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www.clantonassociates.com

Trends in Lighting Technology

City of Fort Collins Utilities

1. Typical Questions Asked about LEDs

- Are LEDs really energy efficient?
- Do LEDs last a long time?
- Are LEDs cost effective?
- What's the difference in quality?
- How do I select the best application?
- How do I select the right equipment?
- What else?

LED Basics

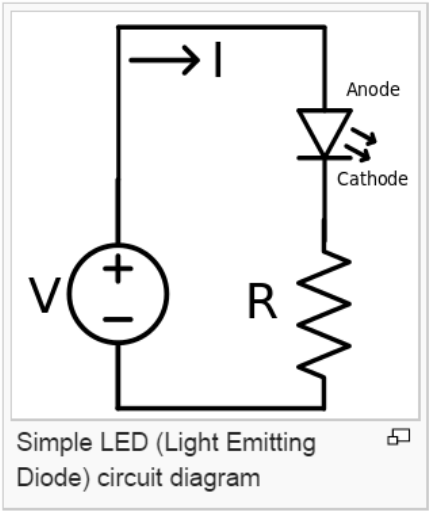
Blue Light Pump

Directional

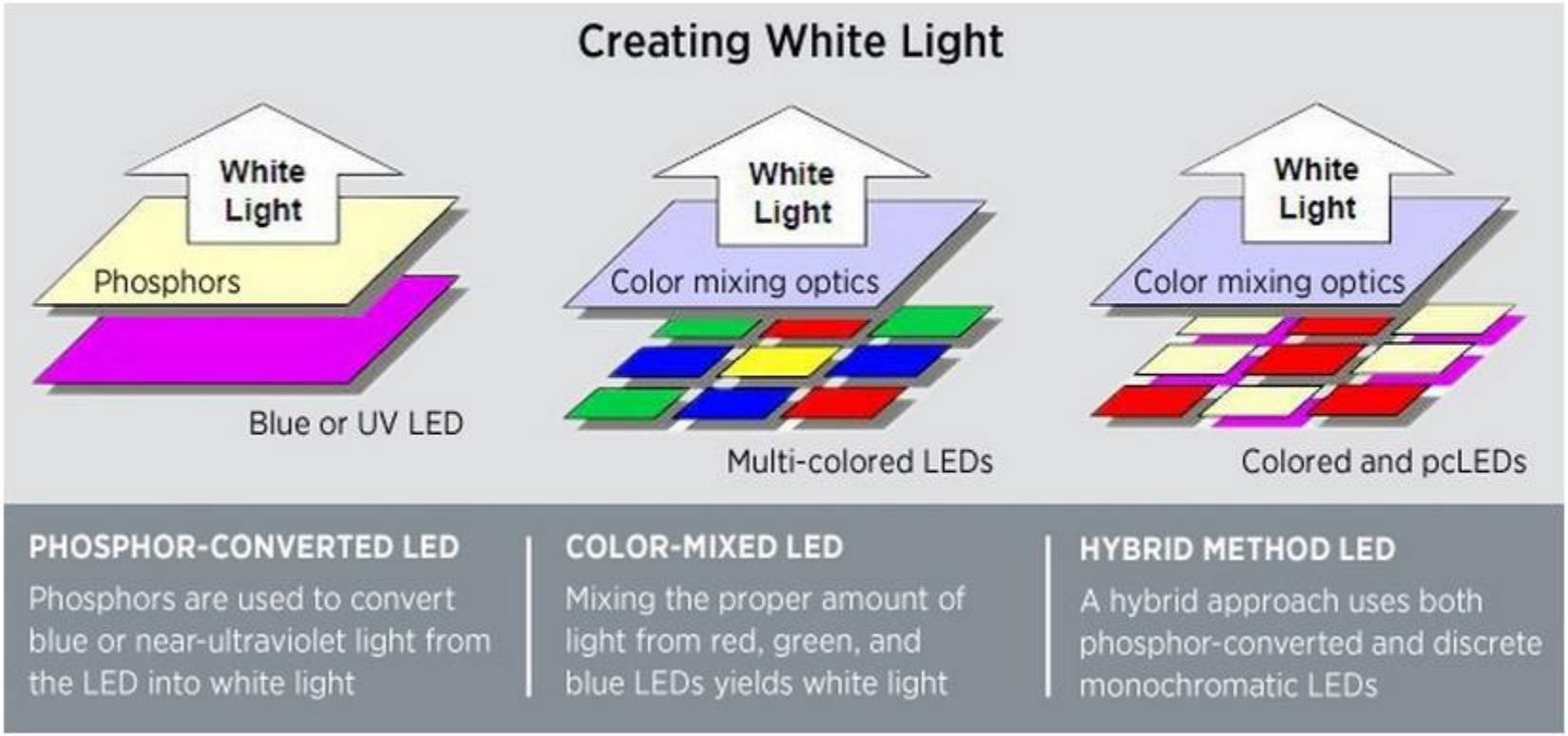
Energy Use

LED

Light Emitting Diode



Simple LED (Light Emitting Diode) circuit diagram



Source: DOE

Blue pump + phosphor = white light

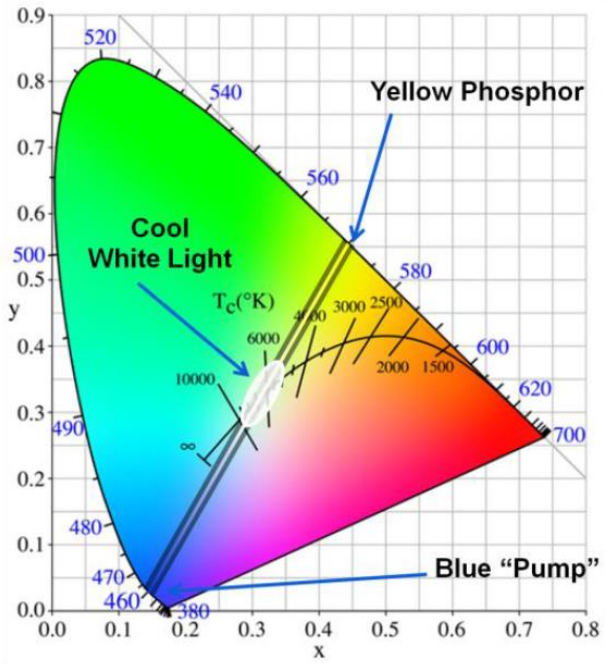


Figure 5. Blue pump with yellow phosphor produces cool white light. Illustrations courtesy of Philips Lumileds Lighting Company.

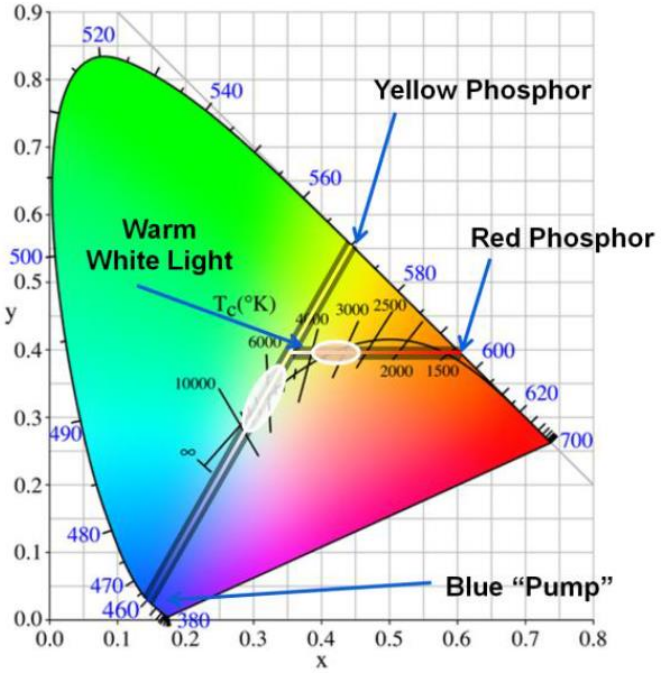
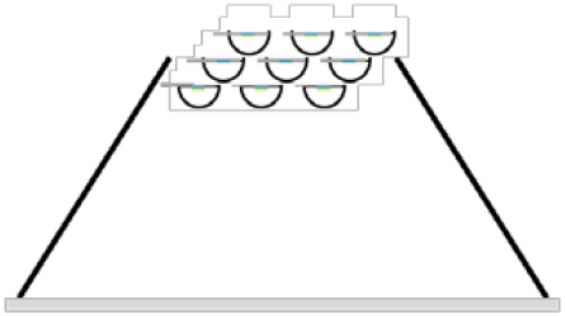


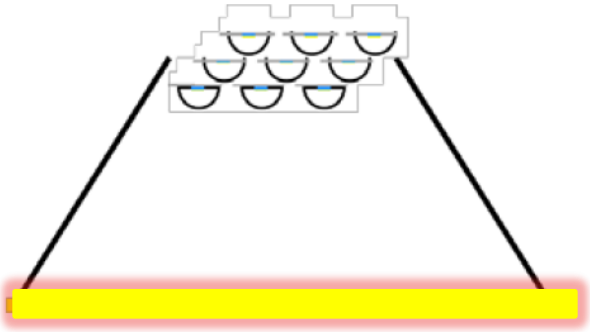
Figure 6. Blue pump with yellow + red phosphors produces warm white light. Illustrations courtesy of Philips Lumileds Lighting Company.

Downlight Application

White LEDs + Reflector & Diffuser

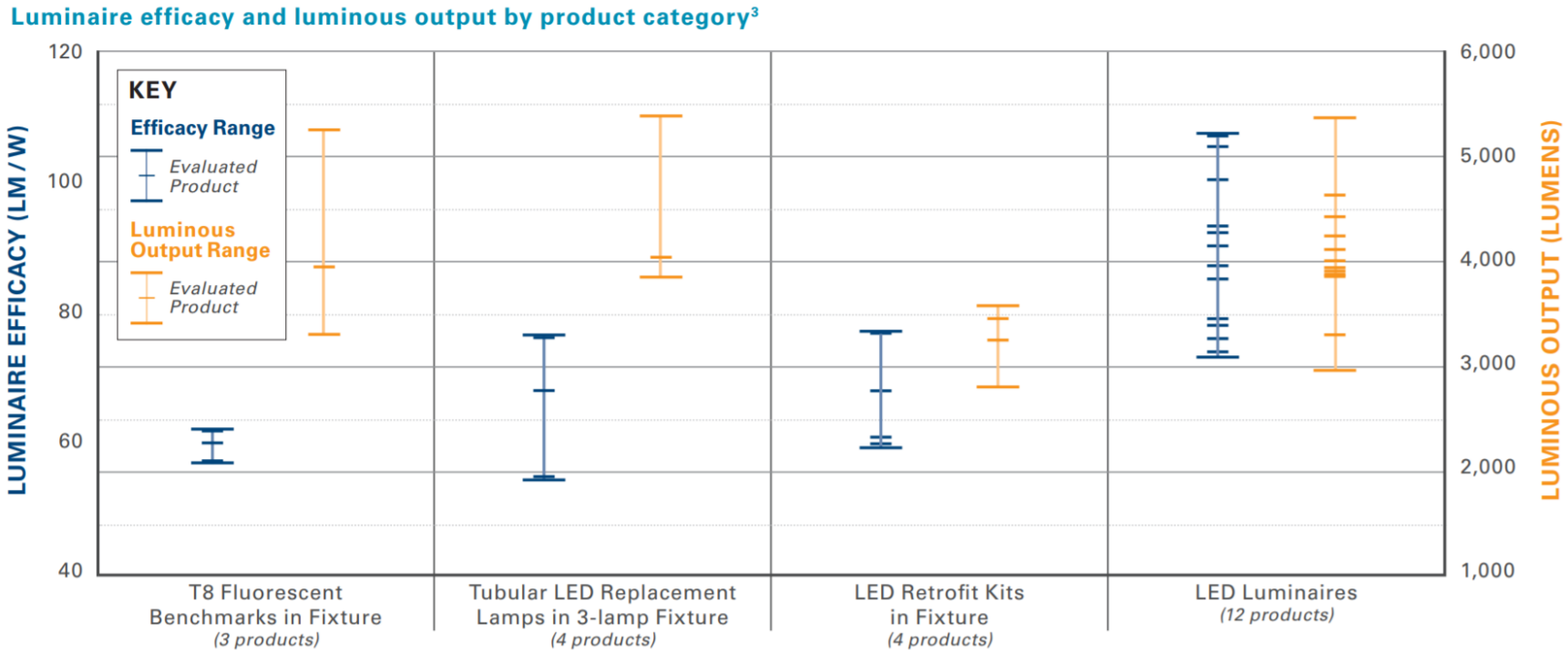


Blue LEDs + Reflector & Phosphor Disc



Remote Phosphor 20% more efficient

TLED – UC Davis CLTC Report



[3] CALiPER Exploratory Study: Recessed Troffer Lighting, Prepared for the U.S. Department of Energy by the Pacific Northwest National Laboratory, PNNL-22348, 2013.

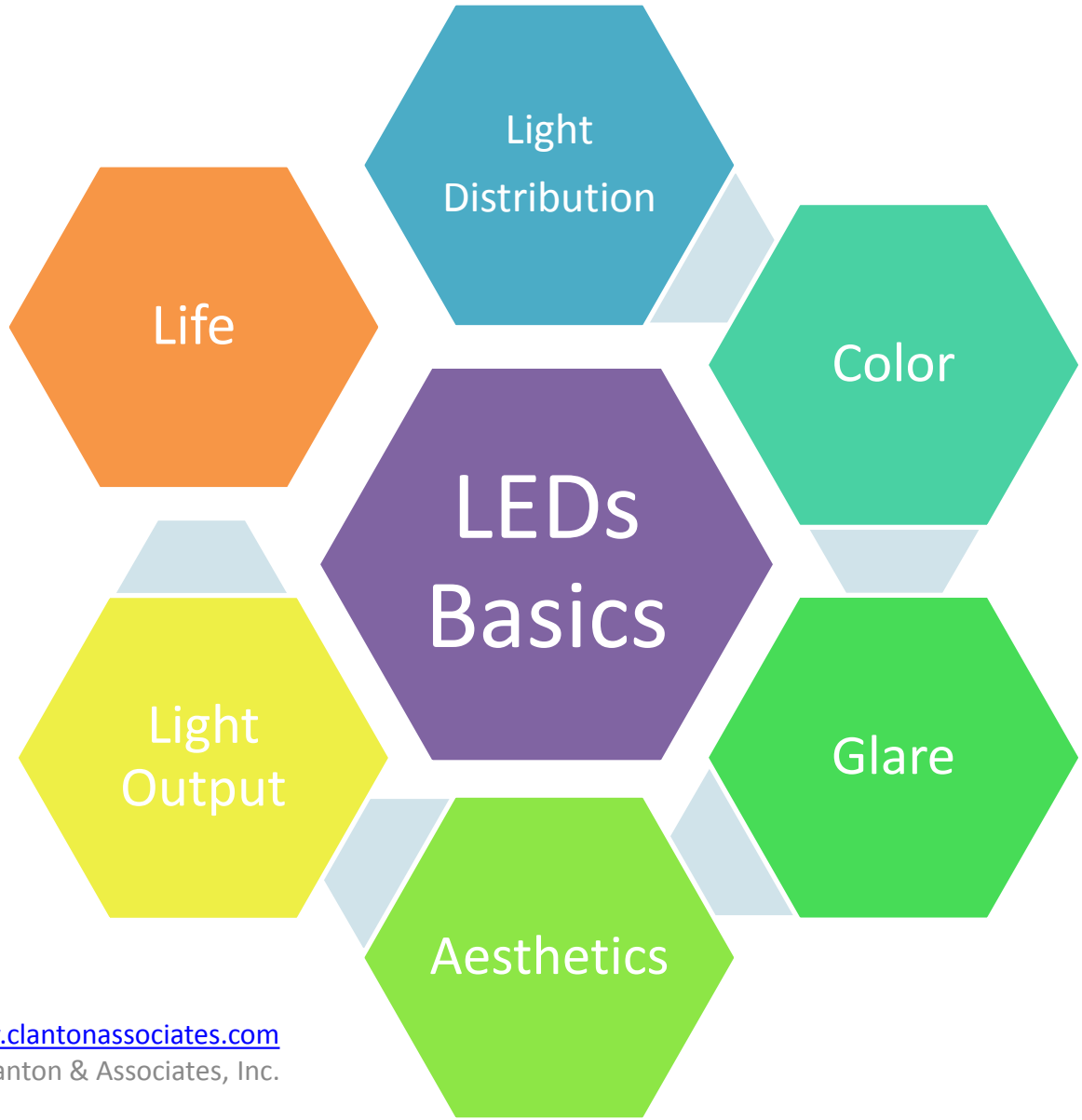
http://cltc.ucdavis.edu/sites/default/files/files/publication/LED_Retrofit_Options_Linear_Fluorescent_FINAL.pdf

TLED - UC Davis CLTC report

- LED replacement lamps typically require wiring modifications to the existing luminaire, increasing labor costs and raising safety concerns
- Installation and maintenance teams must observe safety protocols and pay careful attention to luminaire labeling, both during and after installation
- The performance characteristics and energy savings of tubular LED replacement products vary widely from product to product, even within the same product category
- Tubular LED replacement lamps often require un-shunted lamp-holders for successful operation; facility managers should keep this in mind during project planning and preparation
- Thermal performance should be analyzed in the specific troffer considered for retrofit, with attention paid to how the LED lamp manages heat
- As a directional source, LED replacement lamps require custom optics to achieve distribution patterns like those typical of omni-directional fluorescent lights

http://cltc.ucdavis.edu/sites/default/files/files/publication/LED_Retrofit_Options_Linear_Fluorescent_FINAL.pdf

Some LED Characteristics



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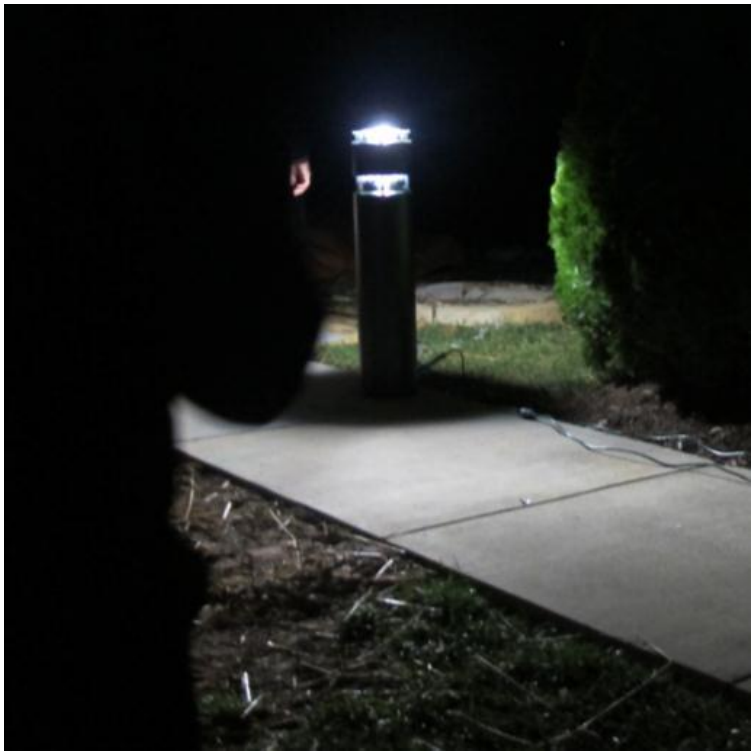
Light Distribution –
(*LM-79 report for photometric .ies files)*



NGL exterior lighting judging 2012 http://www.ngldc.org/

US Embassy Innovation Center in Helsinki

Color – CRI (<70 exterior; <80 interior)

LM-79 and Energy Star

US Embassy Innovation Center in Helsinki

Color – CCT

LM-79 and Energy Star

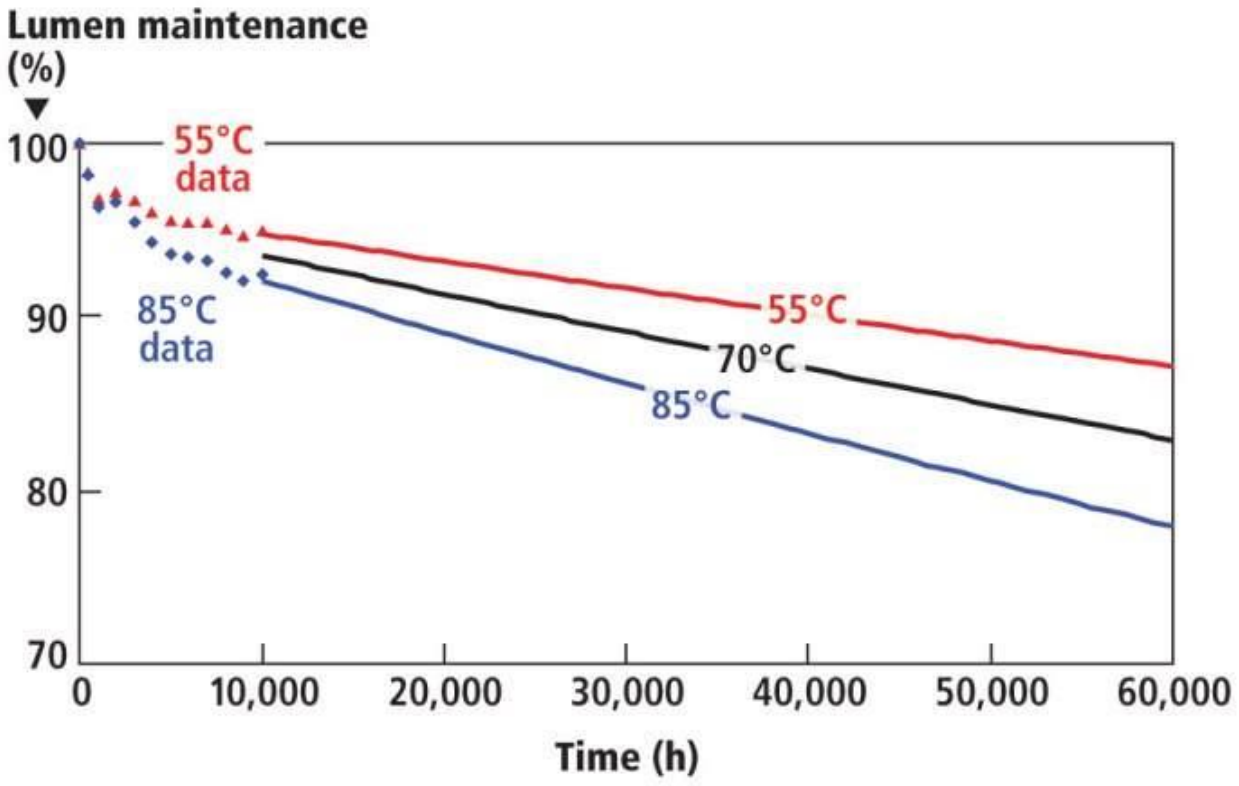
Measures light color

- "Cool" colors (3500–5500 K)
- "Warm" colors (2700–3000 K)
- Use warm colors!!

Aspen Institute, Aspen Colorado

Life - Do LEDs last a long time? –
It depends on operating temperature

- L70 (hours) = time to 70% lumen maintenance

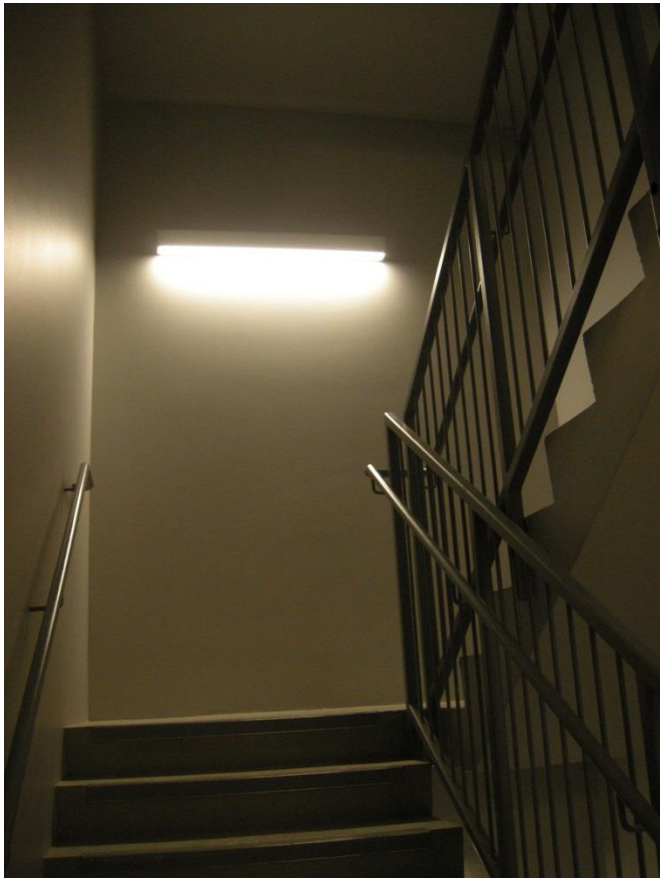


EPA ENERGY STAR Lamp Round Table

Glare

LM-79 photometric luminance
Exterior – TM-15 BUG

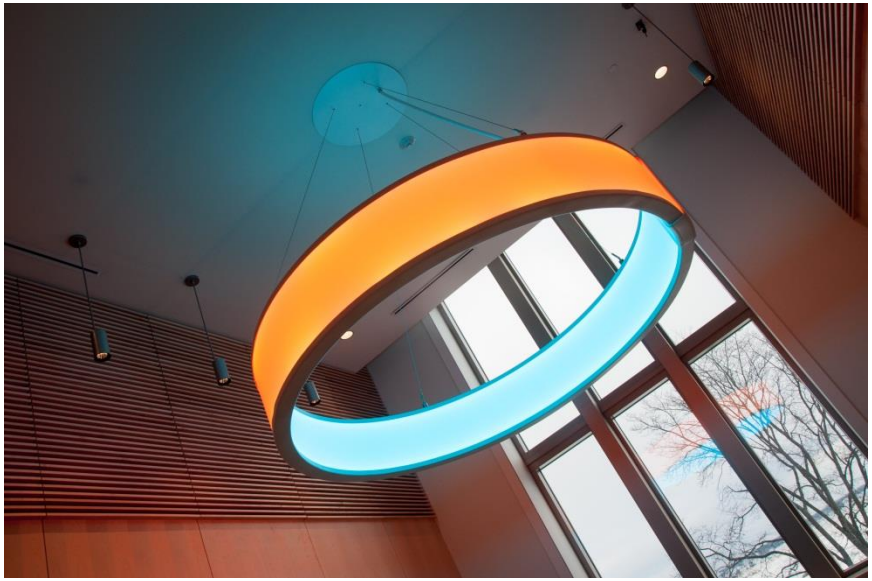
-



US Embassy Innovation Center in Helsinki

NGL exterior lighting judging 2012 http://www.ngldc.org/

Aesthetics

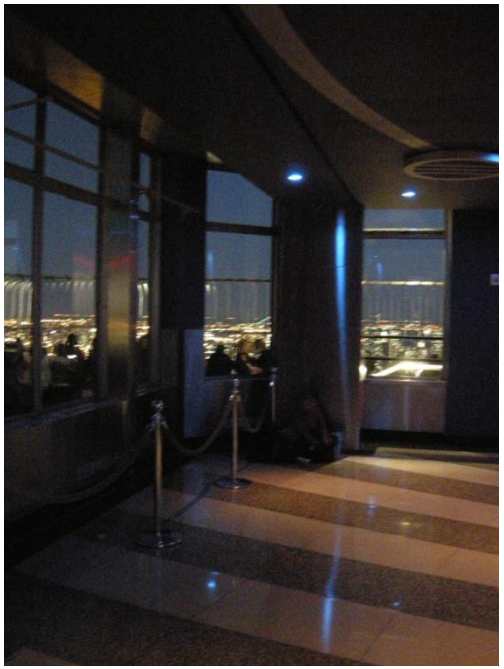


US Embassy Innovation Center in Helsinki

Light Source Replacement Issues

- Heat management issues
  - Base up lamps may overheat
  - IC rated luminaire
- Control system compatibility

USGBC Headquarters – Washington DC



The Empire State Building – Clanton & Associates

Heat Management – Power Conversion of White Light Sources

Description	Incandescent* (60W)	Fluorescent* (Typical linear CW)	Metal Halide*	LED**
Visible Light	8%	21%	27%	15-25%
IR	73%	37%	17%	≈0%
UV	0%	0%	19%	0%
Total Radiant Energy	81%	58%	63%	15-25%
Heat (Conduction + Convection)	19%	42%	37%	**75-85%**
Total	100%	100%	100%	100%

* IESNA Handbook and Osram Sylvania
** Varies depending on LED efficacy
Source: DOE Solid State Lighting – Using Light Emitting Diodes www1.eere.energy.gov/buildings/ssl/m/comparing_lights.html

LED Retrofit Issues

- Caution: inserting LEDs into existing luminaires
- Recommendation: Replace entire luminaire with LED luminaire
- Power Quality – affecting existing infrastructure

Dimming and Power Quality Issues

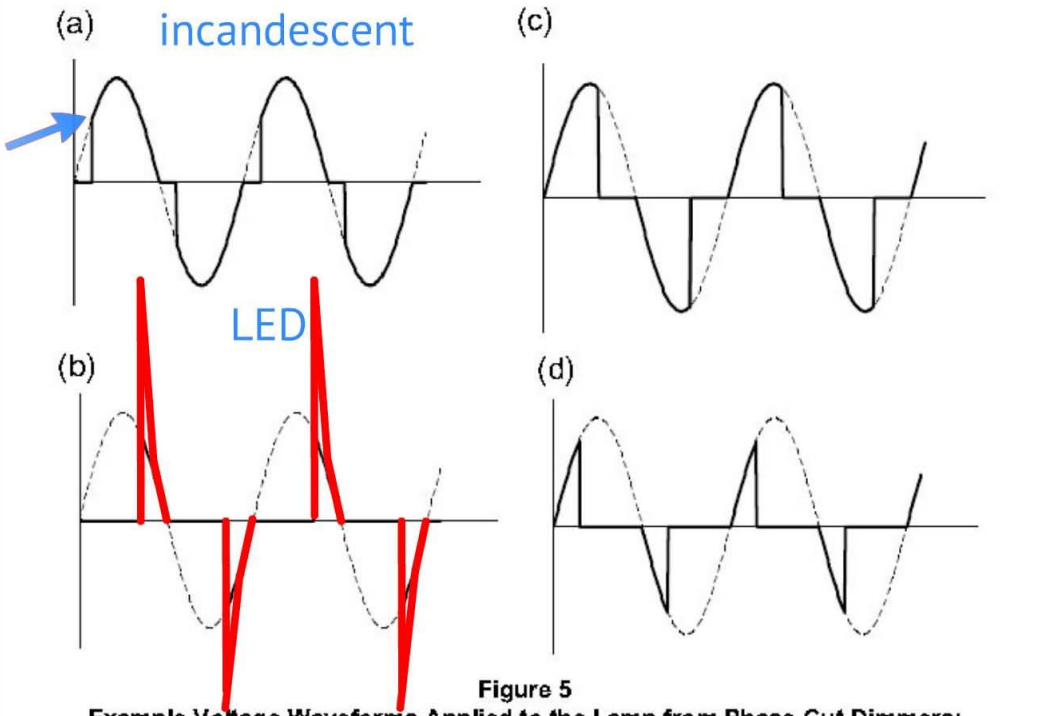


Figure 5
Example Voltage Waveforms Applied to the Lamp from Phase-Cut Dimmers:
(a) leading edge, high light level;
(b) leading edge, low light level;
(c) trailing edge, high light level;
(d) trailing edge, low light level.
Dashed line represents uncut line voltage, what would be applied if the switch were "on."

Repetitive Peak Current

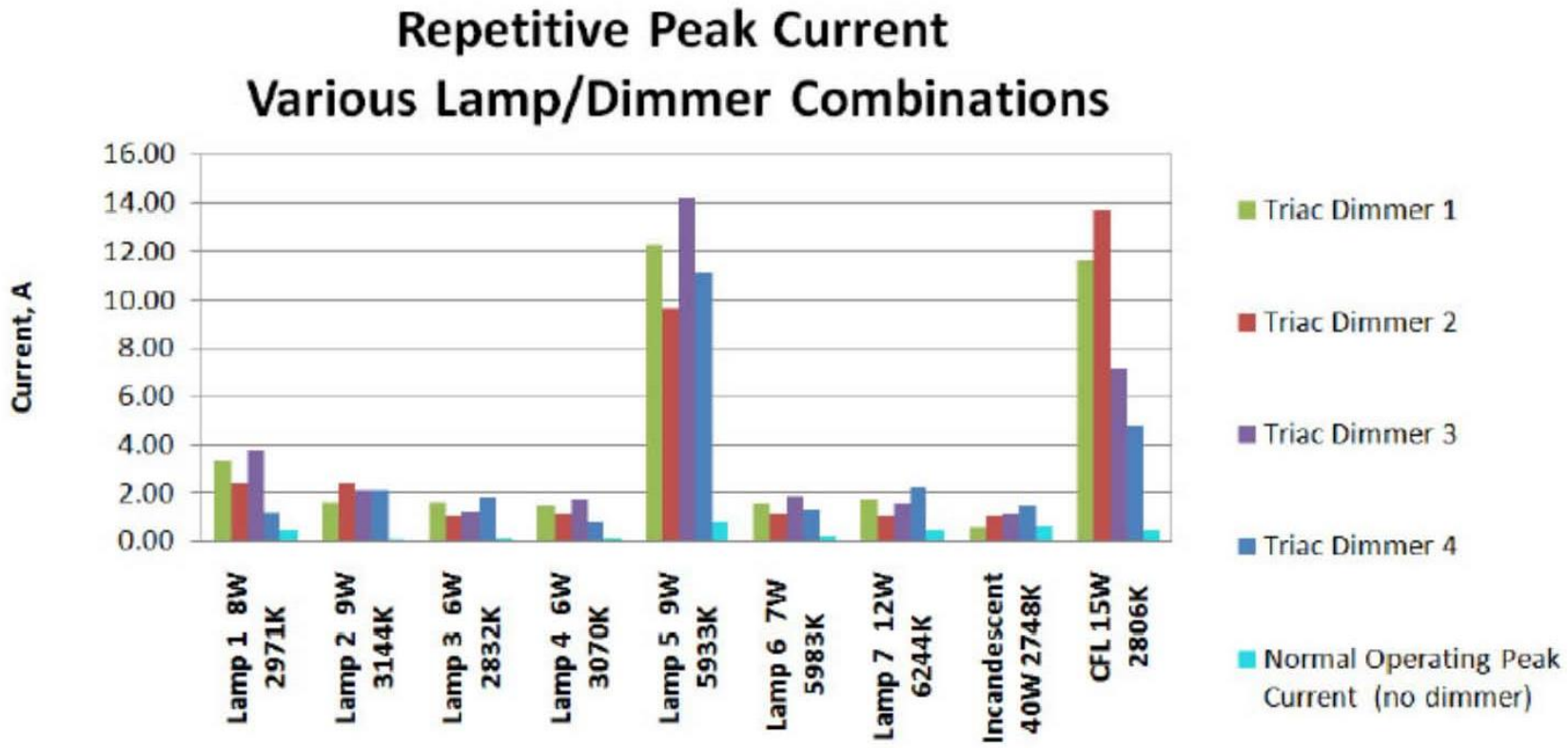


Figure 2. Repetitive peak current for various lamps and dimmers.

Source: Lighting Research Center

Equipment Coordination

- Light Sources
- Luminaires
- Drivers
- Controls

BEST Applications

- Close to the task application
  - Task
  - Grazing surfaces
- Directional
  - Accent
- Lower output

Encana – Denver, CO

Other Applications

- Ambient lighting
- Higher directional light output
- Full dimming range

Encana – Denver, CO

Hospitality Applications

www.clantonassociates.com

Westin - Snowmass

www.clantonassociates.com

Westin - Snowmass

Viceroy- Snowmass

www.clantonassociates.com

Westin - Snowmass

Correlated Color Temperature (CCT)

www.clantonassociates.com

Correlated Color Temperature (CCT)

LM-79 and Energy Star

"Warm" colors (2700–3000 K)

"Cool" colors (3500–5500 K)

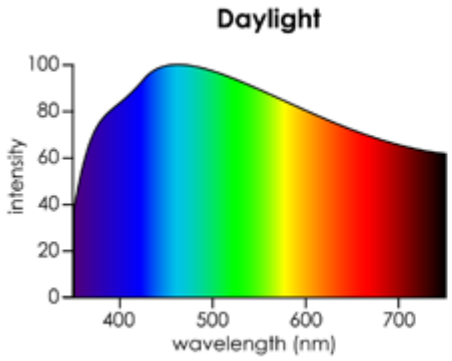
www.clantonassociates.com

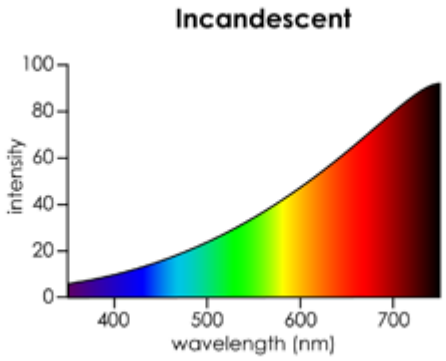
Color Rendering Index

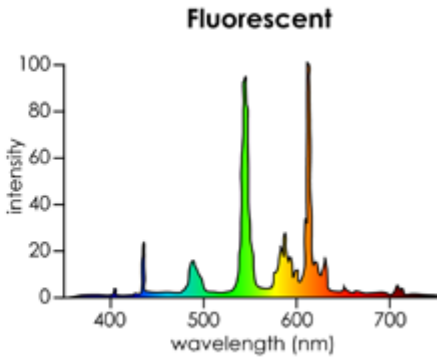
LM-79 and Energy Star

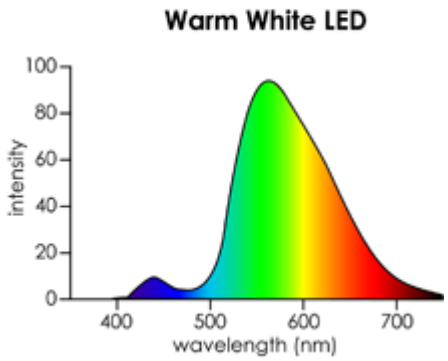
http://www.luxtg.com/color-rendering-index-cri/

Spectral Distribution (IES TM-30)



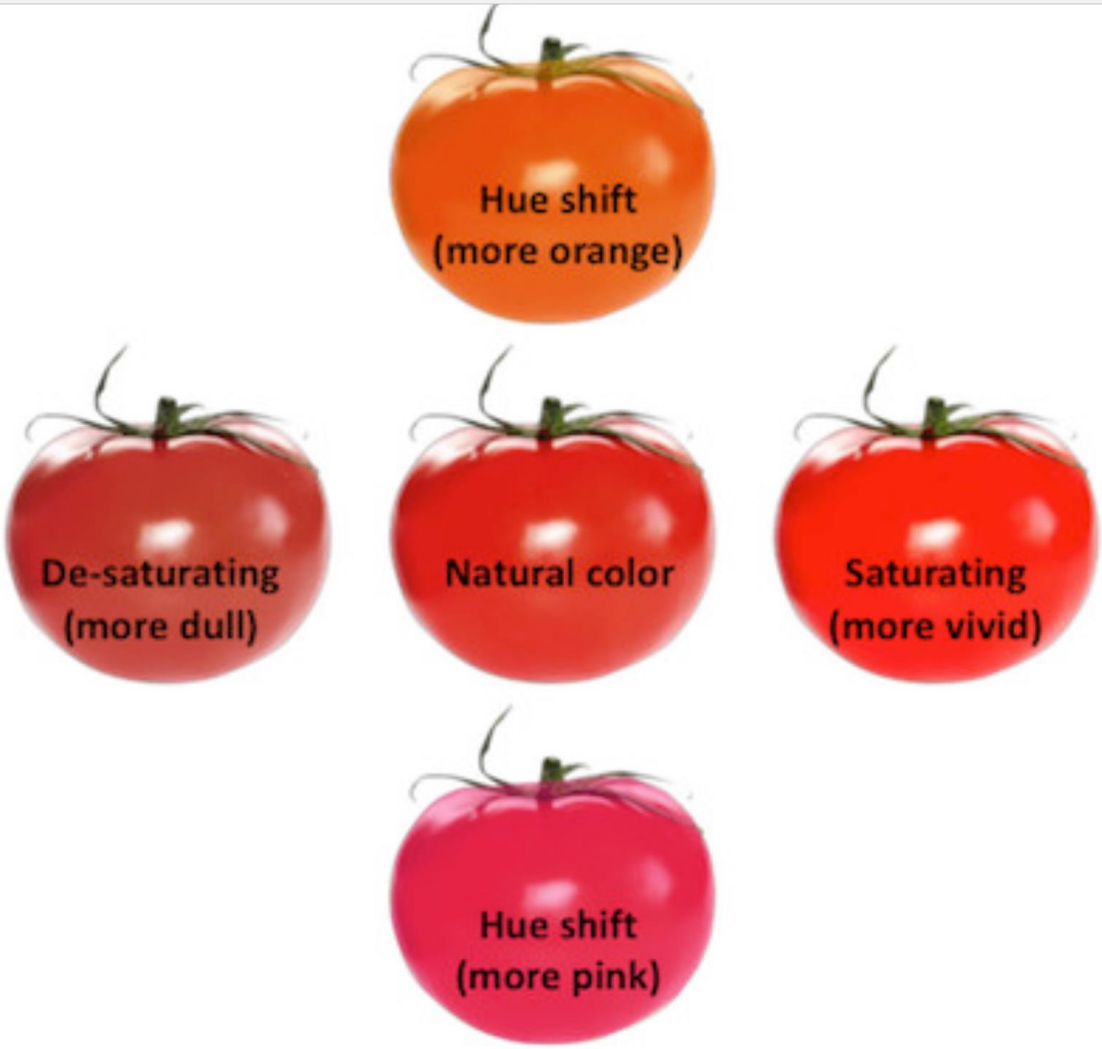






SPD graphs from GLARminy

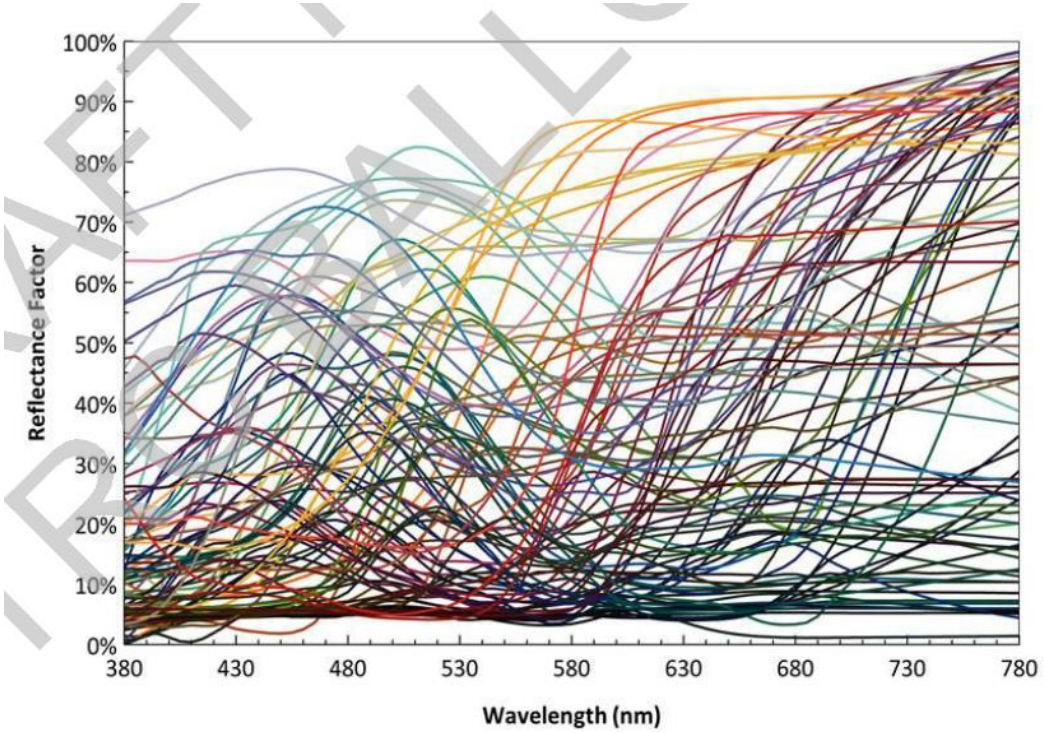
www.clantonassociates.com



March 2016 - by Aurelien David, Soraa's Chief Scientist

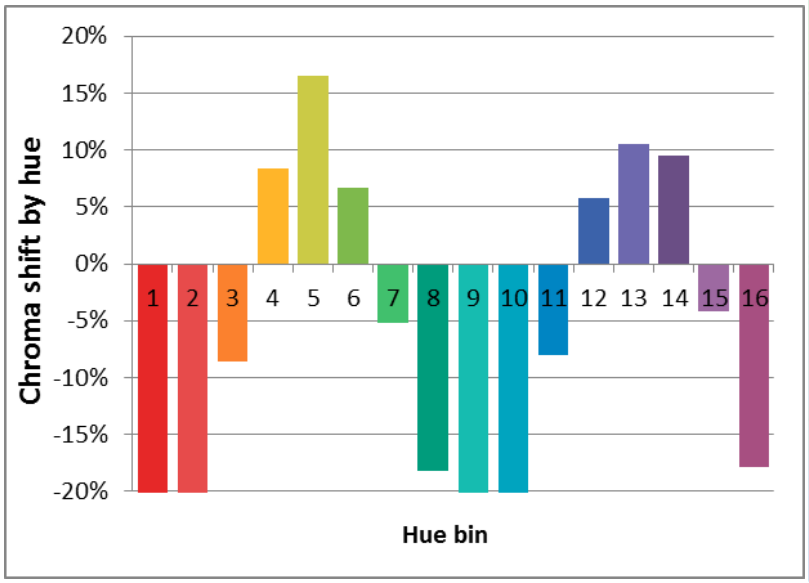
IES TM-30-15 – Fidelity Index

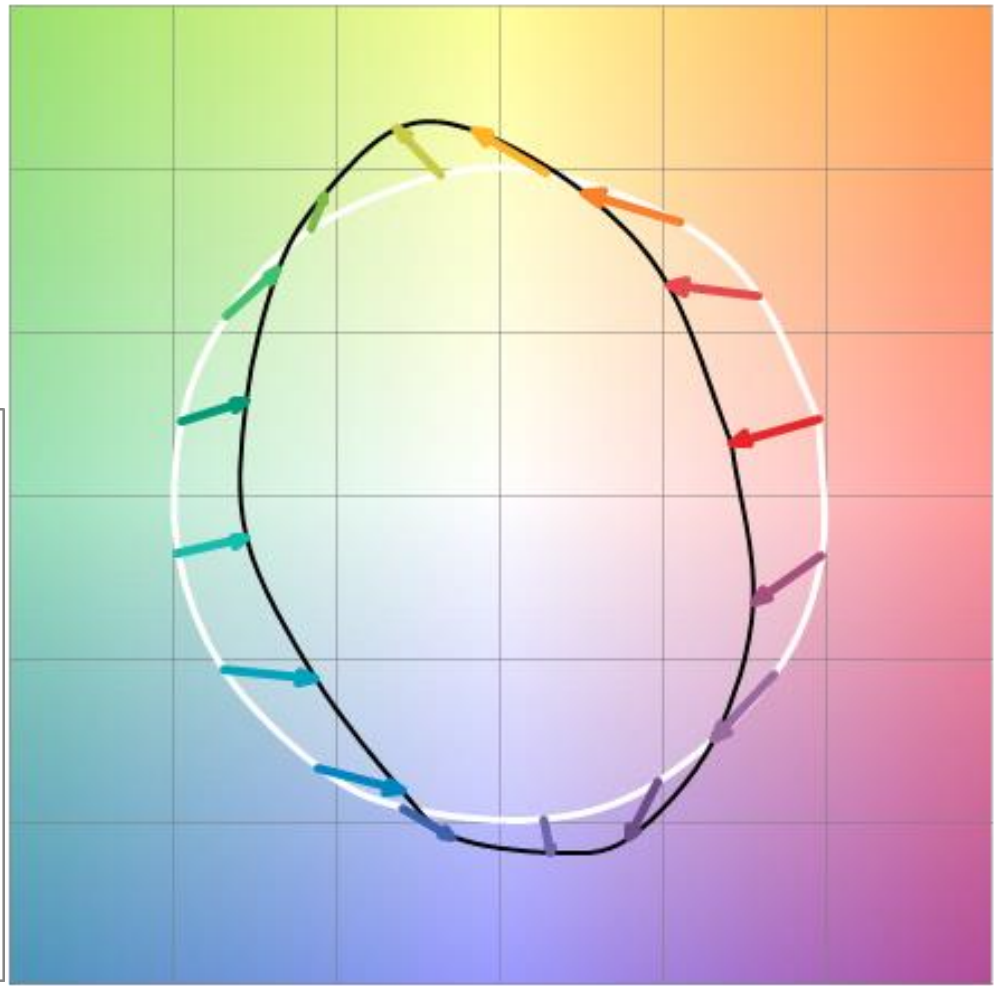
- Similar to CRI but…
  - 99 Color Samples



IES TM-30-15 – Gamut Index

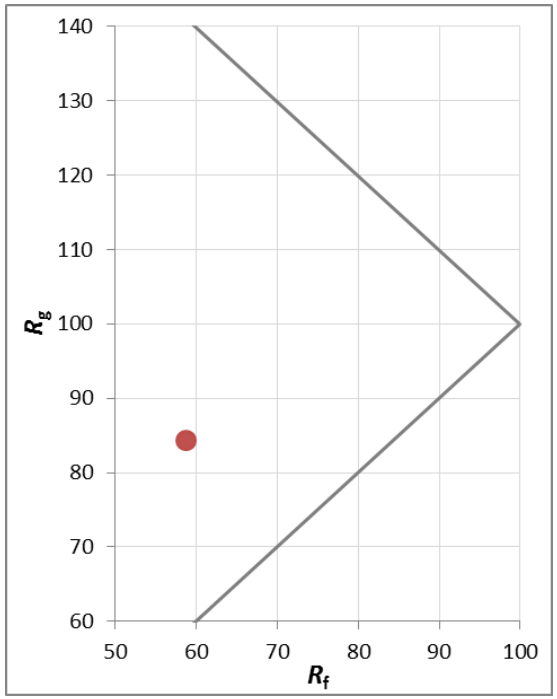
- Greater than 100 = increased saturation
- Less than 100 = decreased saturation

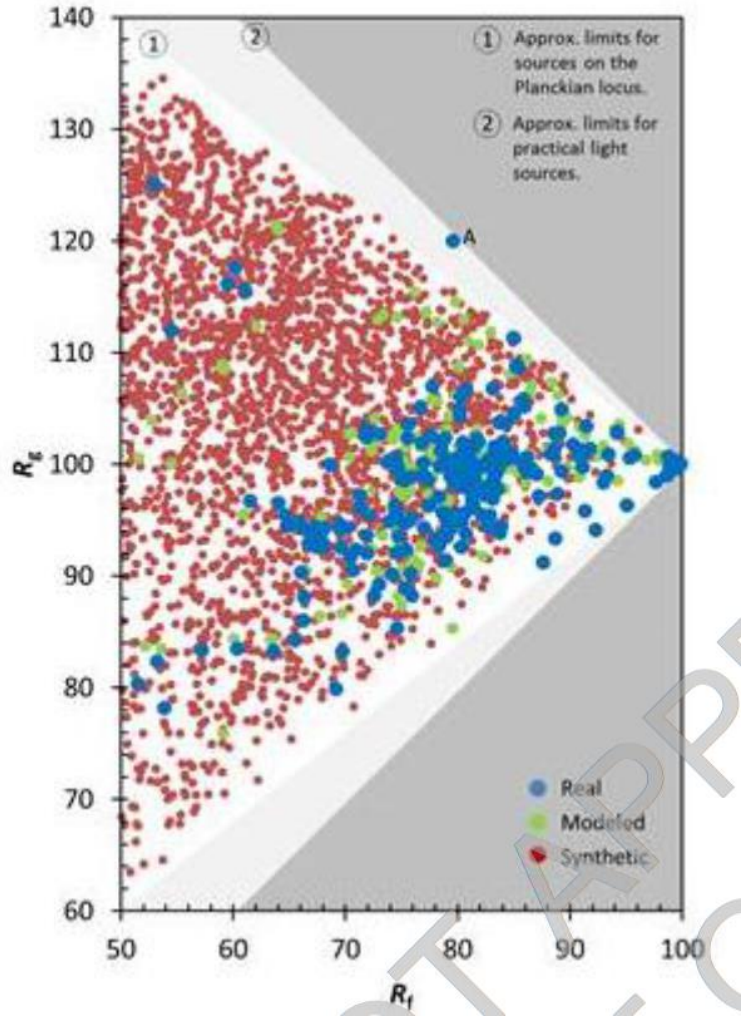




TM-30-15 – Two-Axis System

- Compare sources
  - Fidelity (accuracy)
  - Gamut (saturation)



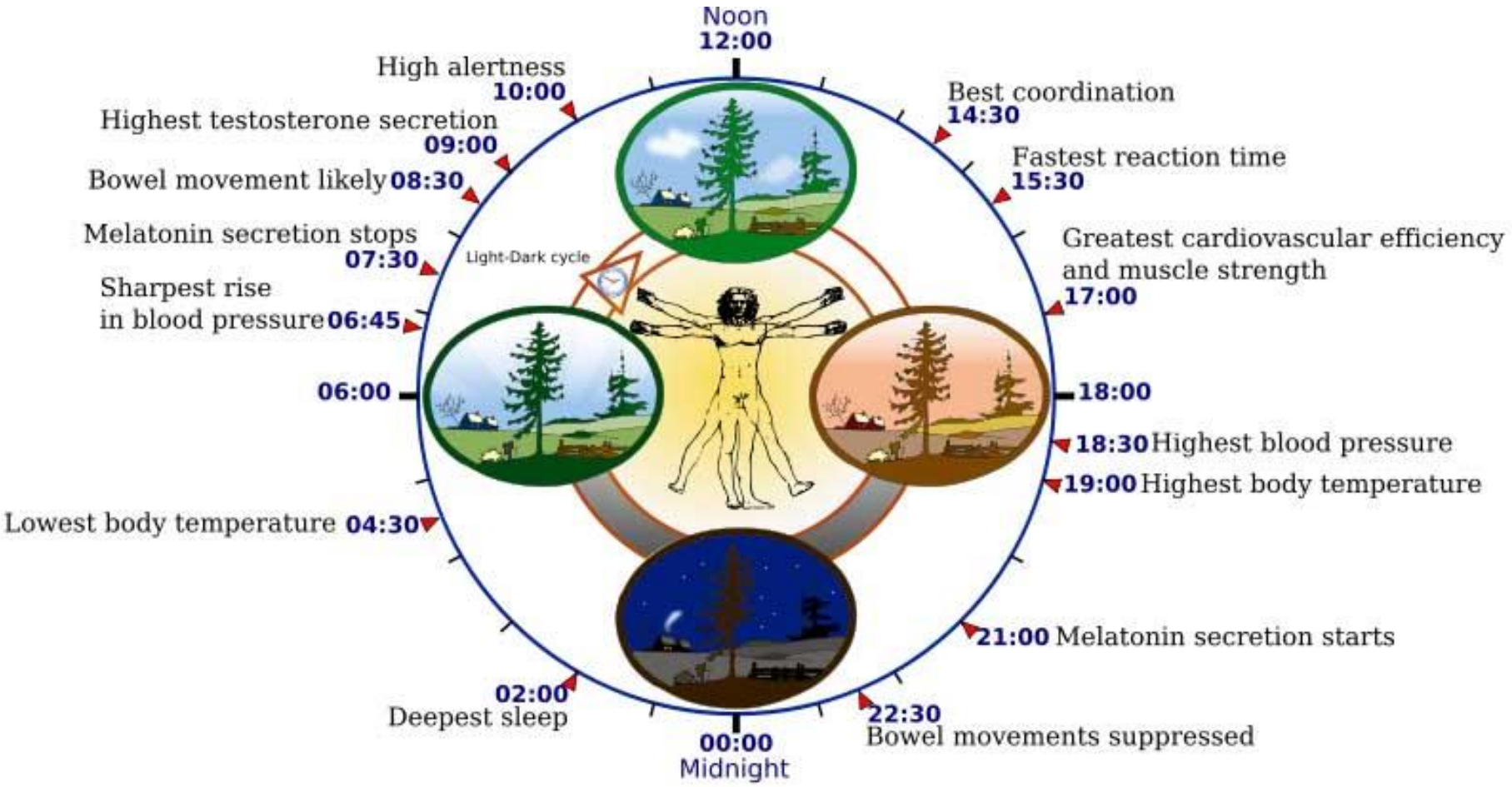


https://www.ies.org/store/technical-memoranda/ies-method-for-evaluating-light-source-color-rendition/

https://www.ies.org/store/technical-memoranda/ies-method-for-evaluating-light-source-color-rendition/

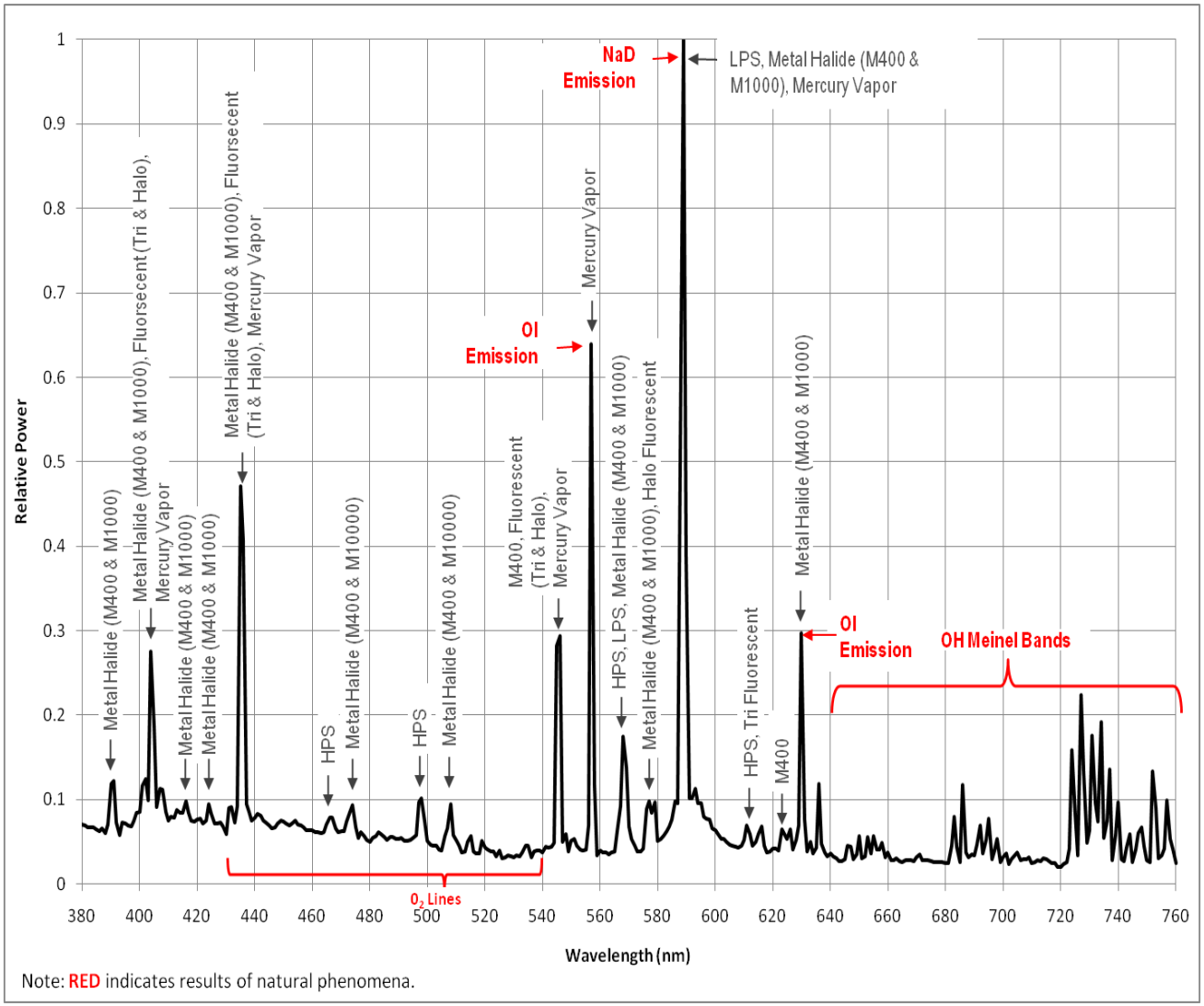
Importance of Circadian Cycles

- Patterns of Light and Dark are key to “Entrainment”



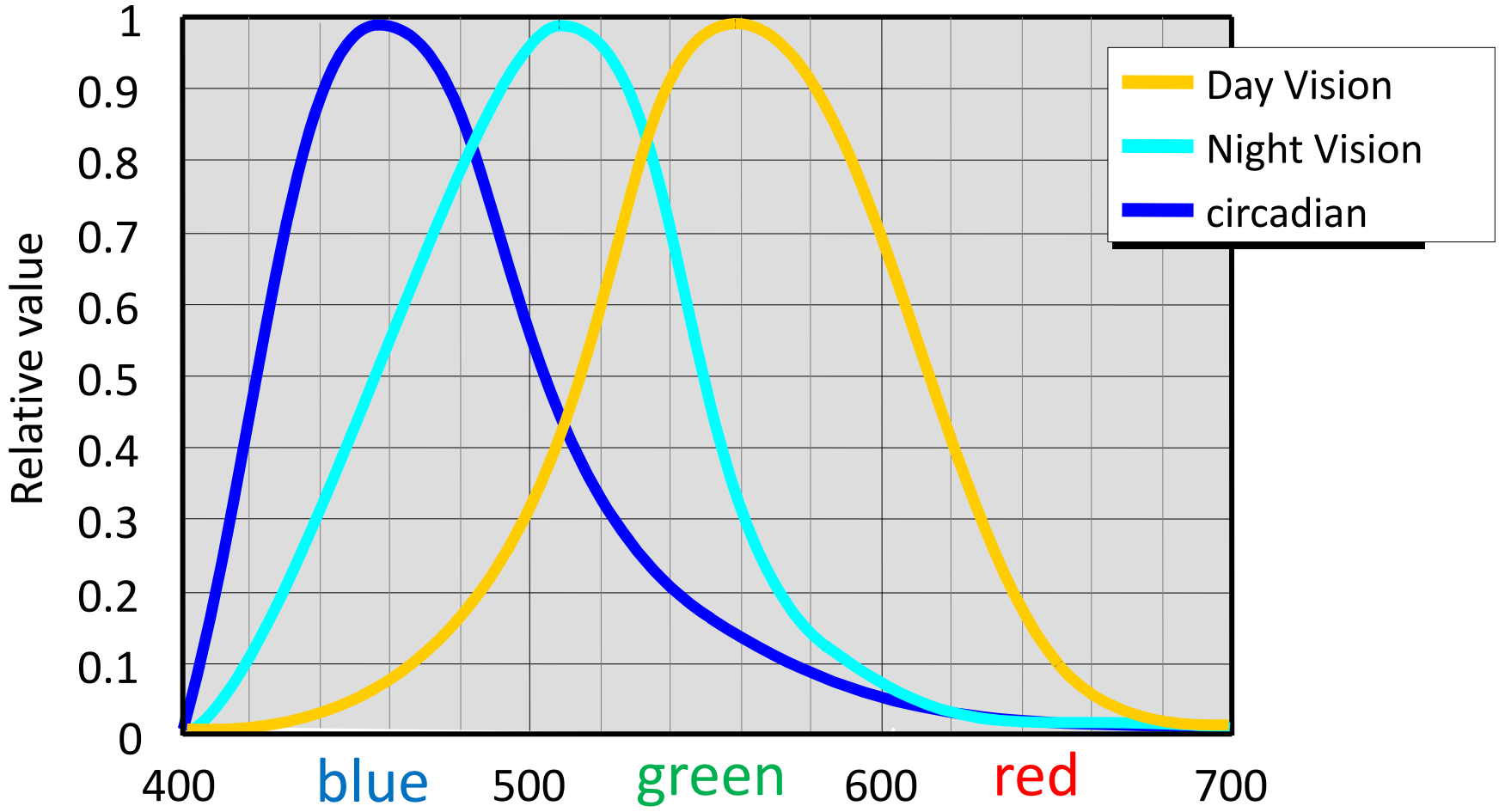
www.clantonassociates.com

Sky glow mapping



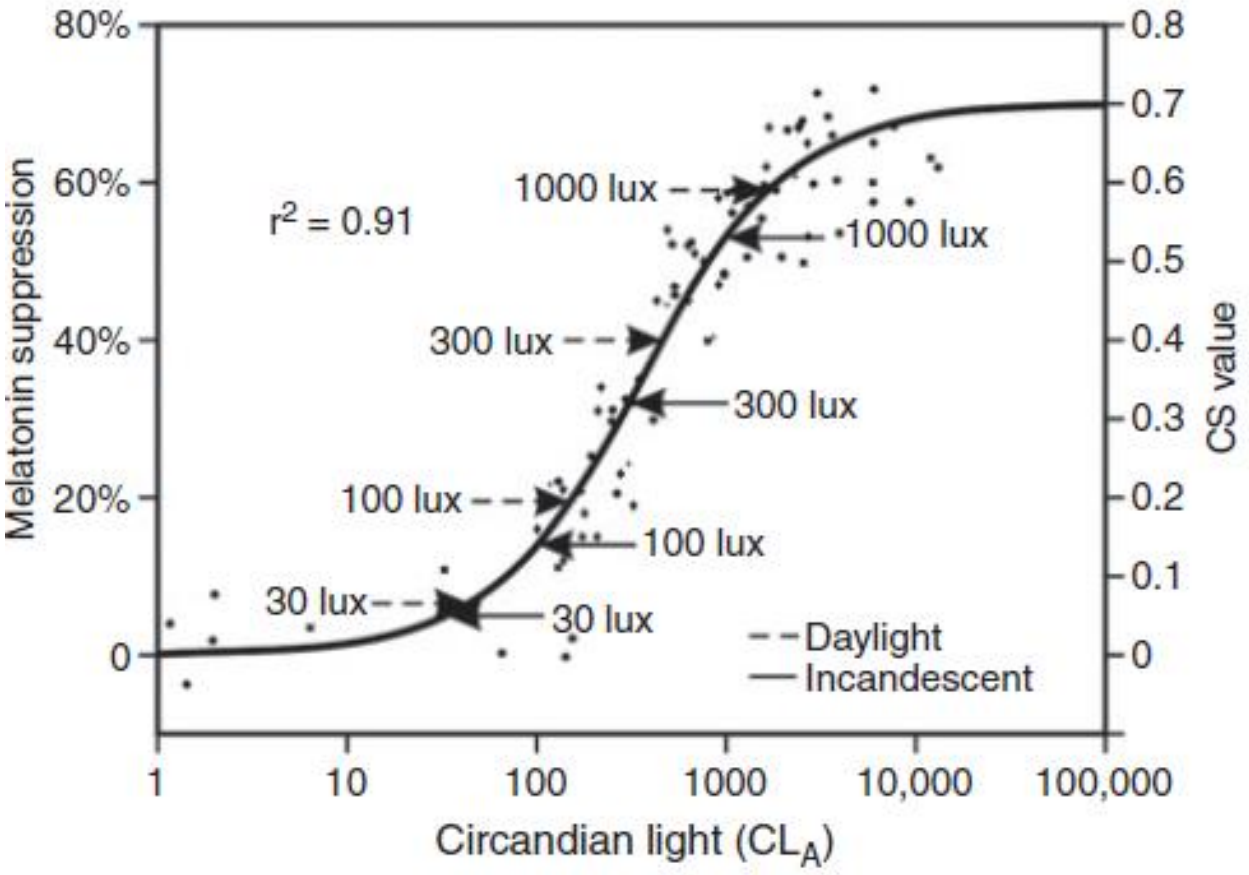
Note: **RED** indicates results of natural phenomena.

Ocular Action Spectra – Melanopic Lumen



Adapted from Brainard et al. Journal of Neuroscience, 2001

What metrics should we achieve … Circadian Stimulus (CS), ???



Source: Rea and Figueiro (2015)

Using the Circadian Stimulus calculator (LRC)

SOURCE	CS
Equal energy	0.576
D65	0.589
Incandescent (A-lamp)	0.523
Halogen 3277 K	0.553
CFL	0.473
RE 3500 K	0.535
Cool white	0.428
Design50	0.526
PS MH	0.447
Ceramic MH	0.492
HPS	0.377
LED 2700 K	0.499
LED 6500 K	0.563
LED 470nm	0.691
Red LED	0.01

Source: Light Research Center CS Calculator

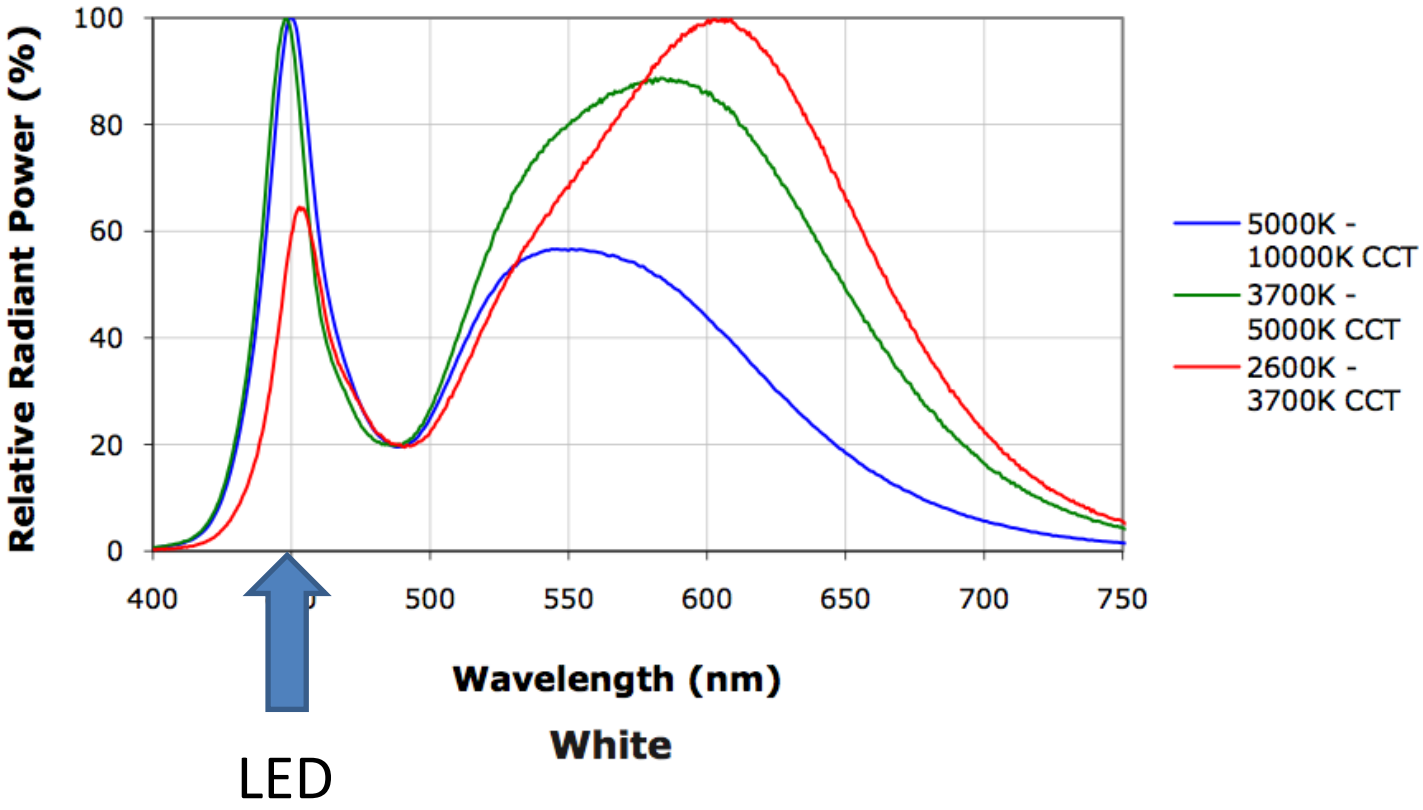
http://www.lrc.rpi.edu/resources/CSCalculator_2017_05_05.xlsm

Is there a difference between genders?

Color Tuning per time of day

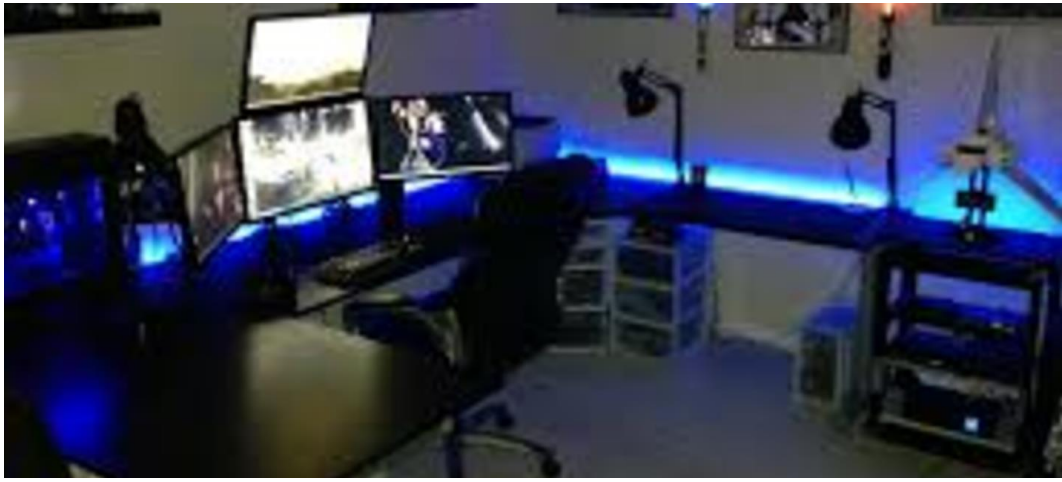
http://www.ngldc.org/

Is white tuning achieving the expected results?



What are the unexpected consequences?

- Static environments?
- Too much CS at the wrong time?
- High blue content … visual issues?
- Not enough daylight and views?

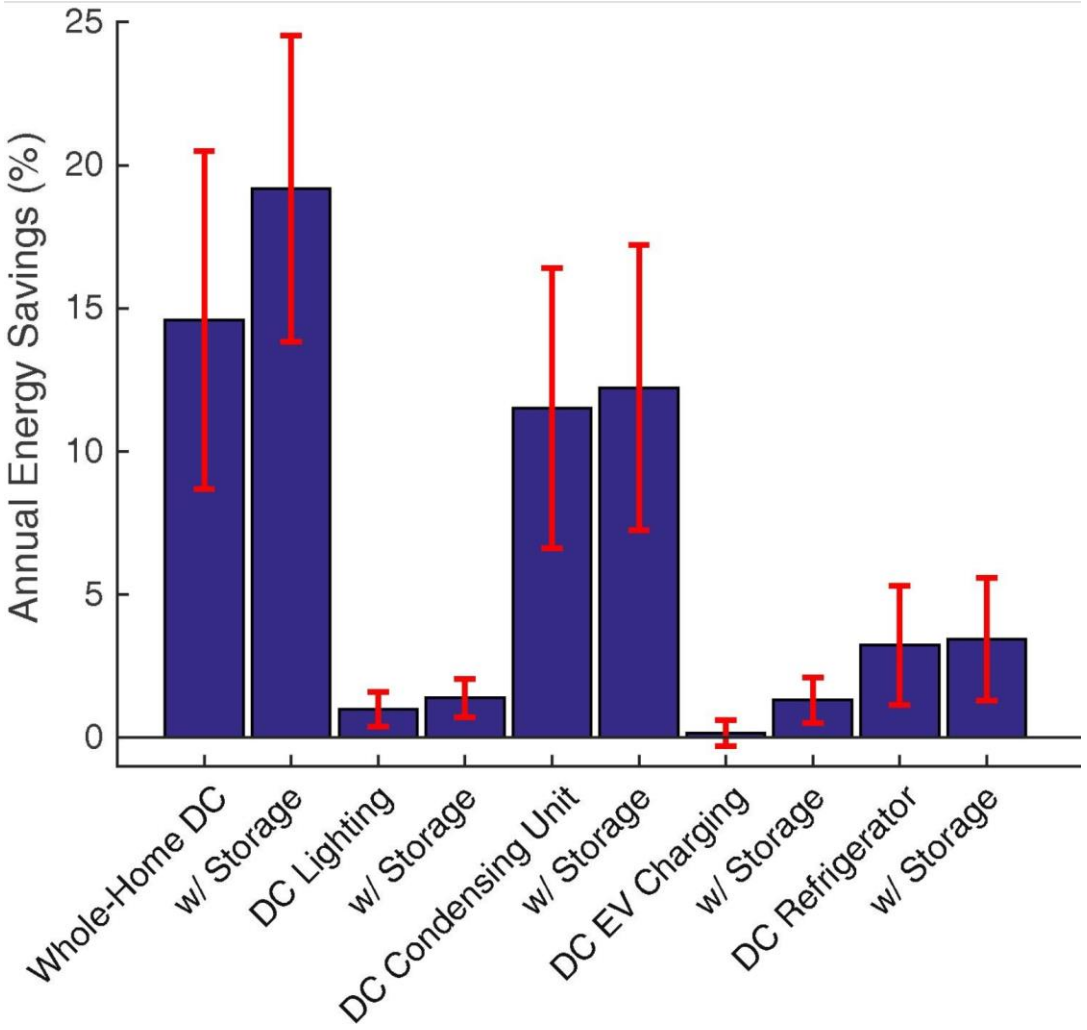


- What is driving the design … CS?

Residential DC Distribution?

- Renewables Generate DC
- Converts to AC
- Powering native DC loads

Potential Energy Savings (14% - 25% with storage)



https://www.sciencedirect.com/science/article/pii/S0306261916309771

City of LA Building an e-Highway

https://www.citylab.com/life/2014/09/los-angeles-is-building-an-e-highway/380914/

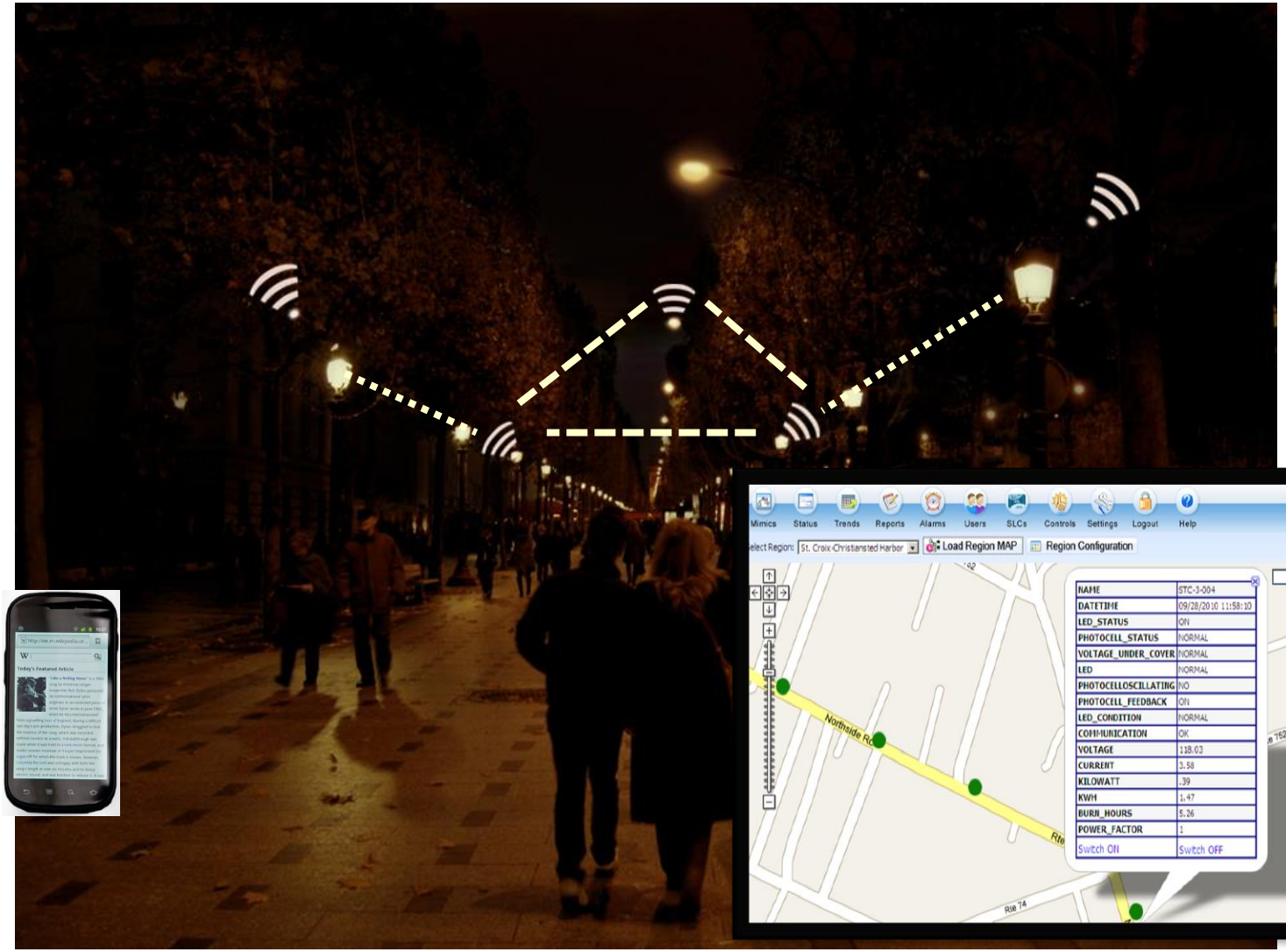
Charge as you drive …

www.citylab.com/life/2015/11/netherlands-dutch-solar-powered-bike-lane-cycling-solaroad/416601/

PV charging …

www.citylab.com/life/2015/11/netherlands-dutch-solar-powered-bike-lane-cycling-solaroad/416601/

Controls – GPS Device to Lighting



One Luminaire = Multiple Effects

Osram OmniPoint™

https://www.youtube.com/watch?v=ueQ-1OtQ80A

Design Palette of OLED Technology

Rectangular & Flexible

Acuity Brands

Acuity Brands

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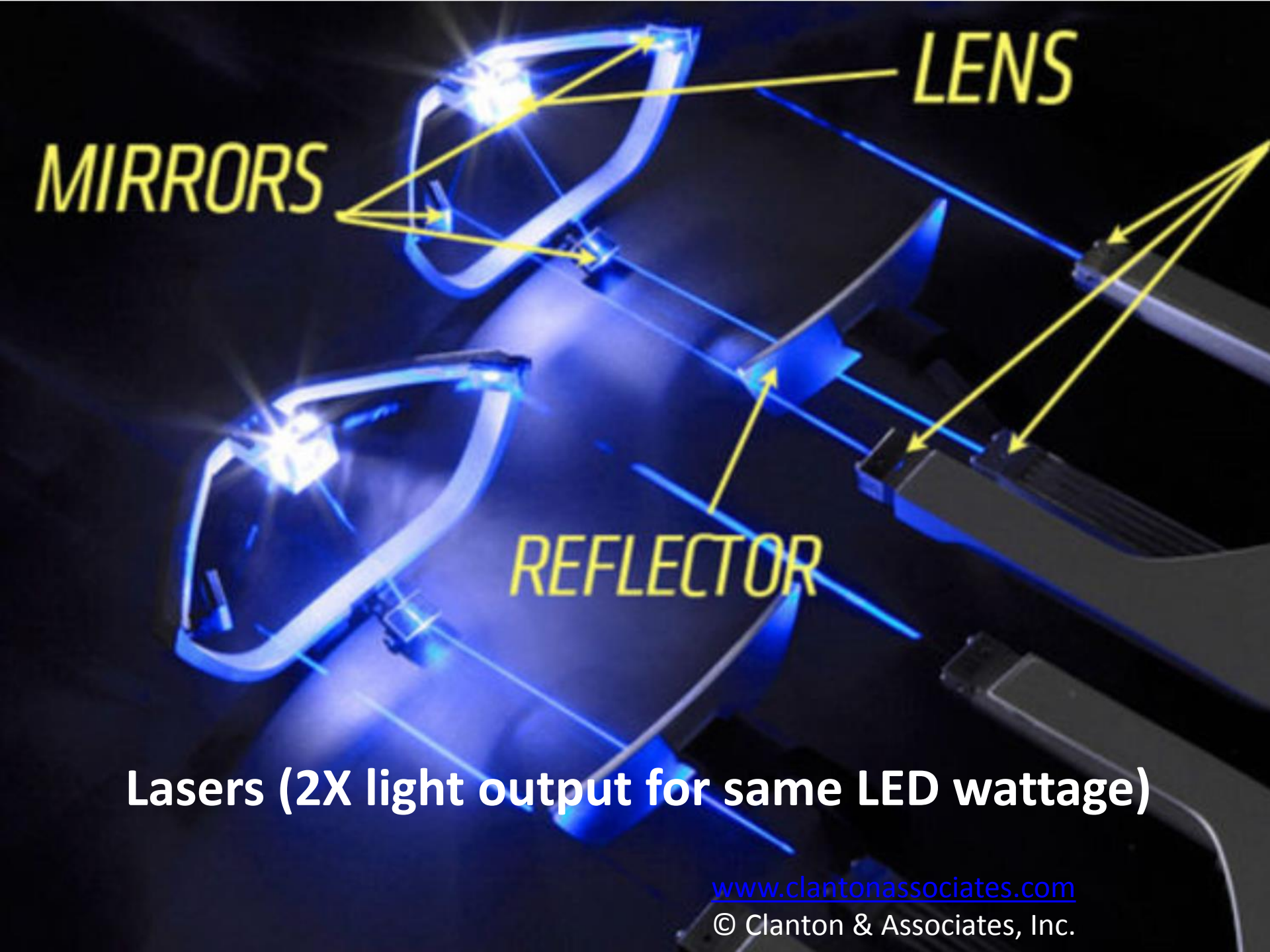

Lasers (2X light output for same LED wattage)

Contact Information

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