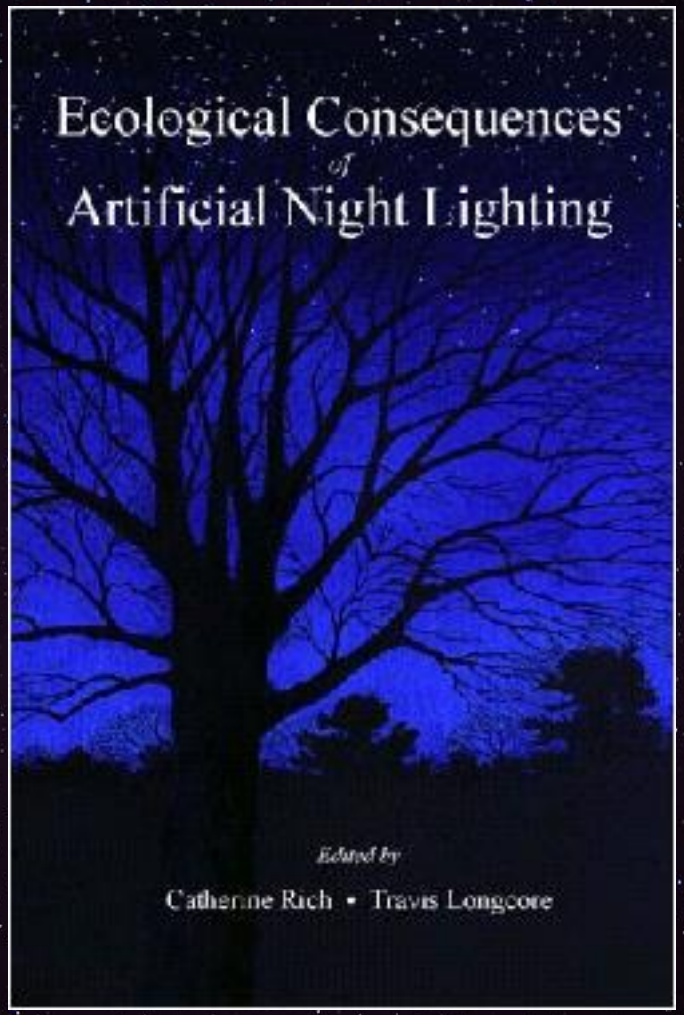
Some use 2700K CCT For Residential and 3000K for Commercial

States with Light Pollution laws

- Arizona
- Arkansas
- California
- Colorado
- Connecticut
- Delaware
- Hawaii
- Maine
- Michigan
- Minnesota
- Montana
- New Hampshire
- New Mexico
- Rhode Island
- Texas
- Vermont,
- Virginia,
- Wyoming

…and growing

AMA 2016 Research Paper on LED Lighting was co-authored by Travis Longcore



Light Pollution and Wildlife

Wildlife concerns due to obtrusive light include:

Habitat Disturbance

Wildlife Behavior

Wildlife Survival

A Few Examples:

- Artificial Light Contributes to an Estimated **100,000,000** Bird Deaths Annually in USA
- Artificial Light Contributes to Thousands of Sea Turtle Deaths Annually

New York state to dim lights to save migrating birds

Migratory birds are thought to be confused by constellations of city lights, causing them to fatally crash

Attraction/Repulsion

For frogs, a quick increase in illumination causes a reduction in visual capability from which the recovery time may be minutes to hours

After becoming adjusted to a light, frogs may be attracted to it as well

Communication

- Female glow-worms attract males up to 45 m away with bioluminescent flashes; the presence of artificial lighting reduces the visibility of these communications.

- The complex visual communication system of fireflies could be impaired by stray light

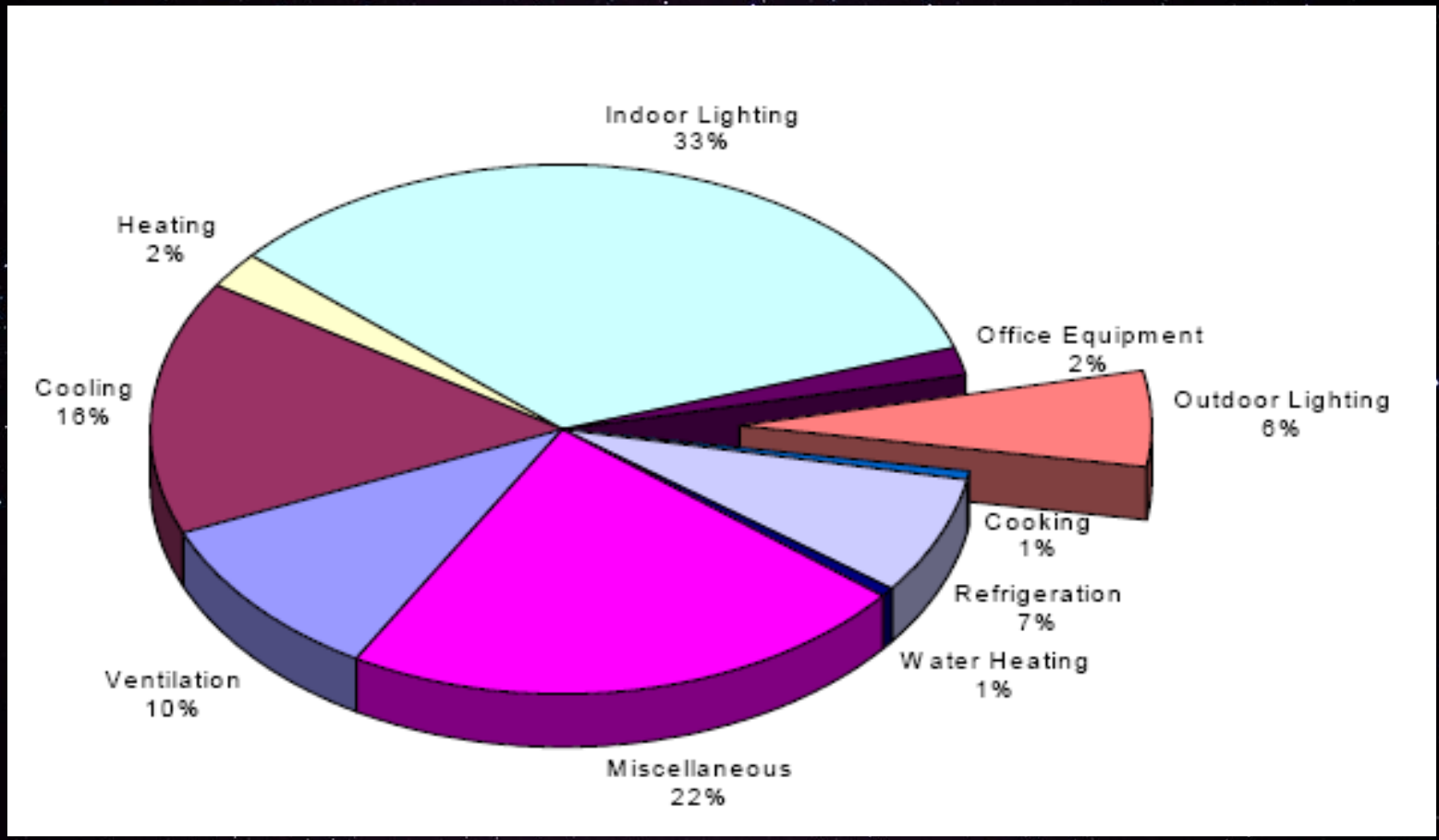
Community Ecology

- Competition for times for foraging
- Increased Predatory Risk
- Ecosystem effects – long term changes in the balance

Implementing Good Light Pollution Controls Contributes to Improving Energy Conservation


$2 Billion
In Wasted Energy!

Energy Consumed by End User
Outdoor Lighting = 6%



Energy Waste

Generation of one KWh of electricity creates 1.34 pounds of carbon dioxide waste (CO_2).

Lighting the sky with wasted uplight creates 14.7 million tons of CO_2 annually.

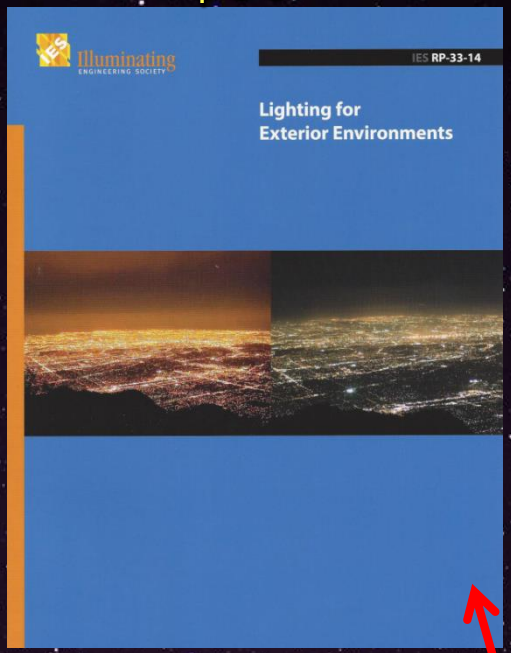
Coal needed to generate the wasted light would be about 3.6 million tons of per year.

Outdoor Lighting - Recommended Practices

No Charge

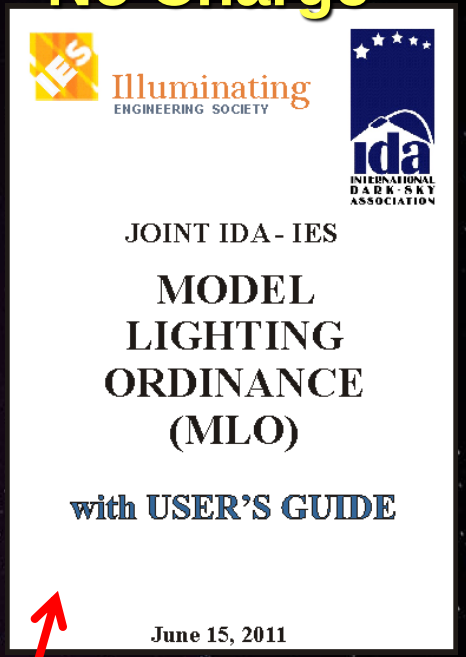
Natural Sounds and Night Skies Division

$60



RP-33 Lighting for The Exterior Environment

No Charge



Model Lighting Ordinance

Both at Illuminating Engineering Society Bookstore at IES.ORG

Best Practices for Night Skies

Light only WHERE & WHEN to the Minimum Level Needed

Shield – Point Downward – Consider Dimmer & Timer

https://www.nps.gov/subjects/nightskies/practices.htm

Wilderness Value of Night Skies

"Dark night skies are a wilderness characteristic"

"A single glaring light can reel back those seeking solitude or communion with nature…"

https://www.nps.gov/subjects/nightskies/wilderness.htm

Night Skies are a Public Resource

- A Resource of Nature

Natural darkness essential for wildlife

Nearly 50% of species are nocturnal

As a Cultural Resource

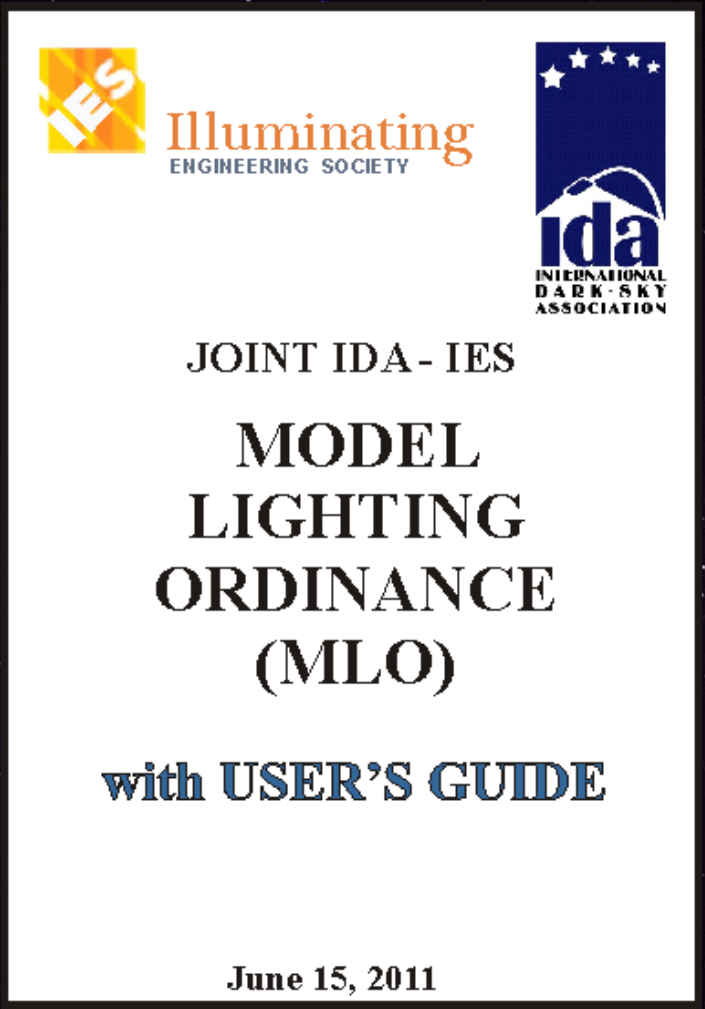
The same dark and starry sky has evoked countless myths, art, literature and music from cultures around the world

As an Economic Resource

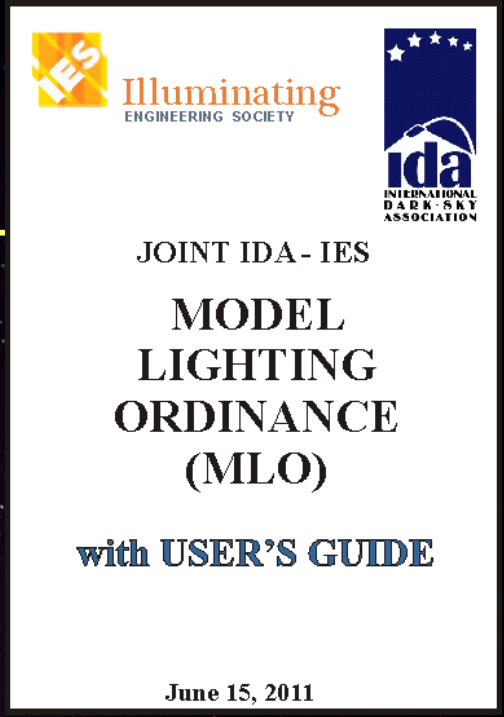
- Astronomical/Optical Research
- Amateur Stargazing
- Wilderness Camping

https://www.nps.gov/subjects/nightskies/resources.htm

IES/IDA Recommended Practices
A Quick Overview of the MLO

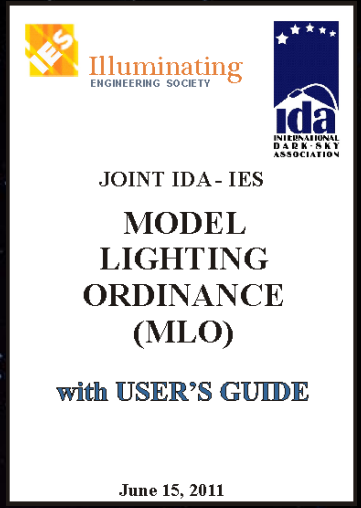


Model Lighting Ordinance Uses 5 Lighting Zones



- **LZ-0** - no ambient light
  - Nature preserves, parks, trails
  - 2 acre single family residential
- **LZ-1** - low ambient light
  - Single family residential in 1+ acre zones
  - Single stand alone suburban small business
- **LZ-2** - moderate (some) ambient light
  - Concentrated commercial downtown strip
  - Parking lot for malls or large apartment complex

Lighting Zones Continued



LZ-3 - moderately high ambient light

- Concentrated urban commercial district
- Major City urban core business district
- Applies mostly to street front settings

LZ-4 - extremely high ambient light

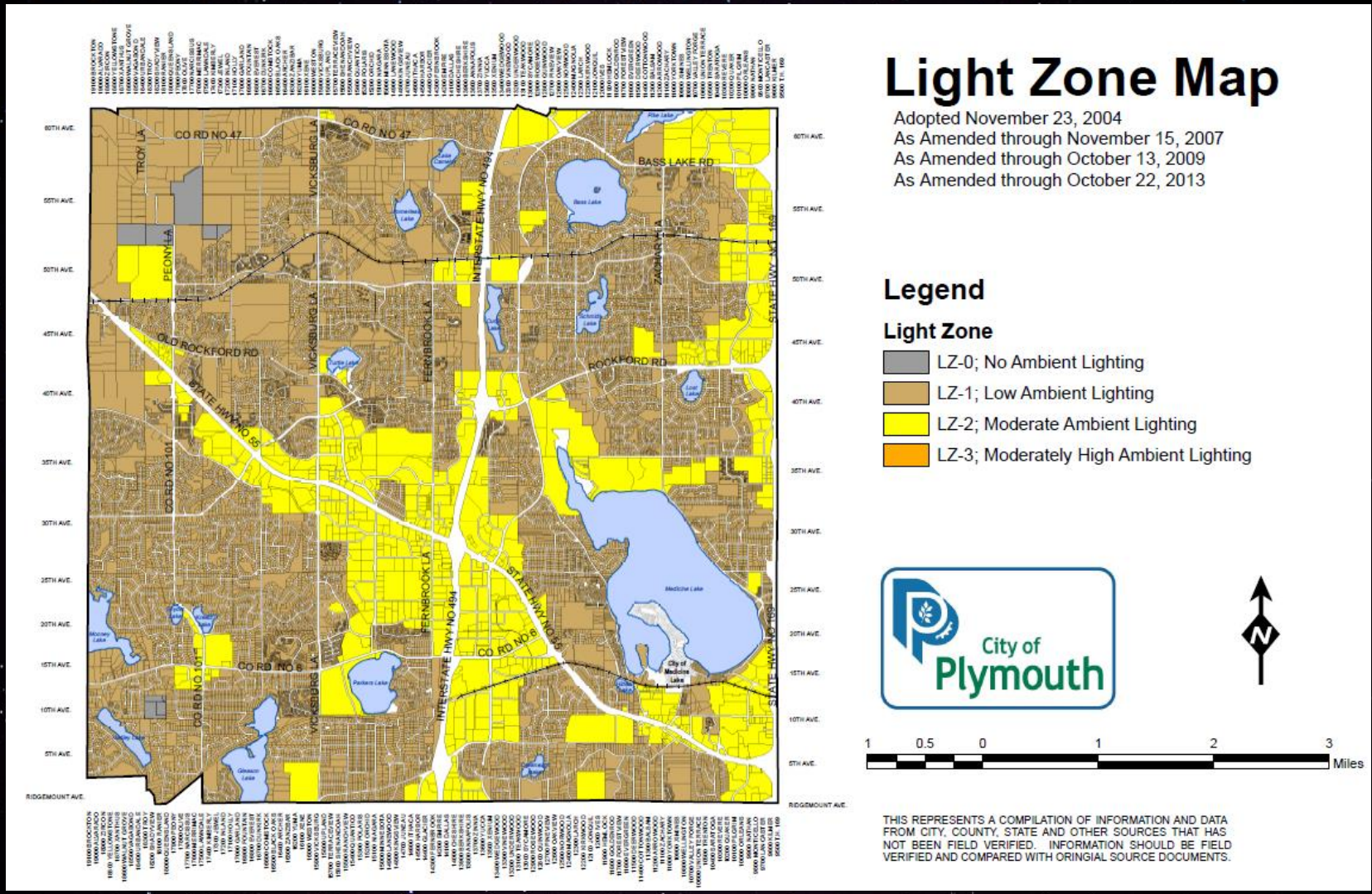
- Rare – Times Square, Las Vegas Strip

LZ-3 and **LZ-4** Ambient Light are usually limited to areas tangent to the street and sidewalk – where ambient light exists.

Lighting Zones now widely used by National Code Developers

- Illuminating Engineering Society
- California Title 24 Energy Code
- National League of Cities – Sustainable Cities
- US Green Building Council
- US Department of Energy Programs
- International Energy Conservation Code
  - IECC Lighting Zone specifications are part of Connecticut's State Building Code

Example of Lighting Zones, taken from RP-33 Lighting For The Exterior Environments



Exterior Lighting Zones

Table C405.6.2(2)

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

		Zone 1	Zone 2	Zone 3	Zone 4
Base Site Allowance		500 W	600 W	750 W	1300 W
Tradable Surfaces	**Uncovered Parking Areas**				
	Parking areas and drives	0.04 W/ft^2	0.06 W/ft^2	0.10 W/ft^2	0.13 W/ft^2
	Building Grounds				
	Walkways less than 10 feet wide	0.7 W/linear foot	0.7 W/linear foot	0.8 W/linear foot	1.0 W/linear foot
	Walkways 10 feet wide or greater Plaza areas Special Feature Areas	0.14 W/ft^2	0.14 W/ft^2	0.16 W/ft^2	0.2 W/ft^2
	Stairways	0.75 W/ft^2	1.0 W/ft^2	1.0 W/ft^2	1.0 W/ft^2
	Pedestrian Tunnels	0.15 W/ft^2	0.15 W/ft^2	0.2 W/ft^2	0.3 W/ft^2

Lighting's Off-Site Impacts - Use of Shielding/Glare Control

Set Requirements for Fully Shielded Lighting Fixtures for all new commercial applications

- **By Special Permit, exception for decorative post top parking lot and street lighting fixtures**

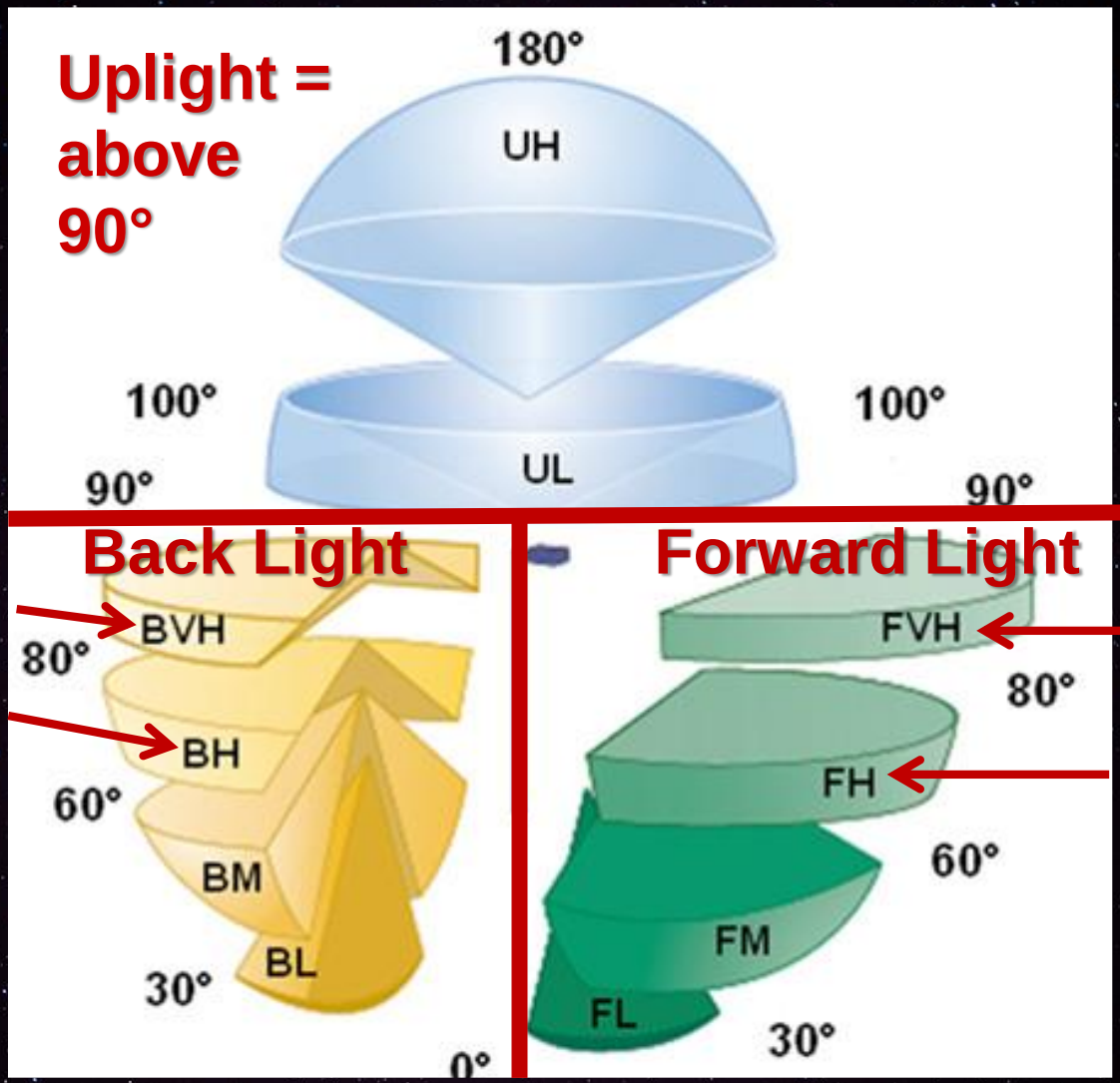
Adopt BUG Rating Limits from the MLO

* **Backlight, Uplight and Glare**
* **BUG Allowances vary by Lighting Zone**

Set Lighting Curfews in Business districts

*** 1 hour after closing, exterior lights are turned off (or programmed to dim to 30%) – Motion activation if necessary.**

Backlight, Uplight and Glare – BUG Rating

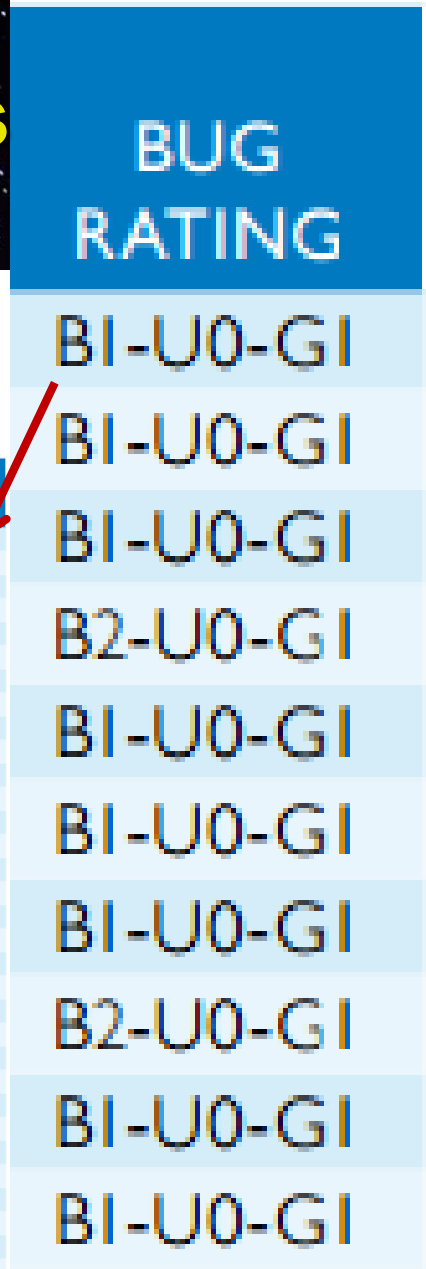


BUG Ratings now included as part of Luminaire Manufacturer's Photometrics – easy to check

LED Lamp Details

LED = Philips Lumileds Luxeon R, CRI = 70, CCT = 4000K (+/- 350K)
System (LED + driver) rated life = 100,000 hrs[1]

LAMP	TYPICAL DELIVERED LUMENS	TYPICAL SYSTEM WATTAGE[2] (W)	TYPICAL CURRENT @ 120V (A)	TYPICAL CURRENT @ 208V (A)	TYPICAL CURRENT @ 240V (A)	TYPICAL CURRENT @ 277V (A)	LED CURRENT (mA)	HID EQUIVALENT[3]	LUMINAIRE EFFICACY RATING (LM/W)	BUG RATING
35W32LED4K-R-LE2	3200	35	0.29	0.17	0.16	0.15	350	70 -100	91.4	B1-U0-G1
35W32LED4K-R-LE3	3200	35	0.29	0.17	0.16	0.15	350	70 -100	91.4	B1-U0-G1
35W32LED4K-R-LE4	3200	35	0.29	0.17	0.16	0.15	350	70 -100	91.4	B1-U0-G1
35W32LED4K-R-LE5	3200	35	0.29	0.17	0.16	0.15	350	70 -100	91.4	B2-U0-G1
55W32LED4K-R-LE2	4500	52	0.40	0.23	0.21	0.19	530	100 - 150	86.5	B1-U0-G1
55W32LED4K-R-LE3	4500	52	0.40	0.23	0.21	0.19	530	100 - 150	86.5	B1-U0-G1
55W32LED4K-R-LE4	4500	52	0.40	0.23	0.21	0.19	530	100 - 150	86.5	B1-U0-G1
55W32LED4K-R-LE5	4500	52	0.40	0.23	0.21	0.19	530	100 - 150	86.5	B2-U0-G1
55W48LED4K-R-LE2	5000	55	0.38	0.22	0.23	0.21	350	100 - 150	90.9	B1-U0-G1
55W48LED4K-R-LE3	5000	55	0.38	0.22	0.23	0.21	350	100 - 150	90.9	B1-U0-G1
55W48LED4K-R-LE4	5000	55	0.38	0.22	0.23	0.21	350	100 - 150	90.9	B1-U0-G1
55W48LED4K-R-LE5	5000	55	0.38	0.22	0.23	0.21	350	100 - 150	90.9	B2-U0-G1
80W48LED4K-R-LE2	7200	79	0.63	0.36	0.34	0.31	530	150-200	91.1	B2-U0-G1
80W48LED4K-R-LE3	7200	79	0.63	0.36	0.34	0.31	530	150-200	91.1	B2-U0-G1
80W48LED4K-R-LE4	7200	79	0.63	0.36	0.34	0.31	530	150-200	91.1	B2-U0-G1
80W48LED4K-R-LE5	7200	79	0.63	0.36	0.34	0.31	530	150-200	91.1	B3-U0-GI
70W64LED4K-R-LE2	6200	71	0.58	0.34	0.32	0.3	350	100 - 150	87.3	B2-U0-G1
70W64LED4K-R-LE3	6200	71	0.58	0.34	0.32	0.3	350	100 - 150	87.3	B2-U0-G1
70W64LED4K-R-LE4	6200	71	0.58	0.34	0.32	0.3	350	100 - 150	87.3	B2-U0-G1
70W64LED4K-R-LE5	6200	71	0.58	0.34	0.32	0.3	350	100 - 150	87.3	B3-U0-GI
110W64LED4K-R-LE2	9300	103	0.80	0.46	0.42	0.38	530	200 - 250	90.3	B2-U0-G2
110W64LED4K-R-LE3	9300	103	0.80	0.46	0.42	0.38	530	200 - 250	90.3	B2-U0-G2
110W64LED4K-R-LE4	9300	103	0.80	0.46	0.42	0.38	530	200 - 250	90.3	B2-U0-G2
110W64LED4K-R-LE5	9300	103	0.80	0.46	0.42	0.38	530	200 - 250	90.3	B4-U0-G2
90W80LED4K-R-LE2	8600	87	0.78	0.43	0.40	0.34	350	150-200	98.9	B2-U0-G2
90W80LED4K-R-LE3	8600	87	0.78	0.43	0.40	0.34	350	150-200	98.9	B2-U0-G2
90W80LED4K-R-LE4	8600	87	0.78	0.43	0.40	0.34	350	150-200	98.9	B2-U0-G2
90W80LED4K-R-LE5	8600	87	0.78	0.43	0.40	0.34	350	150-200	98.9	B4-U0-G2
135W80LED4K-R-LE2	12000	129	1.15	0.61	0.58	0.5	530	250 - 320	93.0	B2-U0-G2
135W80LED4K-R-LE3	12000	129	1.15	0.61	0.58	0.5	530	250 - 320	93.0	B2-U0-G2
135W80LED4K-R-LE4	12000	129	1.15	0.61	0.58	0.5	530	250 - 320	93.0	B2-U0-G2
135W80LED4K-R-LE5	12000	129	1.15	0.61	0.58	0.5	530	250 - 320	93.0	B4-U0-G2



Model Lighting Ordinance BUG Rating

TABLE C-1	Allowed Backlight Rating				
Lighting Zone	0	1	2	3	4
Greater than 2 mounting Heights from the property line	B4	B4	B4	B4	B4
1 to less than 2 mounting heights from the property line and properly oriented	B1	B2	B3	B4	B4
0.5 to less than 1 mounting heights from the property line and properly oriented	B0	B1	B2	B3	B3
Less than 0.5 mounting heights from the property line and properly oriented	B0	B0	B0	B1	B2

TABLE C-2 Allowed Uplight Rating

Lighting Zone	0	1	2	3	4
Allowed Uplight Rating For street or area lighting	U0	U0	U0	U0	U0
Allowed Uplight Rating for ornamental parking lighting and luminaires not used for street or area lighting	U0	U1	U2	U3	U4
Permitted Lumens	0	20	100	1,000	2,000

TABLE C-3 Allowed Glare Rating

Lighting Zone	0	1	2	3	4
Any Luminaire not ideally oriented with 1 to less than 2 mounting heights to any property line of concern	G0	G0	G1	G1	G2
Any Luminaire not ideally oriented with 0.5 to less than 1 mounting height to any property line of concern	G0	G0	G0	G1	G1
Any Luminaire not ideally oriented with less than 0.5 mounting height to any property line of concern	G0	G0	G0	G0	G1

[1] If the luminaire is not optically symmetric and the nearest property line is less than 2 mounting heights from the front hemisphere of the luminaire distribution, the reduced glare rating must be met.

MLO Recommended Practices For Landscape Lighting For Residential

IX. TABLES (cont.) - Ordinance Text

Table G - Residential Lighting Limits

Lighting Application	LZ 0	LZ 1	LZ 2	LZ 3	LZ 4
Row 1 Maximum Allowed Luminaire Lumens* for Unshielded Luminaires at one entry only	Not allowed	420 lumens	630 lumens	630 lumens	630 lumens
Row 2 Maximum Allowed Luminaire Lumens* for each Fully Shielded Luminaire	630 lumens	1,260 lumens	1,260 lumens	1,260 lumens	1,260 lumens
Row 3 Maximum Allowed Luminaire Lumens* for each Unshielded Luminaire excluding main entry	Not allowed	315 lumens	315 lumens	315 lumens	315 lumens
Row 4 Maximum Allowed Luminaire Lumens* for each Landscape Lighting	Not allowed	Not allowed	1,050 lumens	2,100 lumens	2,100 lumens
Row 5 Maximum Allowed Luminaire Lumens* for each Shielded Directional Flood Lighting	Not allowed	Not allowed	1,260 lumens	2,100 lumens	2,100 lumens
Row 6 Maximum Allowed Luminaire Lumens* for each Low Voltage Landscape Lighting	Not allowed	Not allowed	525 lumens	525 lumens	525 lumens

* Luminaire lumens equals Initial Lamp Lumens for a lamp, multiplied by the number of lamps in the luminaire

Maximize Energy Efficiency & Minimize Costs

Dimmers and Network Devices with new LED lighting systems will reduce energy use

Curfews for Lights Out – reduced to 30% of full capacity after the close of business and pedestrian activity

Motion activation for outdoor security lighting after business hours

LED lighting systems for new and replacement lighting.

Dimming a little from full capacity extends life of the LED system. Purchase system with a slightly higher light output than is required, then dim down to the light level needed for the project to extend equipment life.

Dimmable Streetlights

May 2018 – Connecticut Regulators ordered Eversource to develop new rate for dimmable streetlights

August 2018 – Eversource did analysis in Westwood MA of actual data on energy consumption for dimmable streetlights

Anticipated electrical savings of 20% to 30%

Connecticut rate for dimmable streetlights should Be in place 2019 – 2020 at the latest

Key Considerations for Replacing older Outdoor Lights with LEDs

- **Specify the maximum CCT** at preferably 2,700K – no more than 3,000K – minimize blue light levels
- **Fixture lumen output** of LED can be reduced by 67% of High Pressure Sodium's fixture output and achieve the same visibility to the eye.
- **Choose a luminaire with a light output** that will be about 30% greater than what is needed – then using a dimmable lighting system, dim the lights down 30%. This dimming will considerably extend the life of the light compared to having the light operating at 100% output – Extended life reduces maintenance costs.
- **Pick best lumens/watt for optimum energy conservation**

Key Considerations, cont.

- **Fully Shield and eliminate glare when possible**

  Controlling Light Trespass and Sky Glow

- **Brightness**

  Controlling Light (Lumen) Levels

- **Energy Efficiency**

  the Use of Dimmers and Timing devices with new LED Lighting systems

Thank you!

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