2019 DLC April 1 - 3 • St. Louis, MO

STAKEHOLDER MEETING

Solutions-Based Lighting


DLC STAKEHOLDER MEETING 2018
July 9 - 11 • Boston, MA
SSL V5.0 Purpose
Continue to accelerate broad scale energy savings by improving the quality of light and controllability of DLC listed products.
Draft policy for stakeholder comment
DLC
Solid-State Lighting
Requirem
Version
Draft 1: Conceptua
Released for Comment: Ja
DRAFT
DRAFT 1: DLC SSL Technical Requirements Versio
Released for comment January 29, 2019
Draft policy for stakeholder comment
DLC
DRAFT Networked Lighting Control System
Technical Requirements
Version 4.0 Draft 1
February 5, 2019
Note: Changes from Version 3.0 are highlighted in yellow.
Schedule of Revisions
Revision Number | Date | Description
1.0 | Apr 21, 2016 | Initial Technical Requirements published.
1.01 | May 7, 2016 | Clarified that the Technical Requirements are for Interior Control Systems. Systems designed and marketed exclusively for exterior applications are not eligible to be qualified.
1.02 | Feb 24, 2017 | Clarified that the Technical Requirements do not cover DC or PoE systems.
2.0 | Jun 1, 2017 | Version 2.0 published, with addition of Exterior Control Systems.
3.0 | Jun 1, 2018 | Version 3.0 published, with addition of DC/PoE Systems, Scenes, and multiyear plans for Energy Monitoring and Cybersecurity.
This document defines requirements to be met or reported for lighting control systems listed on the DesignLights Consortium® (DLC) Networked Lighting Controls Qualified Products List (QPL).
DRAFT
DRAFT Networked Lighting Control V4.0 Technical Requirements
Released for comment February 5, 2019
Page 1 of 13

What's new with SSL V5.0 Proposal: Efficacy and Controllability

Efficacy

- Average 9.6% Efficacy Increase

Dimming

- Dimming required for all products with limited exceptions

Integral Controls

- Additional reporting of presence and types of controls/sensors

Compatibility

- Reporting required of controls protocol

Why it Matters

Efficacy

- Energy savings

Dimming

- Energy savings, can improve quality of light

Integral Controls

- Energy savings, enables IoT capabilities

Compatibility

- Lack of compatibility is barrier to large scale adoption

What's new with SSL V5.0 Proposal: Quality of Light

Color Quality
R9, ANSI-IES TM-30 metrics added; raise CCT limit to 6,500K; new color maintenance and consistency requirements, reporting of SPD

Distribution
Reporting of polar plot distribution; reporting of beam angle, field angle; reporting of BUG rating for Outdoor

Glare
Reporting of UGR; Designation of glare potential: low, medium, high

Flicker
Minimum requirements for Short Term Flicker (Pst) and Stroboscopic Visibility (SVM); Reporting of percent flicker and flicker index

Circadian Wellness
Reporting of Melanopic Flux, M/P Ratio, Melanopic Daylight Ratio; Reporting of SPD

Why it Matters

Color Quality
Can impact performance, safety, aesthetics, and wellbeing

Distribution
Can impact energy consumption, task performance, safety, aesthetics, and wellbeing

Glare
Can impact task performance, comfort, safety, and wellbeing

Flicker
Can impact task performance, health, comfort, safety, and wellbeing

Circadian Wellness
Can impact alertness, sleep, and wellbeing

What's new with NLC V4.0 Proposal

Cybersecurity

- Phased approach to require systems to comply with relevant cybersecurity standards.

Energy Monitoring

- Require all listed systems to have Energy Monitoring capability

Interoperability

- New reported capability to characterize interoperability of listed systems

Why it Matters

Cybersecurity

- Critical for customer trust and adoption

Energy Monitoring

- Strengthens the value of the technology for utilities and customers

Interoperability

- Unlocks new energy savings and value propositions by connecting different systems

Challenges with some topics

- Not absolute; needs and impact vary by application
- Technical concerns about the metrics
- Potential for misuse of metrics
- Science and research still ongoing
- Testing burden
- How does this relate to energy efficiency?
- Need for education

Questions to be addressed by this panel

Why does this matter? Why is it important? For whom?

What is at stake? What are the risks and opportunities? For whom?

How does this impact energy efficiency?

Panelists

Carol Jones

Axis Lighting

Naomi Miller

PNNL

Robert Soler

BIOS Lighting

Solutions Based Lighting

DLC Stakeholder Meeting

Carol Jones, VP Integrated Systems Development • April 2019

axis

How did I get here?

- ASHRAE/IES Standard 90.1
- Light Right Consortium
- IES QVE, DG-18
- USDOE Commercial Lighting Solutions

Jorgensen Center for Performing Arts, UConn, Storrs, CT

Mutual Gains Bargaining Example *(thanks Dad.)*

Fast

Cool

Handles well

Safe

Powerful

Affordable

MGB: What can we agree on?

Definition of Mutual Gains Bargaining

- MGB is an approach to collective bargaining intended to reach win-win outcomes for the negotiating parties
- Instead of the traditional adversarial (i.e., "win/lose") approach (also known as "positional bargaining") the mutual gains approach is similar to principled negotiation
- Goal is to reach a sustainable (i.e., lasting) agreement that both/all parties can live with and support

Principles of MGB

- Both sides have legitimate interests to be recognized and advanced
- Approach the issues as problems to be solved
- Listening builds trust
- Enlarge the pie
- Seek sustainable alternatives

MGB: What can we agree on?

Mutual Gains Goals

Utility Support

- $$$
- Education, engagement

Happy Customers

- Utility programs
- Products
- Services

Market Transformation

- Emerging Technologies
- Crossing the Chasm

Shared Solutions

New Utility Models

“Utility of the Future”

Quality Lighting supports our shared customers, the owner/occupants

Beyond efficiency, to Connected Systems & IoT Buildings

What can we agree on?

- Demand Response, demand coincident stuff
- Grid level impacts - intelligence within the grid, including fault detection, life safety, resilience, electrification
- New revenue streams - services, beyond efficiency bundles, leverage building sensors into programs with value for customer
- Connected Systems Enable Renewables - Low wattage plus granular controls allows more renewables and distributed generation, real time adjustments
- Behind the meter - expanding use of renewables due to jurisdictional restrictions

Shared Goal

Handshake

Alignment

Commitment

Let's get creative. Let's do the work. Let's get aligned.

Open plan office

Retail Big Box

Warehouse

Hospital Patient Room

Higher Education Lecture Hall

Etc.

Energy Metering

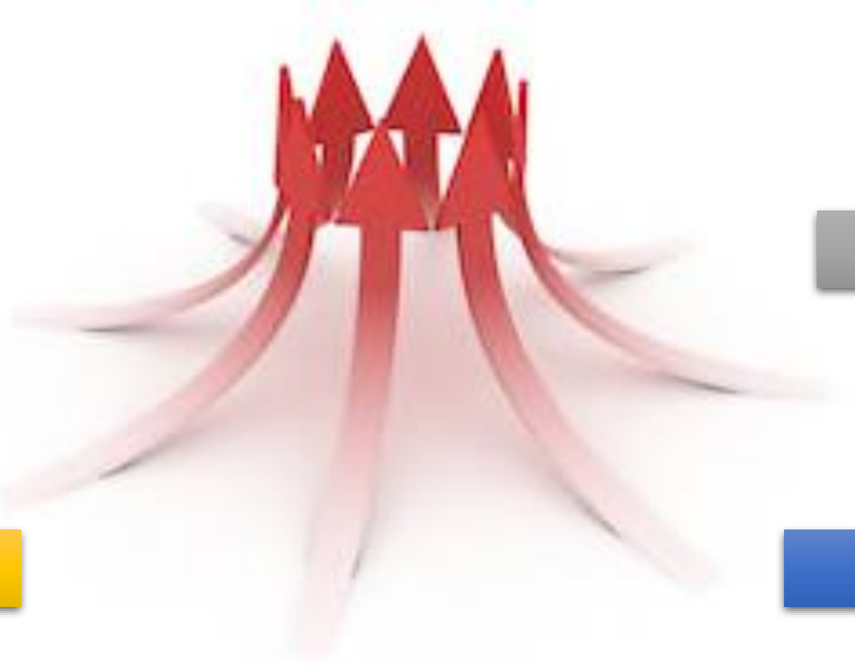
Luminaire Efficacy

Glare

Distribution

Dimming Behaviors

Spectral Quality



Controllability

Flicker


axis

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Why does DLC care about that quality stuff?

Naomi J Miller, FIES, FIALD, LC
Designer/Scientist
Pacific Northwest National Laboratory
Portland OR

Version 5.0 for SSL

DLC Performance targets

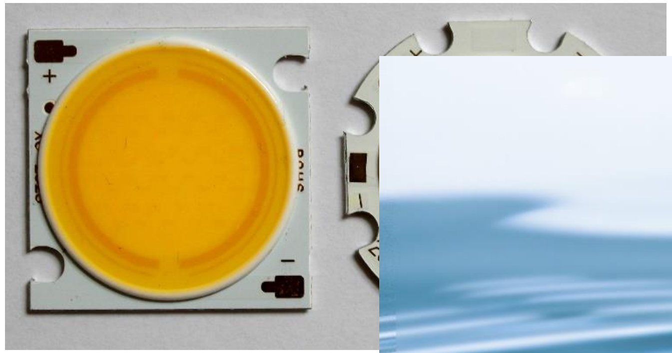
- Efficacy
- Lighting Quality
  - Color quality
  - Discomfort glare
  - Flicker
  - Light distribution
  - Circadian wellness

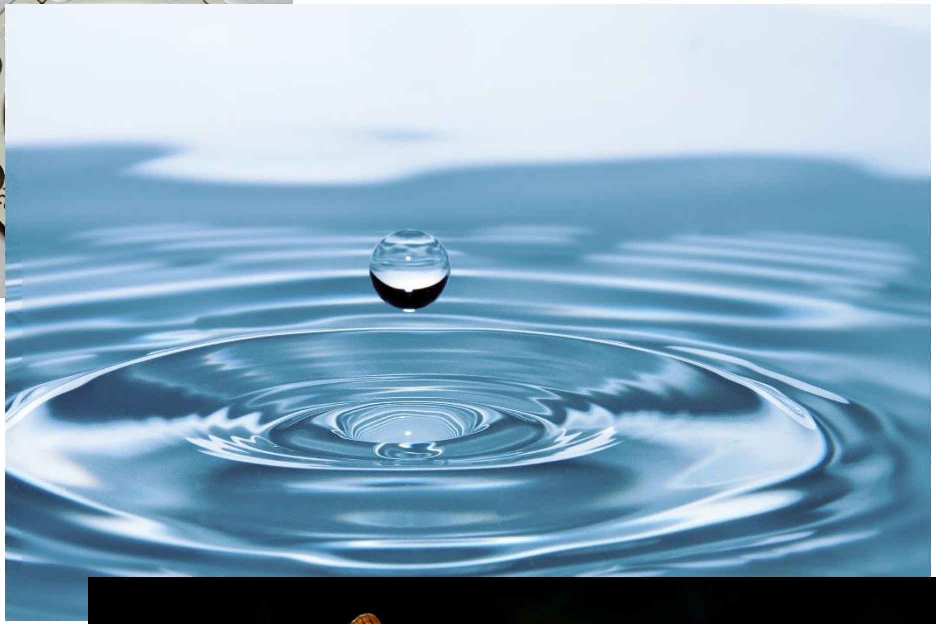
Version 5.0 for SSL

Why does this stuff matter?

- Because climate change is real and scary
- There's more to lighting than energy efficiency
  - Lighting is for people
  - Human comfort and wellness are important goals

Efficacy





- 9.6% proposed average efficacy increase 2019
  - Increasing raw chip efficacy gives us room to trade LPW for lighting quality (glare control, optical control, color, dimming, flicker, etc.)
  - The gains for the air, water, and land quality are considerable

Spectral quality for chromaticity and color rendering

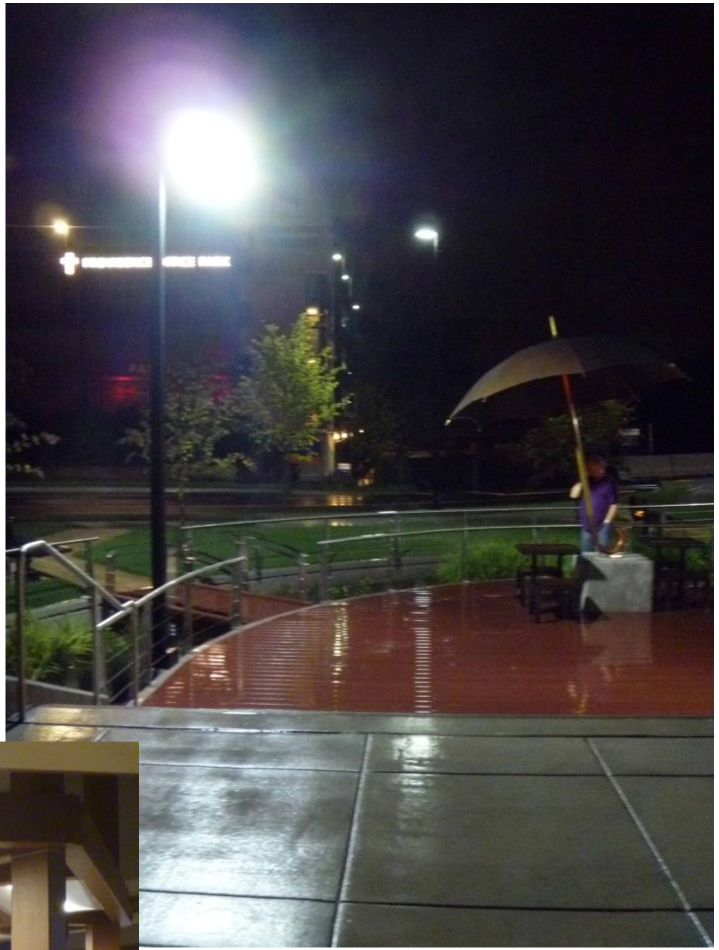
- Color rendering important for higher user acceptance of SSL-lighted spaces
- Color quality is related to color contrast, which improves visual performance for non-black-and-white tasks
- Color quality metrics are all derived from normal sphere testing (Thank goodness!)

Image: Pixabay.com

Pacific Northwest
NATIONAL LABORATORY

Discomfort glare

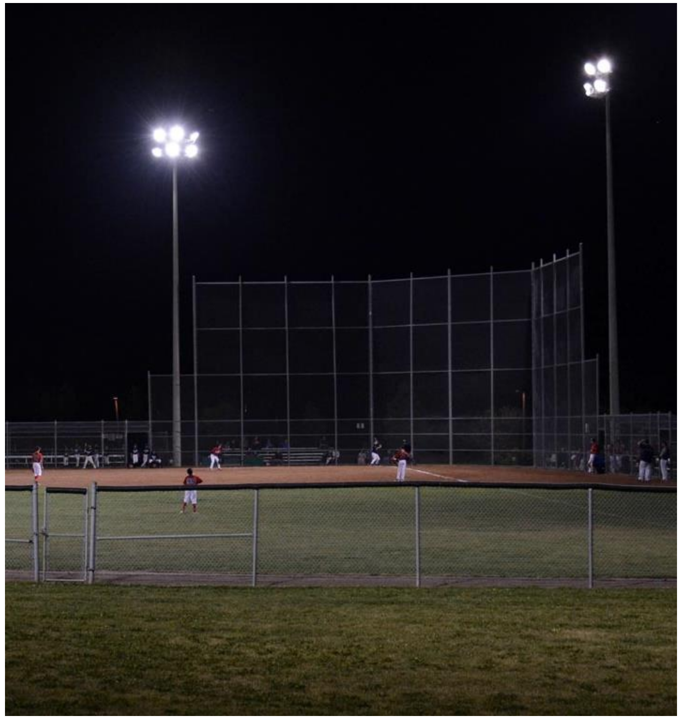
- An issue in task performance because of distraction, squinting, and postures to avoid discomfort
- Wellbeing (headaches, eyestrain, discomfort)
- Lots of painfully bright LED products on the market, many with exemplary efficacy



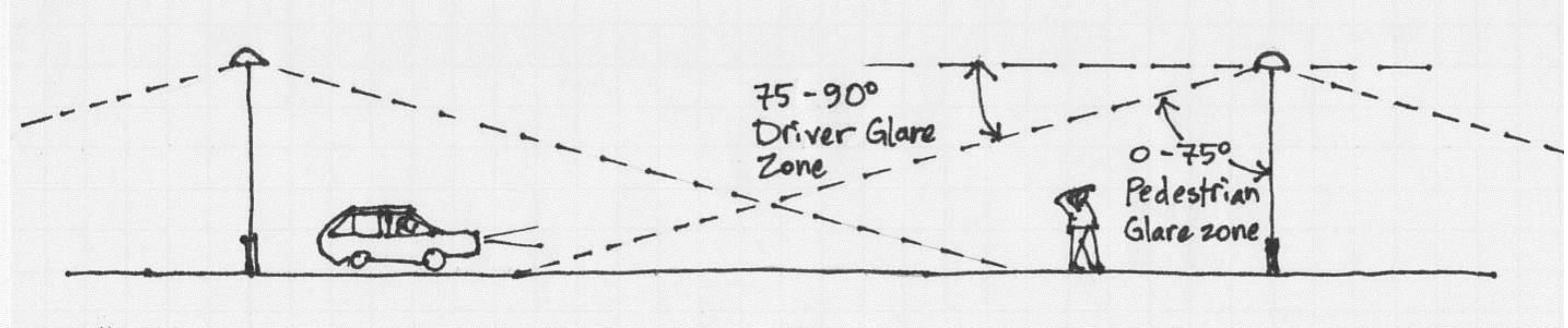
Discomfort Glare - Background

The CIE and IES have been wrestling with glare metrics, indoors and out:

- CIE Joint Technical Committee 7 – looking at modification to UGR for non-uniform luminance luminaires
- IES DGONE Committee – trying to find a metric for outdoor street and area lights and sports lighting at night



Town of Oakville, ON, Canada



Discomfort Glare - Background

Unified Glare Rating (UGR):

- The best of the competing metrics, although it's still not fully predictive for interior lighting
- Based on a ~10-30 scale
- Can be calculated for a specific room and lighting layout, a typical room layout, or for an individual luminaire
- Similar to VCP tables of yore

- Generally relies on the .ies file defined aperture for luminaire "luminous area"
- Larger luminous areas = lower UGR values
- What do we do with LEDs??????

UGR	Discomfort Glare Criterion
10	Imperceptible
13	Just perceptible
16	Perceptible
19	Just acceptable
22	Unacceptable
25	Just uncomfortable
28	Uncomfortable

Table of the corrected unified glare ratings (UGR)

Luminaire distance / suspension height above observer's eye: $s/H = 0,25$

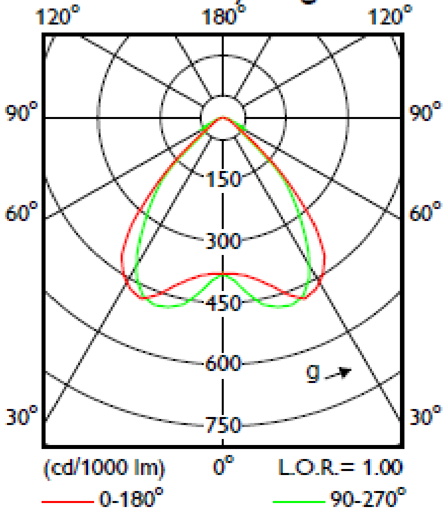
Reflectance values											
Ceiling		**0,70**	0,70	0,50	0,50	0,30	**0,70**	0,70	0,50	0,50	0,30
Walls		**0,50**	0,30	0,50	0,30	0,30	**0,50**	0,30	0,50	0,30	0,30
Floor		**0,20**	0,20	0,20	0,20	0,20	**0,20**	0,20	0,20	0,20	0,20
Room dimensions		**Corrected glare assessments – Luminous flux 3,300 lm**									
X	Y	Viewing direction: oblique					Viewing direction: longitudinal				
$2H$	$2H$	19,8	21,4	20,3	21,9	22,5	16,6	18,2	17,1	18,7	19,3
	$3H$	22,3	23,8	22,8	24,4	25,0	17,8	19,3	18,4	19,9	20,5
	$4H$	23,7	25,1	24,2	25,7	26,3	18,2	19,7	18,8	20,2	20,9
	$6H$	25,2	26,5	25,7	27,1	27,7	18,5	19,8	19,1	20,4	21,1
	$8H$	25,9	27,2	26,5	27,8	28,4	18,6	19,8	19,1	20,4	21,1
	$12H$	26,6	27,9	27,2	28,5	29,1	18,6	19,8	19,2	20,4	21,1
$4H$	$2H$	20,2	21,7	20,8	22,2	22,9	17,9	19,3	18,4	19,9	20,5
	$3H$	23,0	24,3	23,6	24,9	25,5	19,4	20,7	20,0	21,2	21,9
	$4H$	24,6	25,7	25,2	26,3	27,0	20,0	21,1	20,6	21,7	22,4
	$6H$	26,2	27,3	26,8	27,9	28,6	20,4	21,4	21,0	22,0	22,7
	$8H$	|27,1|	28,0	27,7	28,7	29,4	20,5	21,5	21,1	22,1	22,8
	$12H$	27,9	28,8	28,6	29,5	30,2	20,6	21,4	21,2	22,1	22,8
$8H$	**$4H$**	**24,8**	25,8	25,4	26,4	27,1	**|20,9|**	21,9	21,6	22,5	23,3
	$6H$	26,7	27,5	27,3	28,2	28,9	21,7	22,5	22,3	23,2	23,9
	$8H$	27,7	28,4	28,4	29,1	29,8	22,0	22,7	22,6	23,4	24,1
	$12H$	28,7	29,4	29,4	30,0	30,8	22,1	22,8	22,8	23,5	24,3
$12H$	$4H$	24,8	25,7	25,4	26,3	27,1	21,2	22,1	21,8	22,7	23,5
	$6H$	26,8	27,5	27,4	28,2	28,9	22,1	22,9	22,8	23,5	24,3
	$8H$	27,8	28,5	28,5	29,1	29,9	22,5	23,2	23,2	23,9	24,6

UGR on a luminaire cut sheet

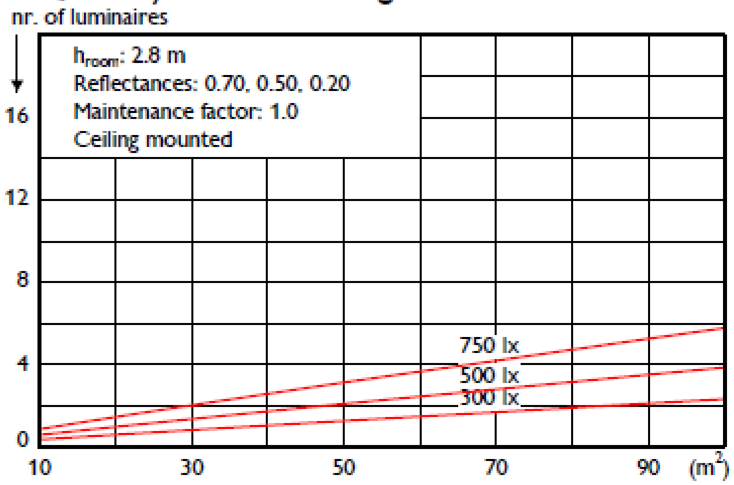
BY470P 1 xGRN130S/840 WB GC

1 x 13000 lm

Polar intensity diagram



Quantity estimation diagram



Light output ratio 1.00
Service upward 0.00
Service downward 1.00

CIE flux code 70 96 100 100 100

S/H ratio crosswise max. 1.5
lengthwise max. 1.7

UGRcen (4Hx8H, 0.25H) 23
UTE71-121: 1.00AS + 0.00T

Utilisation factor table

Room Index k	Reflectances for ceiling, walls and working plane (CIE)										
	0.80 0.50 0.30	0.80 0.50 0.10	0.70 0.50 0.30	0.70 0.50 0.20	0.70 0.50 0.10	0.70 0.30 0.10	0.50 0.30 0.10	0.50 0.10 0.10	0.30 0.30 0.10	0.30 0.10 0.10	0.00 0.00 0.00
0.60	0.62	0.59	0.62	0.60	0.59	0.53	0.53	0.49	0.52	0.49	0.47
0.80	0.73	0.69	0.72	0.70	0.68	0.62	0.62	0.58	0.61	0.58	0.56
1.00	0.82	0.76	0.80	0.78	0.75	0.70	0.69	0.66	0.69	0.65	0.63
1.25	0.90	0.82	0.88	0.85	0.81	0.77	0.76	0.72	0.75	0.72	0.70
1.50	0.95	0.86	0.93	0.89	0.86	0.81	0.80	0.77	0.79	0.77	0.75
2.00	1.04	0.93	1.01	0.96	0.92	0.88	0.87	0.85	0.86	0.84	0.82
2.50	1.09	0.96	1.06	1.01	0.95	0.93	0.91	0.89	0.90	0.88	0.86
3.00	1.13	0.99	1.10	1.03	0.98	0.95	0.94	0.92	0.93	0.91	0.89
4.00	1.17	1.01	1.14	1.07	1.00	0.98	0.97	0.95	0.95	0.94	0.92
5.00	1.20	1.03	1.16	1.08	1.02	1.00	0.98	0.97	0.97	0.96	0.93

Ceiling mounted

Luminance Table

Plane / Cone	0.0	45.0	90.0
45.0	40200	72449	35583
50.0	21386	53339	14700
55.0	10051	30152	10335
60.0	7226	13031	13348
65.0	5924	6458	14050
70.0	5226	5219	7761
75.0	4335	4439	8265
80.0	3331	3142	5226
85.0	1610	1377	2077
90.0	-	-	-

(cd/m2)

UGR = 23

LVP0050300

2017-02-08

Discomfort Glare - Background

Reasons glare metrics don’t work very well

- Average luminance over luminaire aperture is most commonly used for luminaire luminance. This is a highly inaccurate assumption in the era of LEDs. It misstates the AREA and the LUMINANCE.
- What do we do with LEDs??

$$UGR = 8 \cdot \log\left(\frac{0.25}{L_{Background}}\right)\sum_{n}\left(\frac{L^2\omega}{p^2}\right)$$

where

L = Luminance of the luminous area

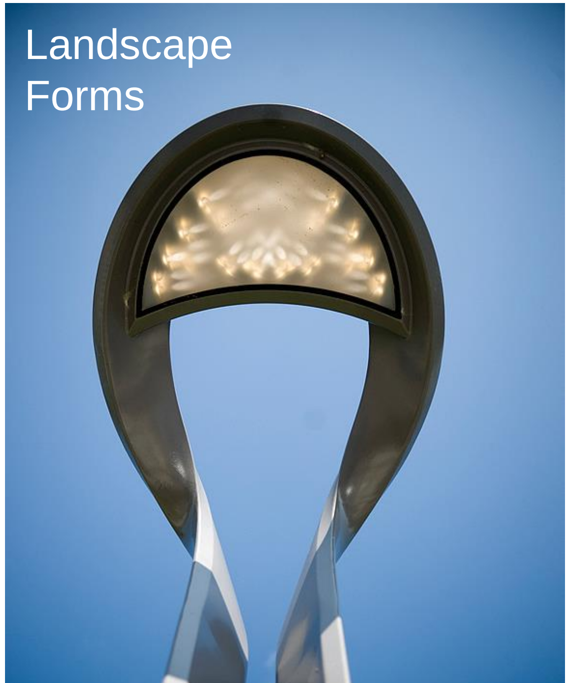
ω = size of the luminous area

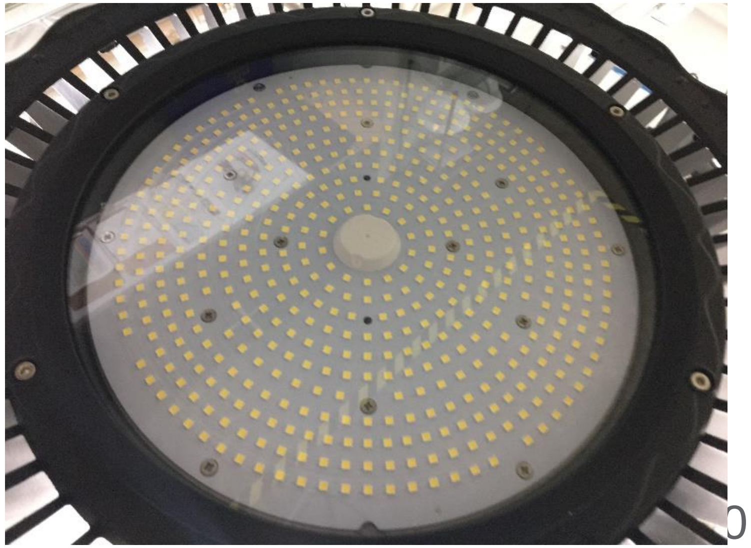
p = Guth position index

$L_{Background}$ = Background Luminance

n = number of luminaires

Photo: Zumtobel





Proposed CIE JTC7 Approach for non-uniform luminaires (future)

Modified UGR luminous area assumption:

- Take HDRi image of luminaire from 50° and 65° from luminaire nadir, and filter image for blur. Sum areas with luminance >500 cd/m^2 into effective luminous area. Calculate effective solid angle.

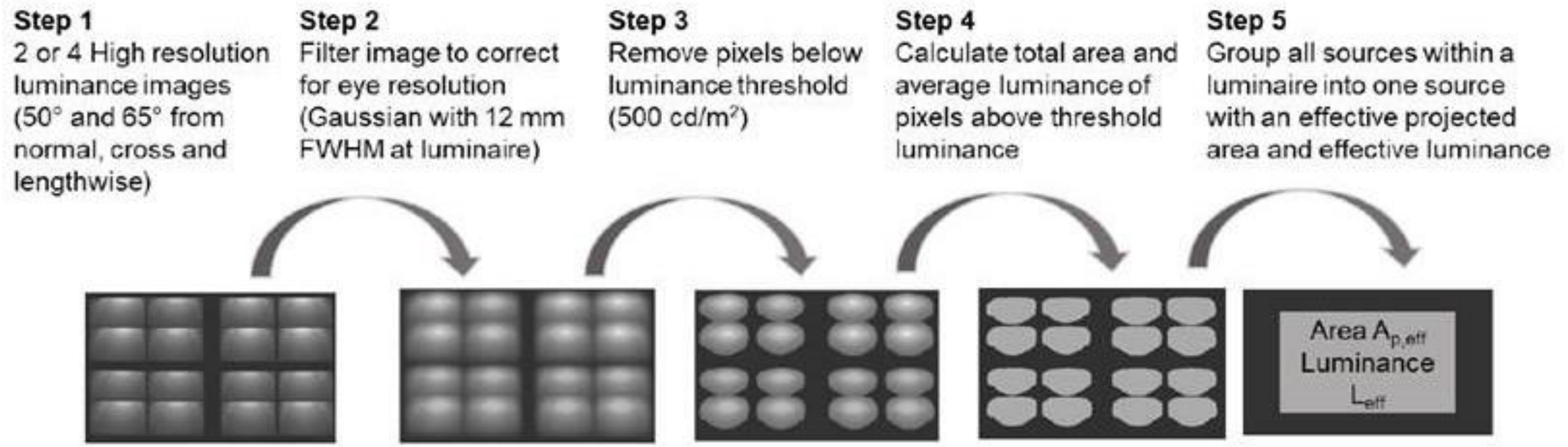


Figure 2 – Overview of the measurement and image processing steps that are required to obtain the effective projected area and effective luminance. Note that the effective solid angle of the source ω_{eff} is equal to the effective projected area $A_{p,eff}$ divided by the measurement distance squared.

Inquiring minds want to know….

- Is UGR based on one luminaire or an installation of luminaires?
  - Technically an installation of luminaires. But it can be calculated for one luminaire, which is the worst case scenario.
  - Thus, it provides BOTH the capabilities of publishing a UGR value for a single luminaire on a spec sheet, and using it in software such as AGI32 to calculate the predicted glare response to a roomful of luminaires.

- Can modified UGR be adapted for use with outdoor lighting as well?
  - Definite MAYBE. The DGONE Committee may want to sponsor human factors experiments to explore this. Background luminance will need to be a factor.
  - There is work by at least one researcher that shows promise for UGR for outdoor use.
  - In the meantime…..

Outdoor: The "G" in BUG Rating

Glare Designation in TM-15-11

- Adopted in policies/standards:
  - ANSI/IES RP-7-17
  - ANSI/IES RP-8-14
  - ANSI/IES RP-20-14
  - USGBC LEED
  - CA Title 24: Part 6 & 11 (CalGreen)

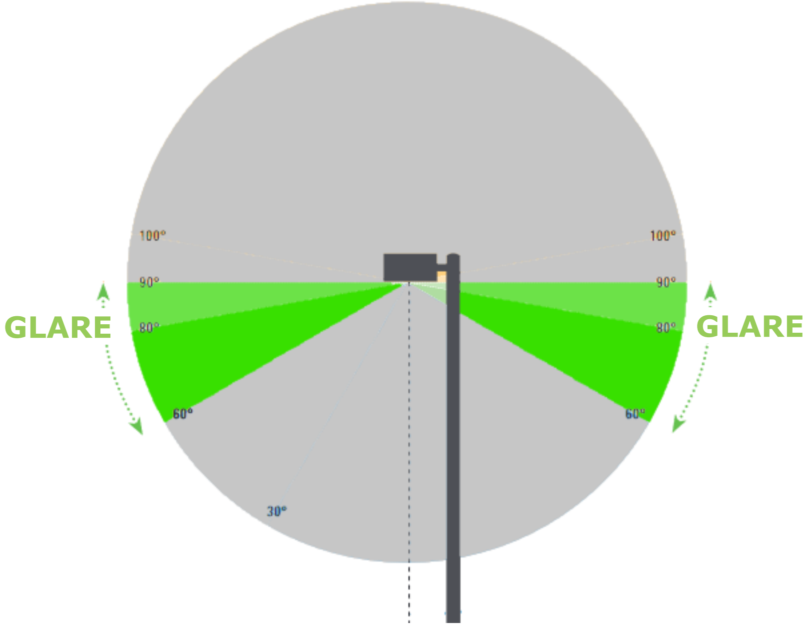


Table A-3: Glare Ratings (maximum zonal lumens)

Glare Rating for Asymmetrical Luminaire Types (Type I, Type II, Type III, Type IV)

	Secondary Solid Angle	G0	G1	G2	G3	G4	G5
Glare / Offensive Light	FVH	10	100	225	500	750	>750
	BVH	10	100	225	500	750	>750
	FH	660	1800	5000	7500	12000	>12000
	BH	110	500	1000	2500	5000	>5000

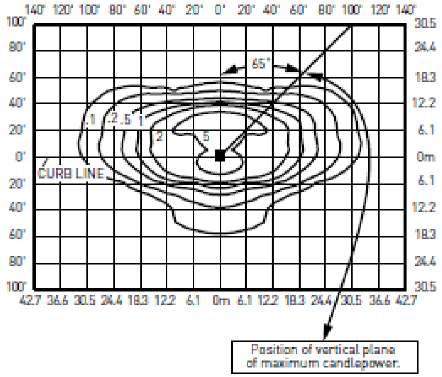
Glare Rating for Quadrilateral Symmetrical Luminaire Types (Type V, Type V Square)

	Secondary Solid Angle	G0	G1	G2	G3	G4	G5
Glare / Offensive Light	FVH	10	100	225	500	750	>750
	BVH	10	100	225	500	750	>750
	FH	660	1800	5000	7500	12000	>12000
	BH	660	1800	5000	7500	12000	>12000

The “G” in BUG Rating

Benefits

- Applicable to individual luminaires
- Provides objective comparison between products
- Glare component can be represented in 2 digits (e.g. "G0" or "G1“)
- Low testing burden: Can use existing photometric data



OSQ-A-**-2ME-U-40K-UL
Mounting Height: 25' (7.6m) A.F.G.
Initial Delivered Lumens: 27,706
Initial FC at grade

Type II Medium Distribution

Input Power Designator	3000K		4000K		5700K	
	Initial Delivered Lumens*	BUG Ratings** Per TM-15-11	Initial Delivered Lumens*	BUG Ratings** Per TM-15-11	Initial Delivered Lumens*	BUG Ratings** Per TM-15-11
S	18,182	B3 U0 G2	21,696	B3 U0 G3	23,179	B3 U0 G3
U	26,258	B3 U0 G3	27,706	B3 U0 G3	28,285	B3 U0 G3

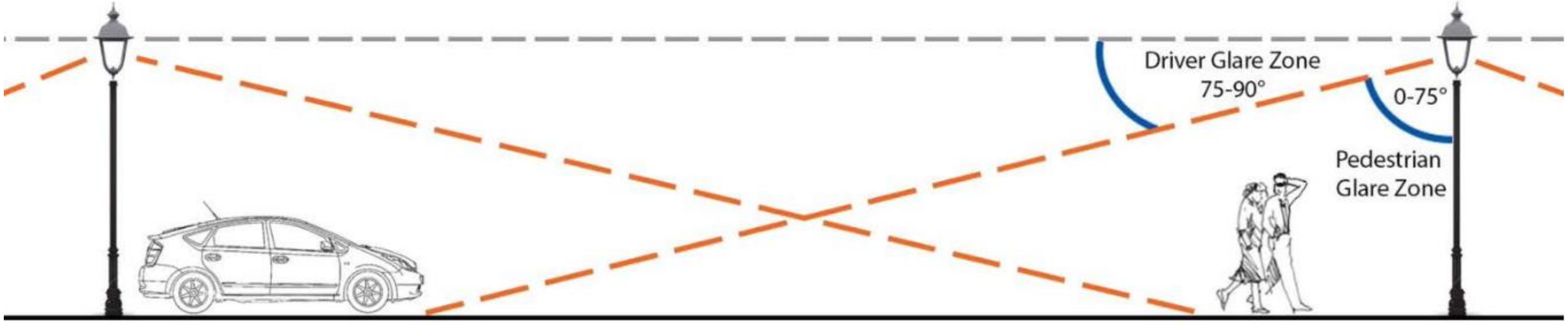
* Initial delivered lumens at 25°C (77°F). Actual production yield may vary between -10 and +10% of initial delivered lumens

** For more information on the IES BUG (Backlight-Uplight-Glare) Rating visit: www.ies.org/PDF/Erratas/TM-15-11BugRatingsAddendum.pdf. Valid with no tilt

The “G” in BUG Rating

Shortcomings

- May not perform well for pedestrians
  - Glare component only between 60°-90° from nadir
- Existing standards use application/lighting zone to determine thresholds (such as LZ0, LZ2)

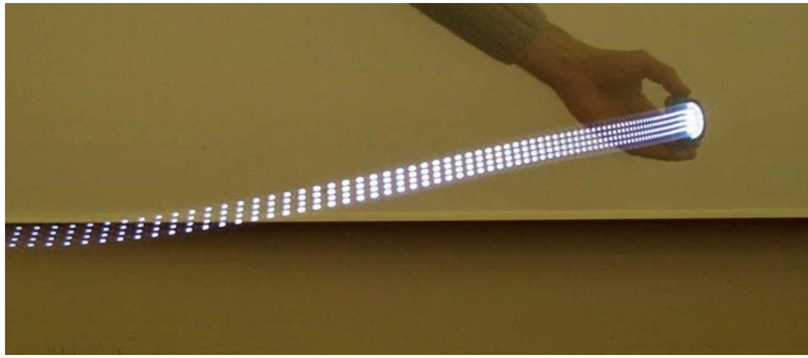


Flicker
(or more accurately, Temporal Lighting Artifacts TLA)

Image: Wikipedia.org

Temporal light artifact (TLA): perception from light source whose luminance or spectral distribution fluctuates with time

- **Flicker**: Perception of *visual unsteadiness*… *for a static observer in a static environment. Up to 3 - ~80 Hz*
- **Stroboscopic effect**: change of *motion perception*… for a *static observer in a non-static environment ~80 Hz - ~2000 Hz*
- **Phantom Array effect** (ghost effect): change in *perceived shape or spatial layout of objects*… for a *non-static observer in an otherwise static environment* (e.g. saccade, normal head movement, or while driving) ~80 Hz – ~2500 Hz



Most people can't SEE flicker, but they may be affected by it.

Is flicker really an issue?

- Photoepilepsy – flashing lights (and other repetitive patterns) stimulate epileptic seizures
- Stroboscopic effect – dangerous when working with rotating machinery
- Migraine or severe headache often associated with nausea and visual disturbances
- Asthenopia (eye strain), including fatigue, blurred vision, conventional headache, decreased performance on sight-related tasks, etc.
- Other: panic attacks, anxiety, increased heart rate, vertigo
- Reduced reading rates and visual task performance
- Also: interference with machine vision and imaging devices (video & security cameras, etc.)

Health.com

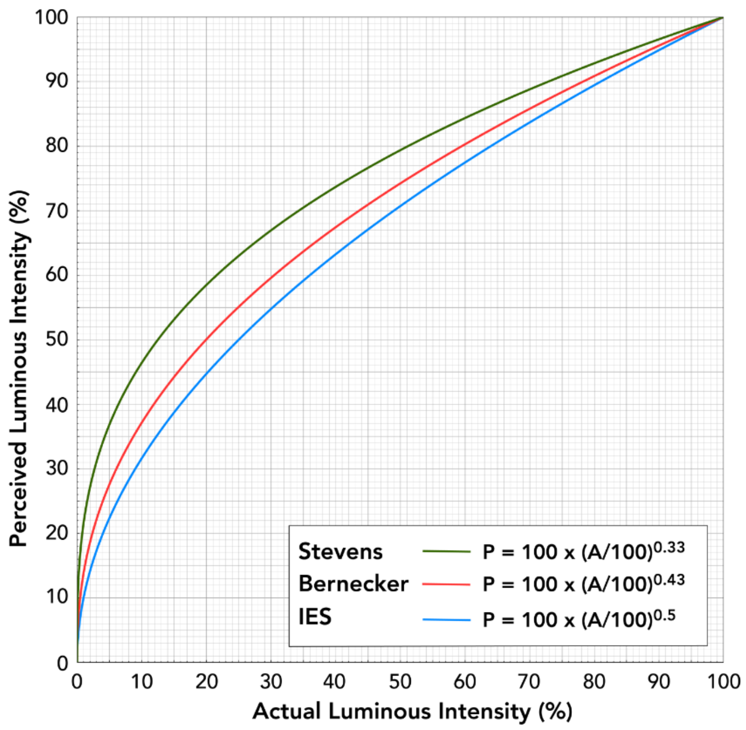
Why do we care, especially now?

LEDs

- Inherently fast-responding devices. No persistence over time.
- Relies on the DRIVER to provide visibly continuous light
- DIMMING. Pairing the driver with a dimmer is tricky, especially at very low dimming levels, especially if color or white tuning is involved

Human visual perception is not linear

- To get a light source to LOOK like it's dimmed to 10% output, actual output need to be <1% output.
- Differences between actual and perceived are particularly large at low relative intensity levels



Actual versus perceived dimming levels

Flicker (or more accurately, Temporal Lighting Artifacts TLA)

Two prominent TLA measures for stroboscopic effect and, perhaps, phantom array effect:

- **Stroboscopic Visibility Measure (SVM)**
- **Standard IEEE P1789-2015**: Limits %Flicker based on fundamental flicker frequency

SVM is the better of the two for predicting visibility

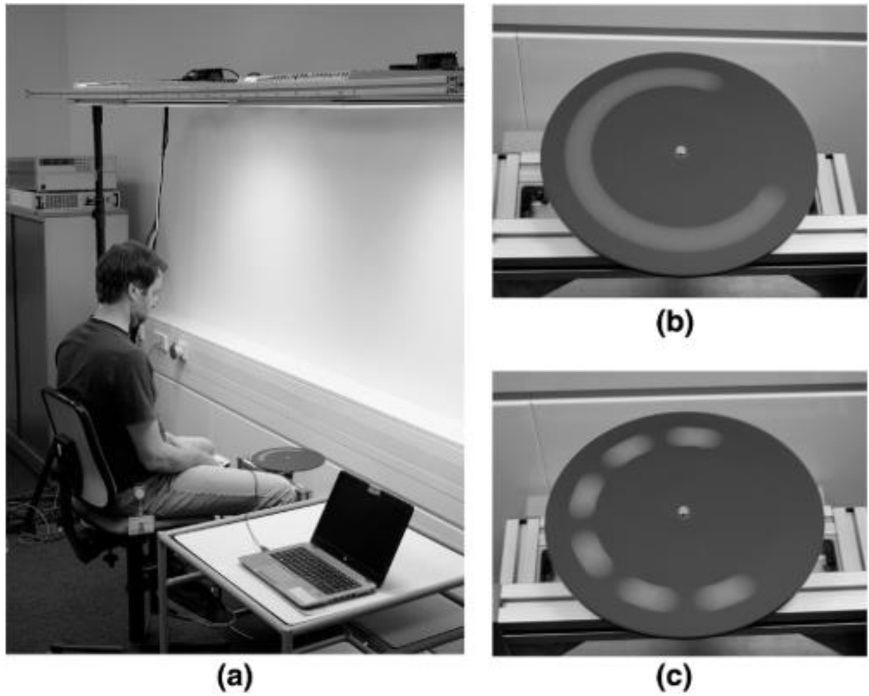
Why now? We have waited too many years for confirmation by the neurological community that visibility predicts seizures, EEG response, headaches, migraines, autistic behaviors, task performance reduction, etc.

Why now? LED lighting products that flicker ***are all too common***

Flicker (or more accurately, Temporal Lighting Artifacts TLA)

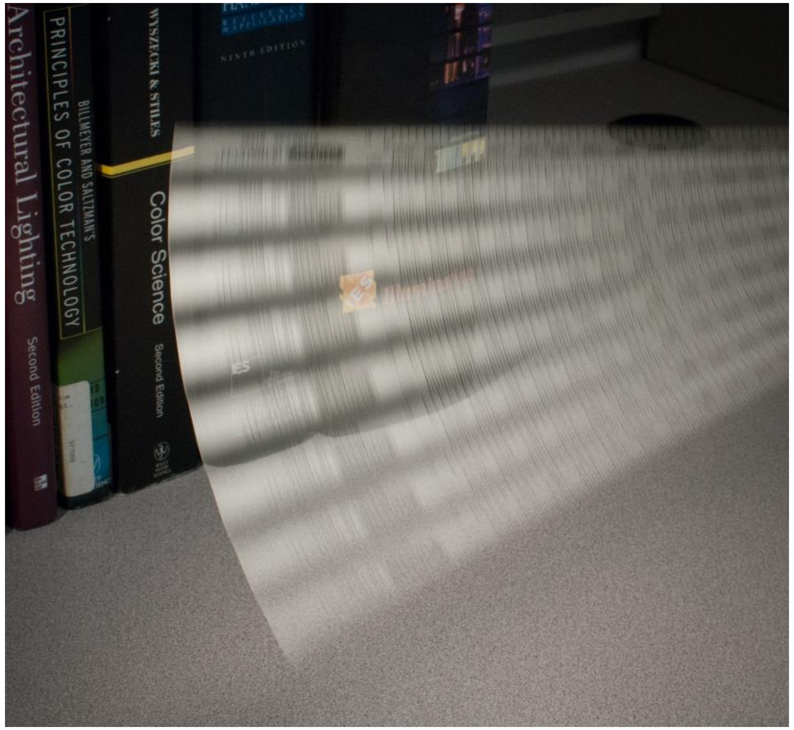
The problems with these metrics:

- **IEEE P1789 standard** is too strict on even incandescent light sources. Also, it does not consider duty cycle, which can dramatically increase or decrease visibility of stroboscopic effect.
- **SVM** based on visibility, a fixed view of a rotating disk. No relative eye or head movement.
- SVM is based on an average observer, not the most sensitive individuals.
- SVM of 1 = 50% of individuals will see flicker, 50% won't. This is a very loose threshold which doesn't protect the sensitive, **so DLC is suggesting tighter SVM thresholds**.
- We don't know how SVM corresponds to headaches, etc., **but it's a healthy start on establishing criteria that gets rid of the really bad stuff out there!!**



Perz et al, experimental setup for TLA

Thank you for listening!



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Senior Lighting Engineer
Pacific Northwest National Laboratory
Naomi . Miller @ PNNL . gov
(503) 417-7571

Pacific Northwest NATIONAL LABORATORY

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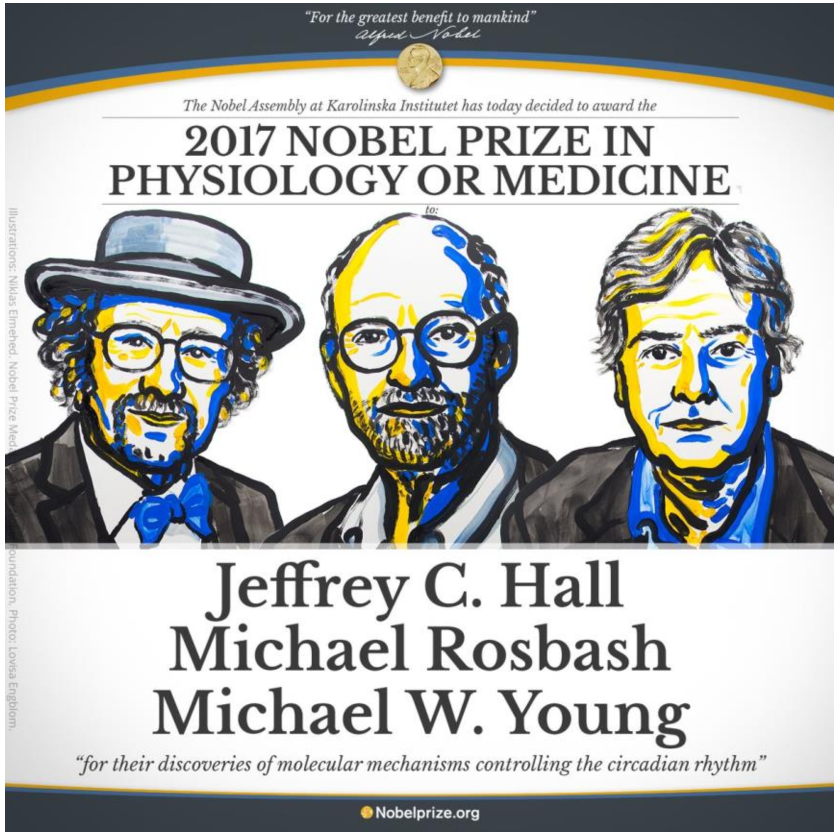
DLC STAKEHOLDER MEETING

Robert Soler – VP Human Biological Research and Technology

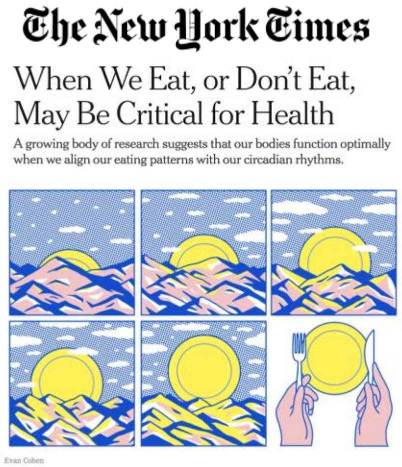
CIRCADIAN RHYTHMS

- 2017 Nobel Prize was awarded to physiologists who discovered mechanisms of circadian rhythms
- Circadian rhythms is a pervasive part of all biology
- Each cell has its own clock (Panda – Circadian Code, 2018)
- 43% of mammalian genetic expression is circadian (Zhang et al. 2014)
- Strategic timing for resource efficiency (Brown 2016)



SOCIAL ACCEPTANCE

- Popular periodicals are beginning to write on the importance of doing things according to your circadian rhythms

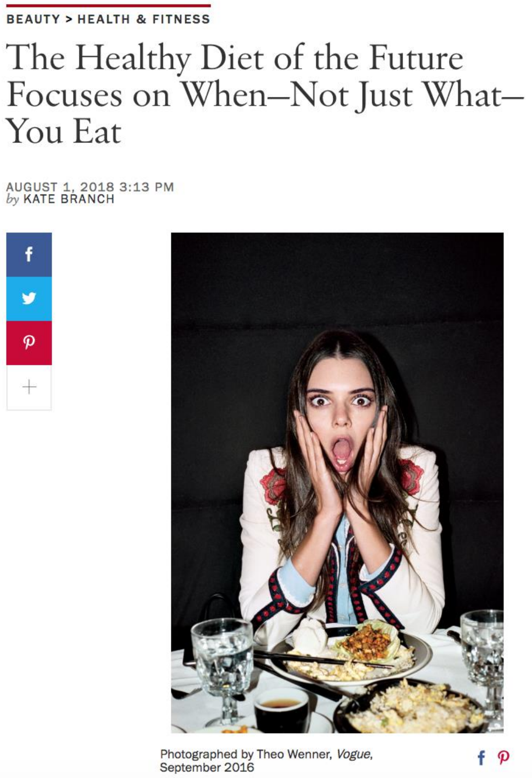


The New York Times

When We Eat, or Don't Eat, May Be Critical for Health

A growing body of research suggests that our bodies function optimally when we align our eating patterns with our circadian rhythms.

Evan Cohen



BEAUTY > HEALTH & FITNESS

The Healthy Diet of the Future Focuses on When—Not Just What—You Eat

AUGUST 1, 2018 3:13 PM
by KATE BRANCH

Photographed by Theo Wenner, *Vogue*, September 2016

SOCIAL ACCEPTANCE

- Popular periodicals are beginning to write on the importance of doing things according to your circadian rhythms
- And the problems that arise when we don't

The Washington Post
Democracy Dies in Darkness

Education

Pediatricians say teens should sleep in. Schools won't let them.

By Moriah Balingit
August 23, 2017 at 4:41 PM

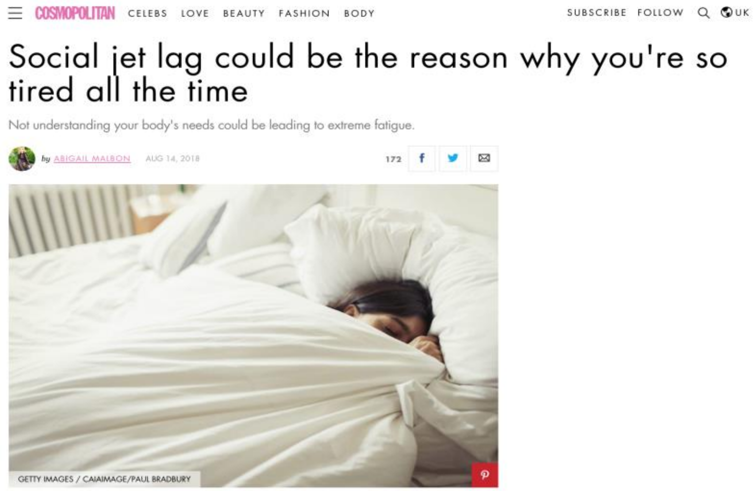
CNN Health » Food | Fitness | Wellness | Parenting | Vital Signs Live TV U.S. Edition +

Your smartphone may be hurting your sleep

By Susan Scutti, CNN
Updated 10:52 AM ET, Fri June 23, 2017

Photos: Tips for better sleep

Setting an alarm might be the only thing that helps you get up in the morning, but try setting one at night to remind you when it's time to go to bed. Click through our gallery for other tips for better sleep.



COSMOPOLITAN CELEBS LOVE BEAUTY FASHION BODY SUBSCRIBE FOLLOW UK

Social jet lag could be the reason why you're so tired all the time

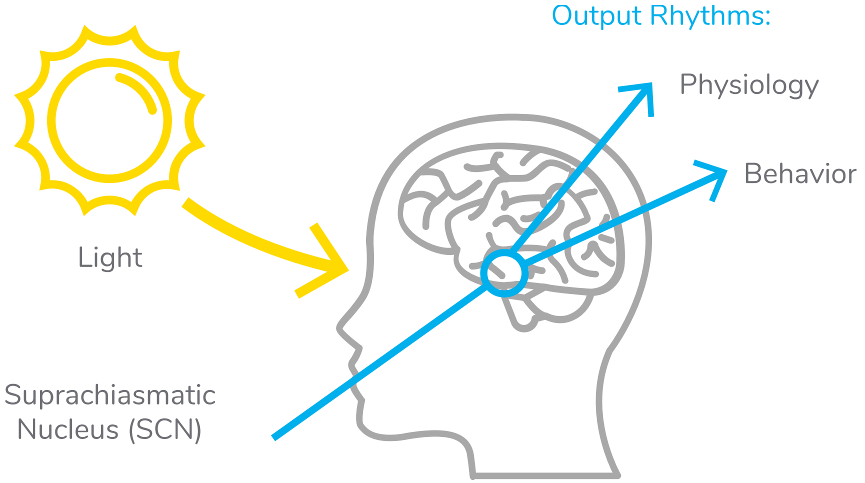
Not understanding your body's needs could be leading to extreme fatigue.

by ABIGAIL MALBON AUG 14, 2018 172

GETTY IMAGES / CAIAIMAGE/PAUL BRADBURY

LIGHT'S ROLE IN ALL OF THIS

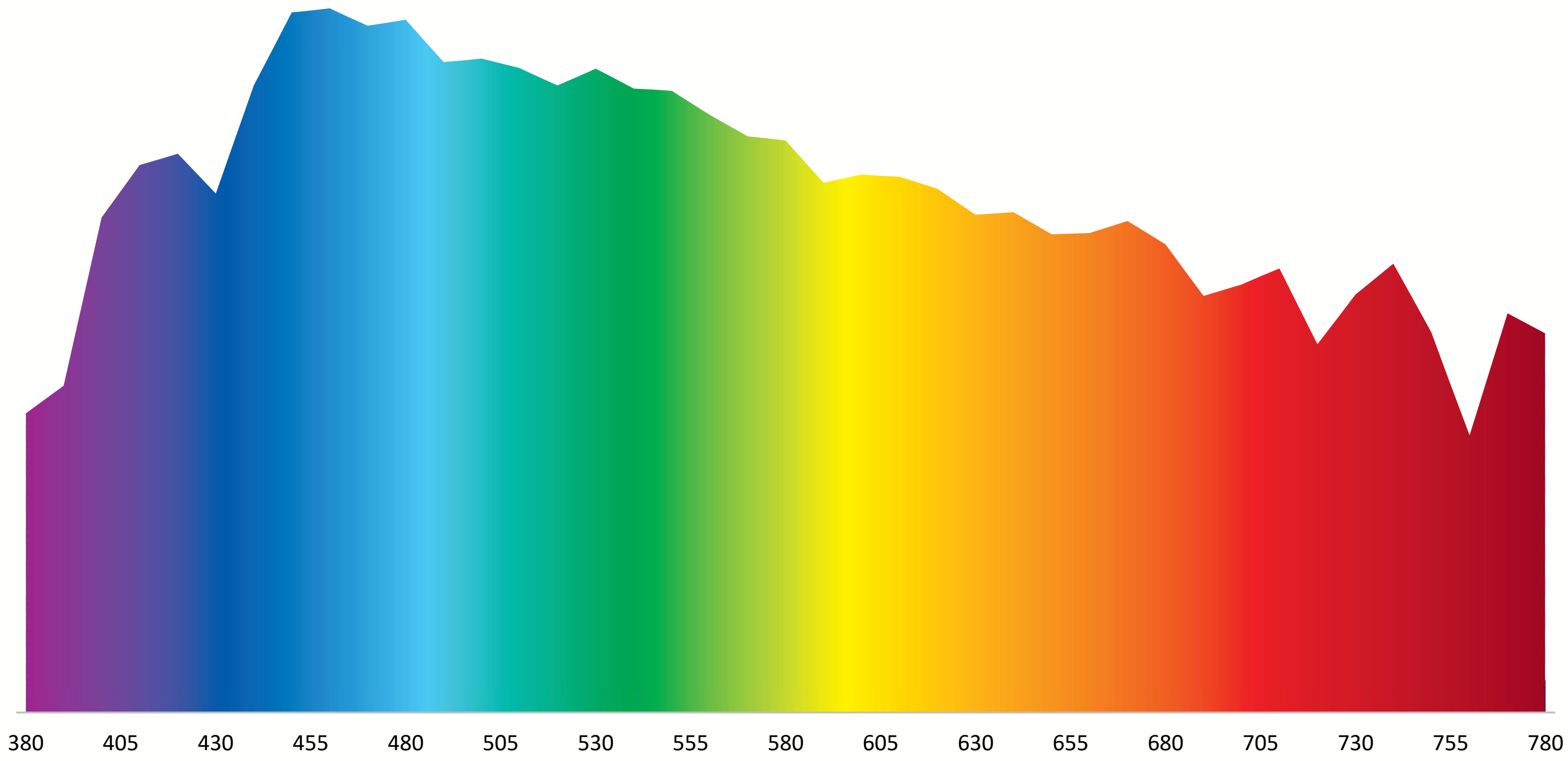
- Newly-discovered photoreceptors project directly to portion of the brain that regulates circadian rhythms



LIGHT’S ROLE IN ALL OF THIS

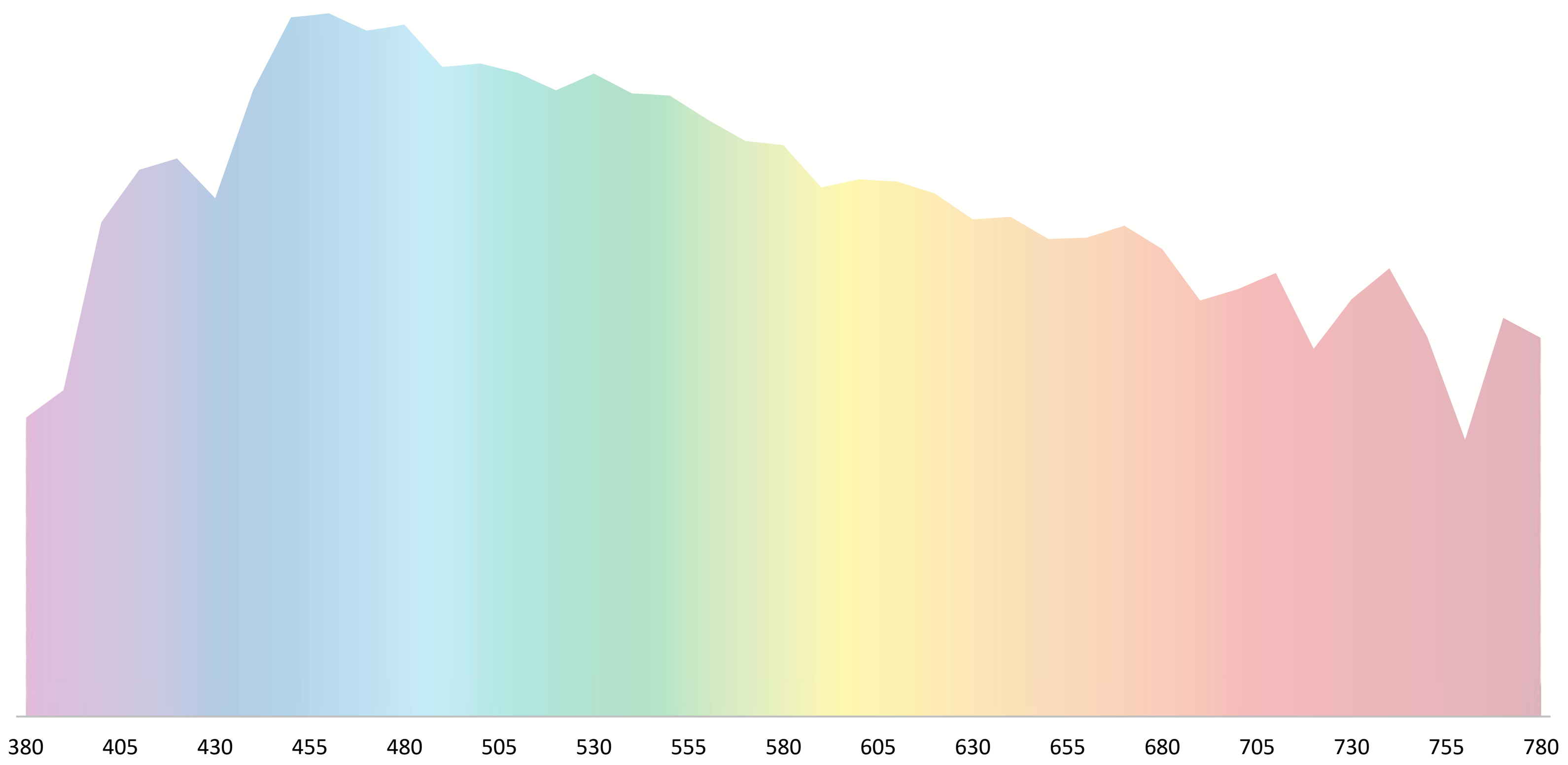
- Newly-discovered photoreceptors project directly to portion of the brain that regulates circadian rhythms
- Demonstrating a evolutionary relationship with the sun
- This relationship has been broken by modern society

DAYLIGHT



380
405
430
455
480
505
530
555
580
605
630
655
680
705
730
755
780

DAYLIGHT


380
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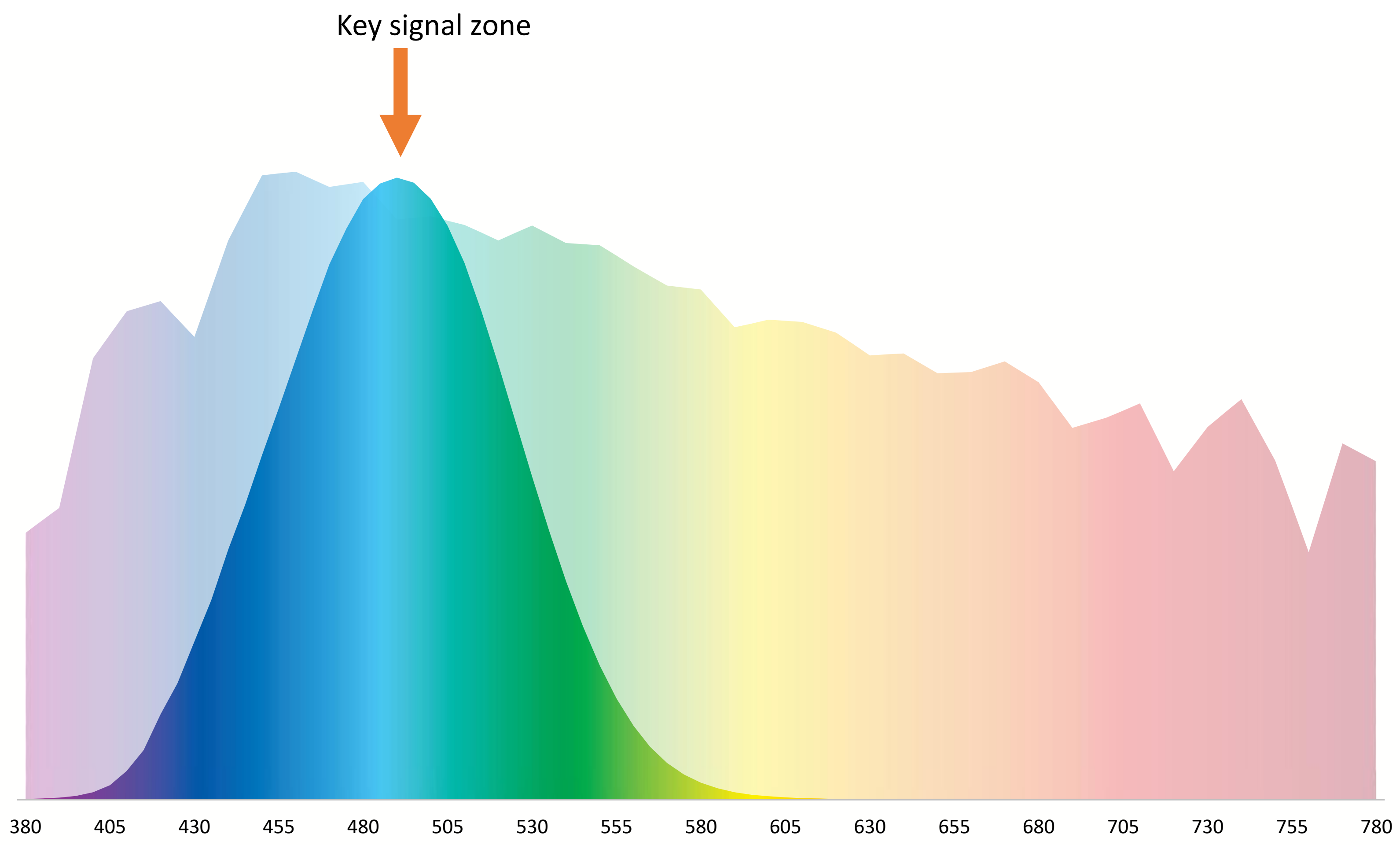
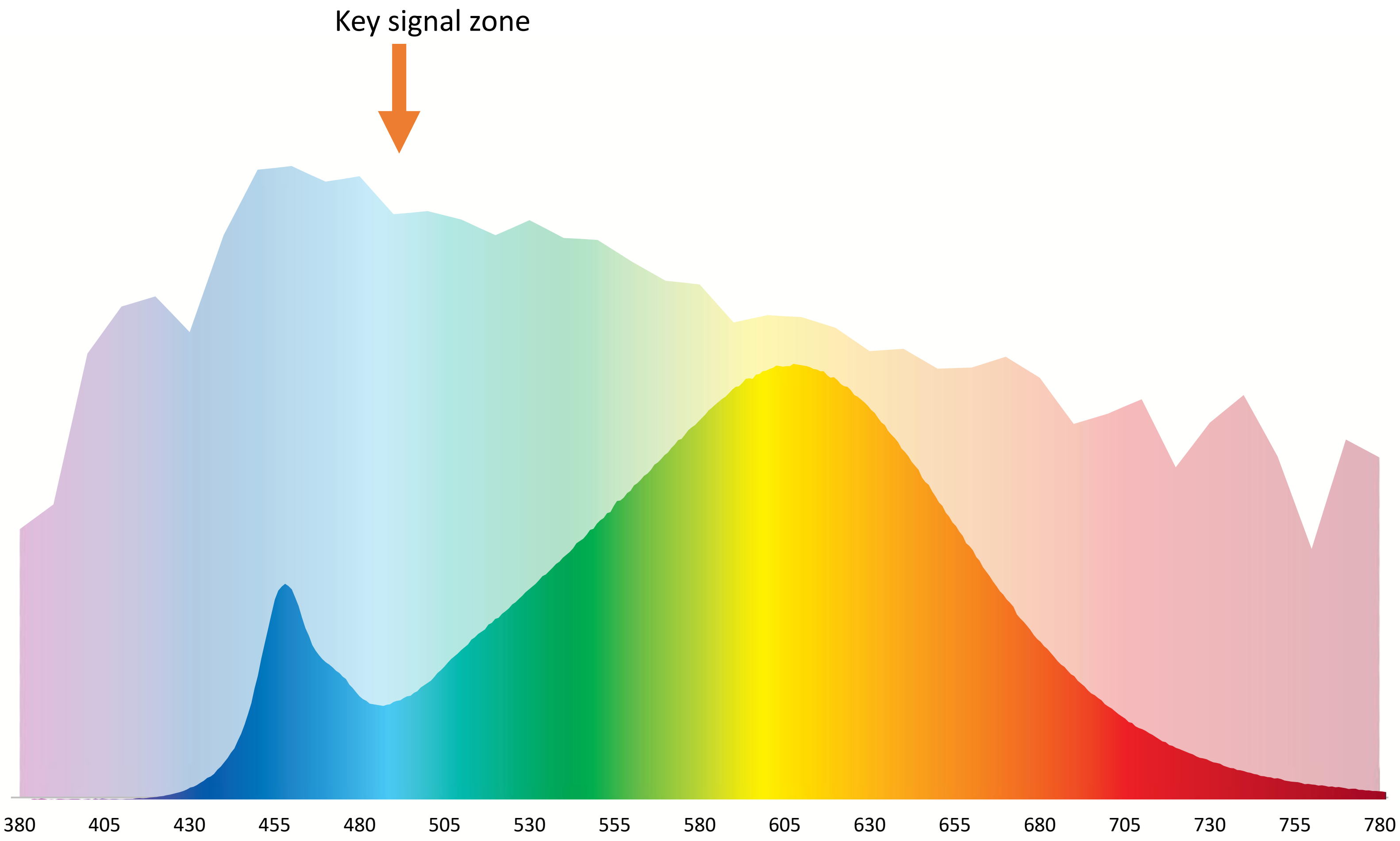
755
780

NEWLY FOUND RECEPTOR

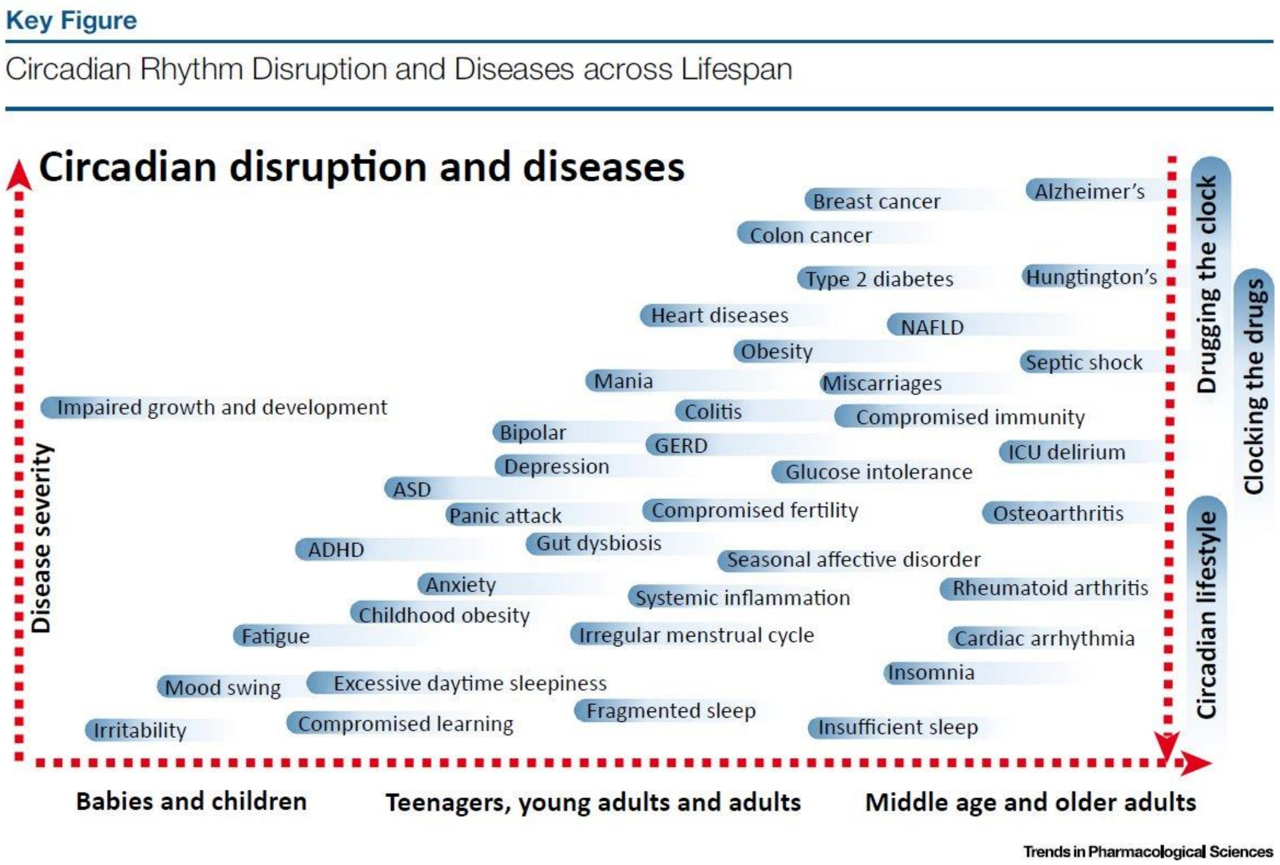


COMMONLY FOUND LED



WE'RE INSIDE MORE WITH REALLY POOR LIGHT

Consequences of Circadian Disruption



Manoogian et al. 2018

87% of day working people have some form of circadian disruption (Ronneberg and Marrow, 2016)

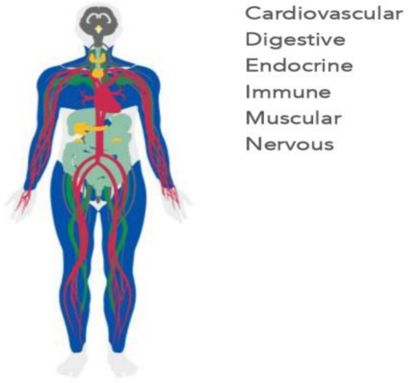
Circadian Lighting Standards

Discovery of novel photoreceptor that drives circadian rhythms is leading to the development of new lighting industry standards:

- WELL Building Standard
- LRC CS Calculator

WELL BUILDING STANDARD

- WELL Building Standard has adopted melanopic lux in part of their standard
- Part 54: Circadian Lighting Design
  - 200 melanopic vertical lux for a minimum of 4 hours per day.
    - Daylight may be incorporated

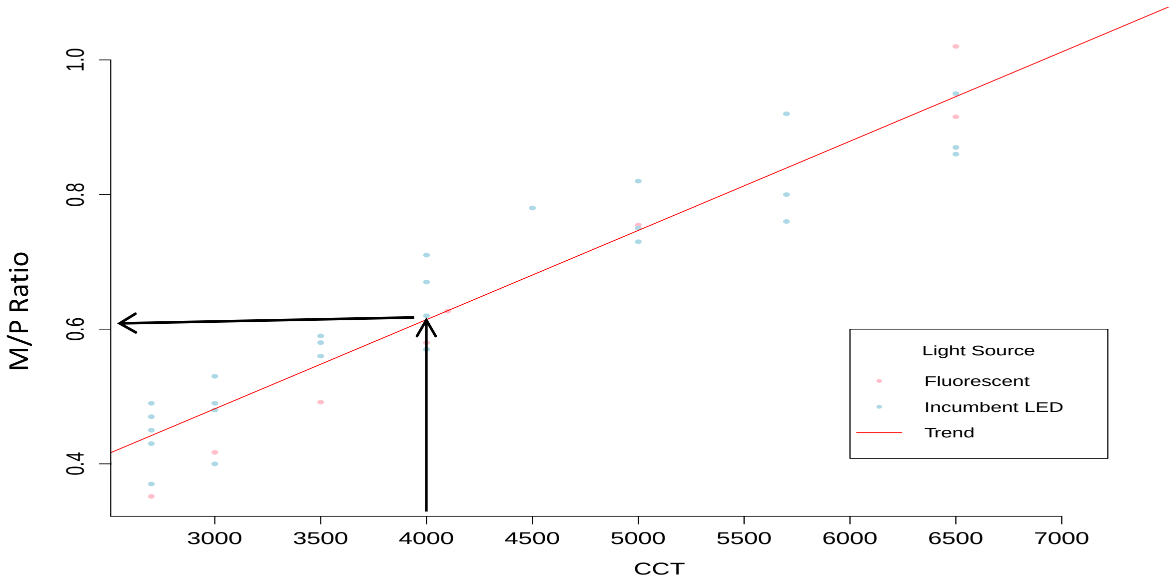


Core and Shell	New and Existing Interiors	New and Existing Buildings
-	P	P

Melanopic Lux requires a M/P ratio

MELANOPIC LUX (GOOD BLUE)

M/P Ratio versus CCT



This is 3 time more than what's normally used

Melanopic Lux =
Photopic Lux * M/P Ratio

Design

Spectrum

Example:

We know: 200 vertical melanopic lux requirement

Customer wants 4000K

M/P ~ 0.61

$\frac{200}{0.61}$ = Photopic Lux * $\frac{0.61}{0.61}$

328 = Photopic Lux

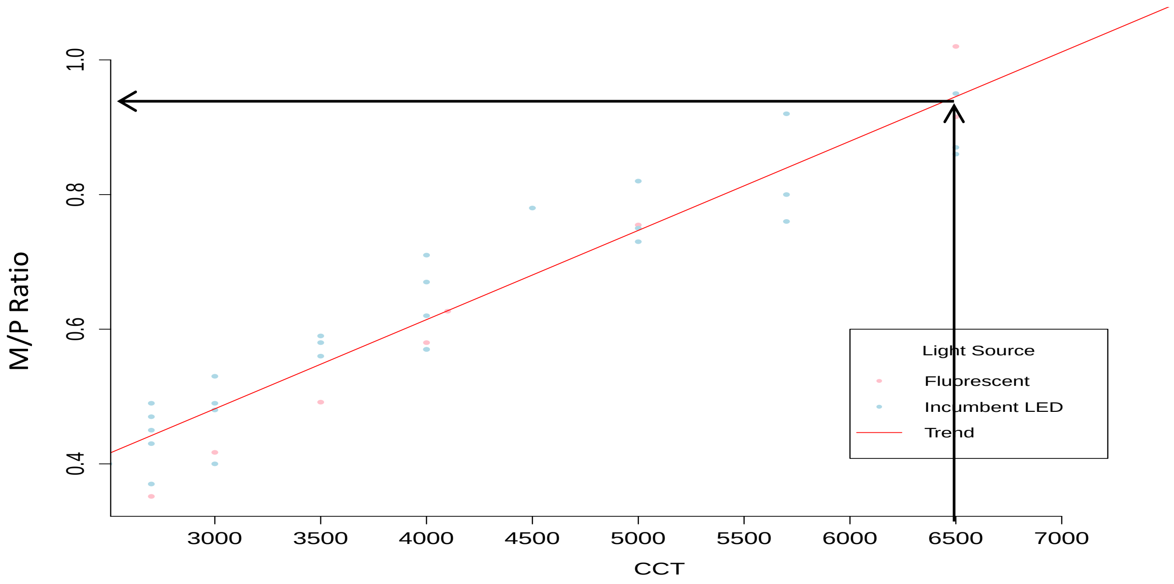
30 = Foot Candles (vertical)
@ 4' AFF, facing outward on 75% of workstations
IESNA recommendation for vertical illuminance in offices is 10 FC

MELANOPIC LUX (GOOD BLUE)

Melanopic Lux =
Photopic Lux * M/P Ratio

Design Spectrum

M/P Ratio versus CCT



This is twice as much light, but cringe-worthy 6500K

Another Example:

We know: 200 vertical melanopic lux requirement

Customer will live with 6500K

M/P ~ 0.93

$\frac{200}{0.93}$ = Photopic Lux * $\frac{0.93}{0.93}$

215 = Photopic Lux

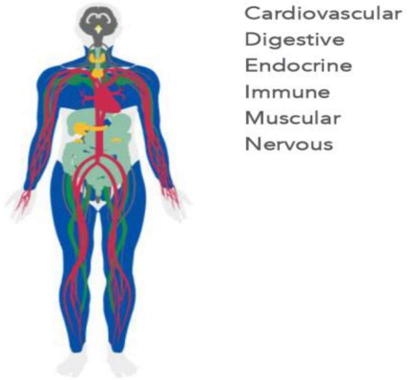
19.5 = Foot Candles (vertical)
@ 4’ AFF, facing outward on 75% of workstations

WELL BUILDING STANDARD

- WELL Building Standard has adopted melanopic lux in part of their standard
- Part 54: Circadian Lighting Design
  - 200 melanopic vertical lux for a minimum of 4 hours per day.
    - Daylight may be incorporated

  OR

  - 150 melanopic vertical lux for the entire day

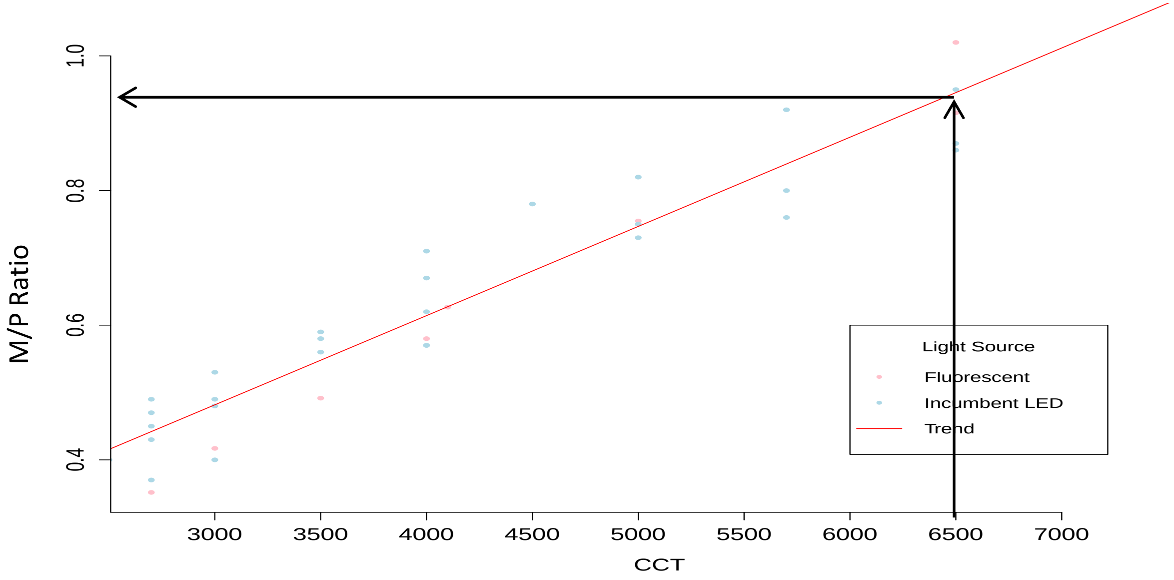


Core and Shell	New and Existing Interiors	New and Existing Buildings
-	P	P

Melanopic Lux requires a EML ratio

MELANOPIC LUX (GOOD BLUE)

M/P Ratio versus CCT



This is much closer to what we expect in interior spaces

Melanopic Lux =
Photopic Lux * M/P Ratio

Design

Spectrum

Another Example:

We know: 150 vertical melanopic lux requirement

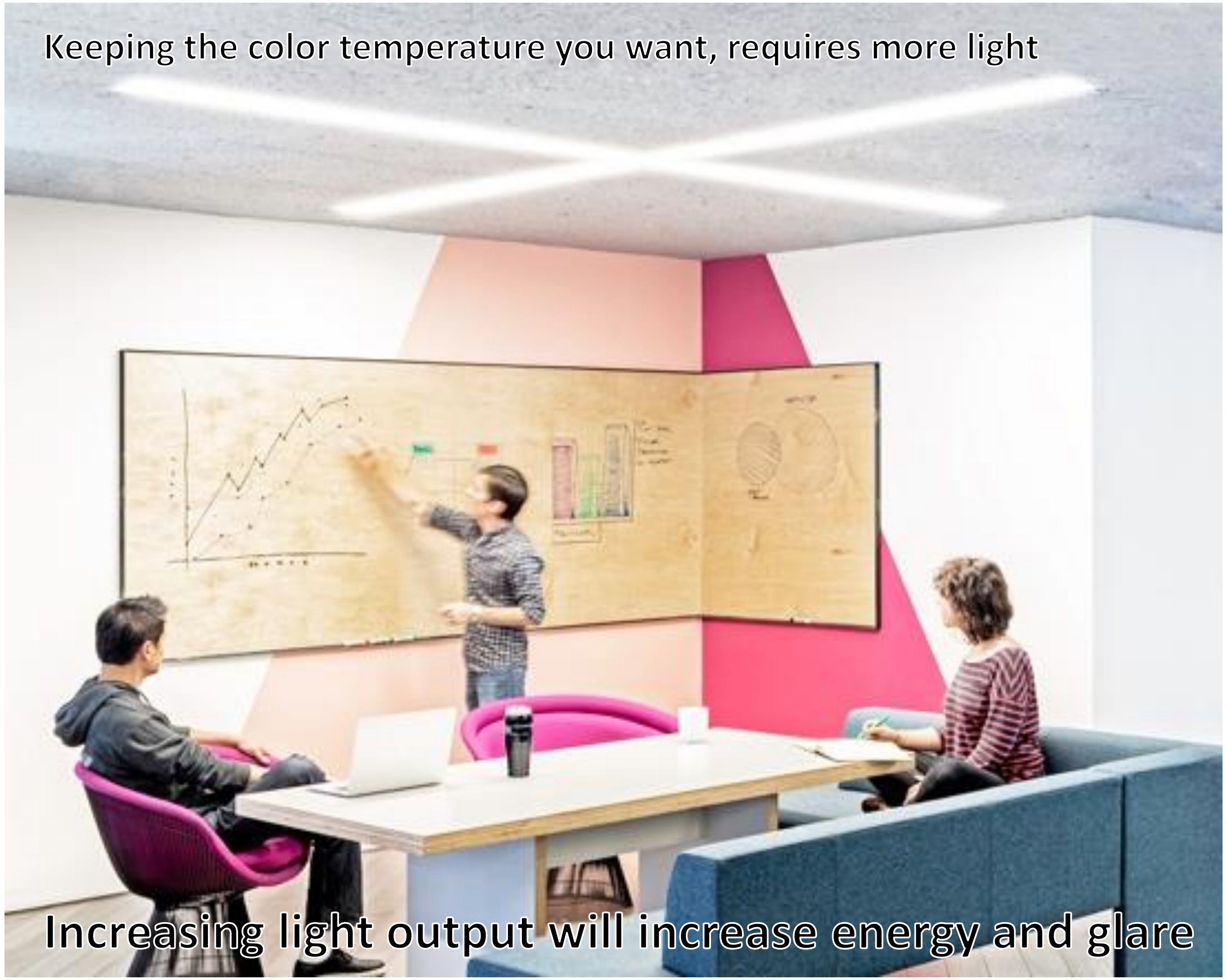
Customer will live with 6500K

M/P ~ 0.93

$$\frac{150}{0.93} = \text{Photopic Lux} * \frac{0.93}{0.93}$$

161 = Photopic Lux

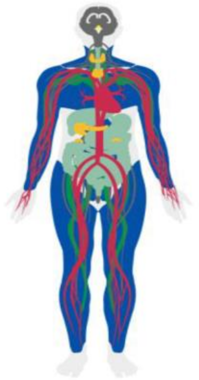
14.5 = Foot Candles (vertical)
@ 4' AFF, facing outward on 75% of workstations


Keeping the color temperature you want, requires more light
Increasing light output will increase energy and glare

WELL BUILDING STANDARD

- WELL Building Standard has adopted melanopic lux in part of their standard
- Part 54: Circadian Lighting Design
  - 200 melanopic vertical lux for a minimum of 4 hours per day.
    - Daylight may be incorporated

  OR
  - 150 melanopic vertical lux for the entire day
- Part 55: Electric Light Glare Control
  - UGR of 19 or Less



Core and Shell	New and Existing Interiors	New and Existing Buildings
-	P	P

Melanopic Lux requires a M/P ratio

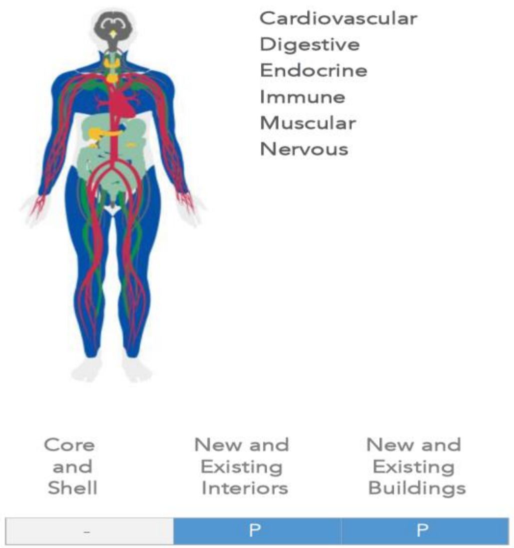

Increasing fixtures keeps glare down, but increases cost

Cooler Color Temperatures can keep intensity down

WELL BUILDING STANDARD

- WELL Building Standard has adopted melanopic lux in part of their standard
- Part 54: Circadian Lighting Design
  - 200 melanopic vertical lux for a minimum of 4 hours per day.
    - Daylight may be incorporated
  - IES-ANSI RP-1-12 equivalent melanopic vertical lux
    - Categories 25-65 in Table B1
- Part 55: Electric Light Glare Control
  - UGR of 19 or less
- Part 58: Color Quality
  - CRI > 80, R9 > 50

Melanopic Lux requires a M/P ratio

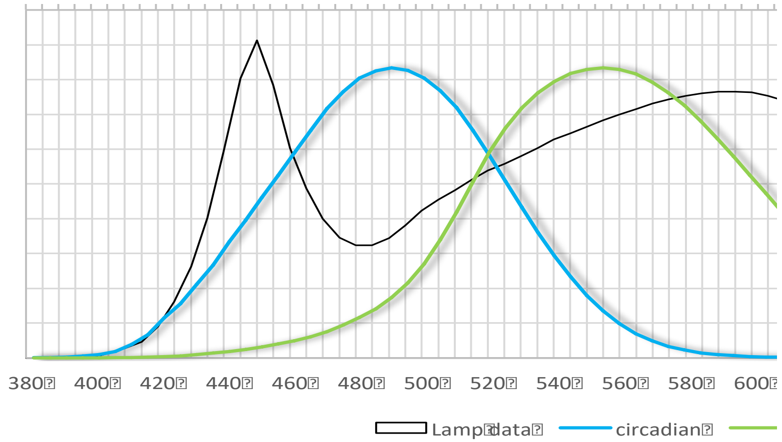


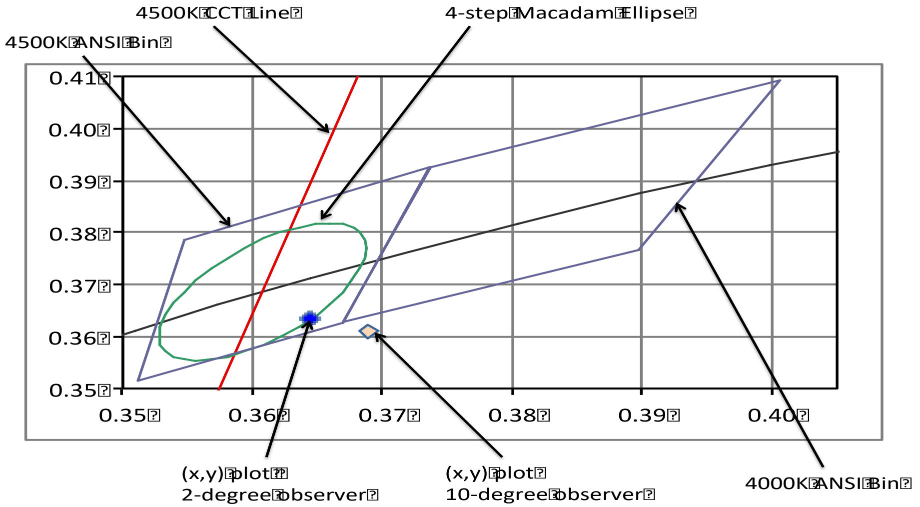
BUT WAIT...THE WELL SAYS 4000K IS 0.76

- Reference guide shows a EML ratio of 0.76 for 4000K LED

CCT(K)	Light Source	Ratio
2700	LED	0.45
3000	Fluorescent	0.45
2800	Incandescent	0.54
4000	Fluorescent	0.58
4000	LED	0.76
5450	CIE E (Equal Energy)	1.00
6500	Fluorescent	1.02
6500	Daylight	1.10
7500	Fluorescent	1.11

4000K SPECTRUM PROVIDED TO WELL



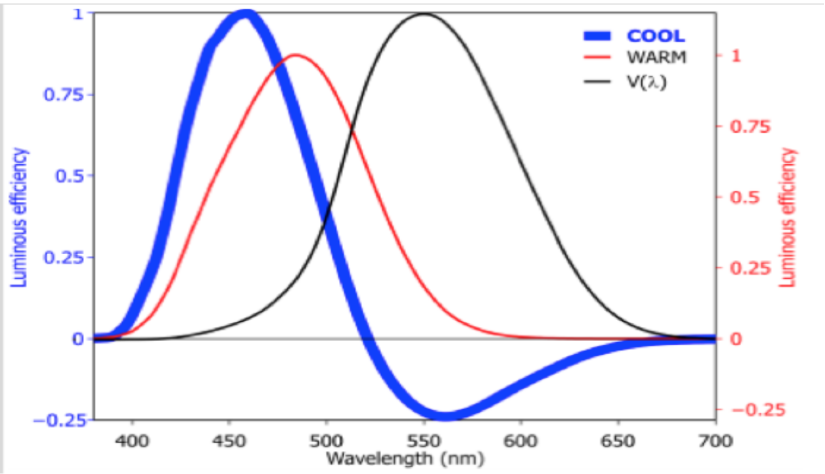


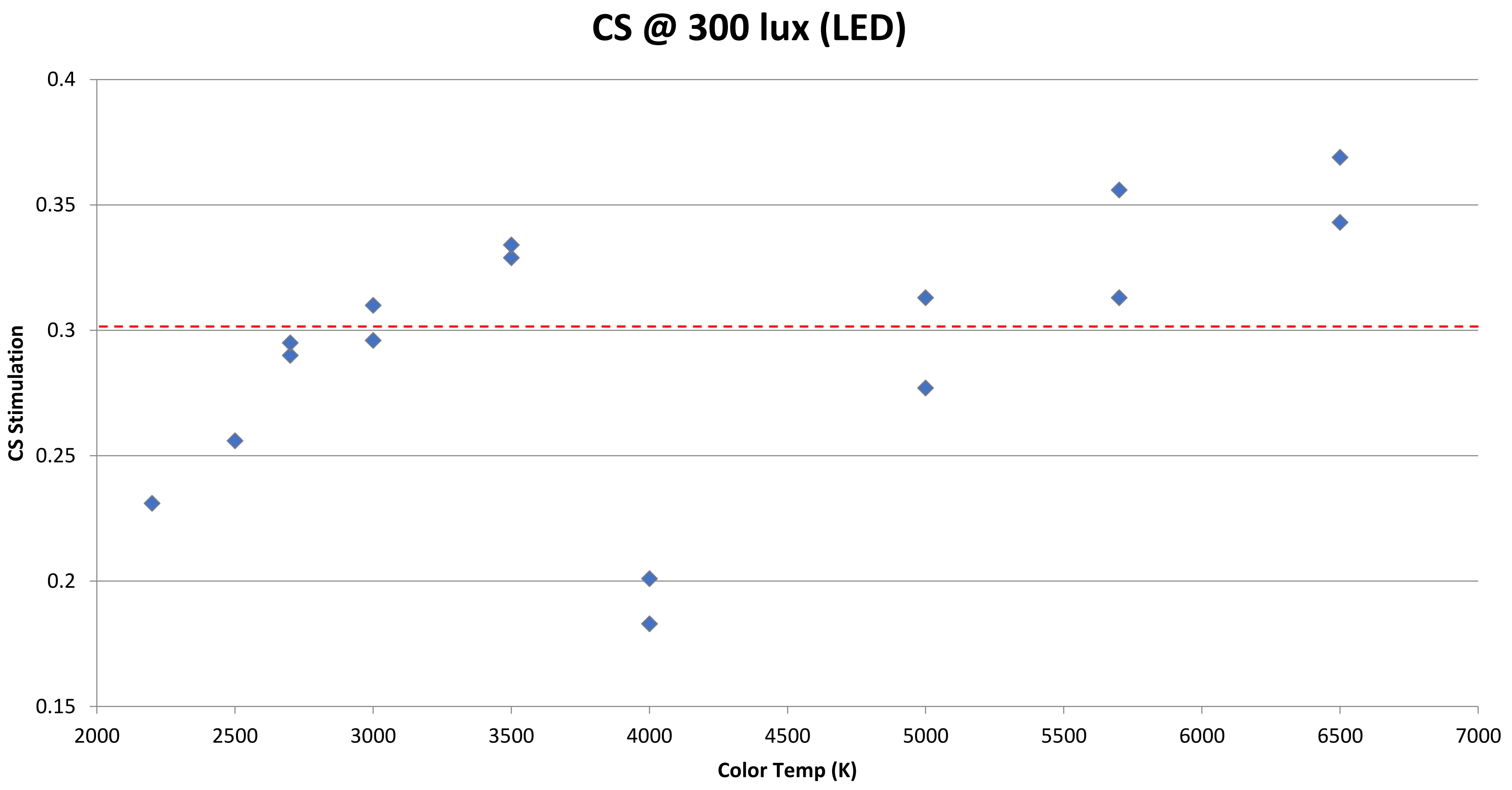
Turns out this is NOT a commercially viable LED

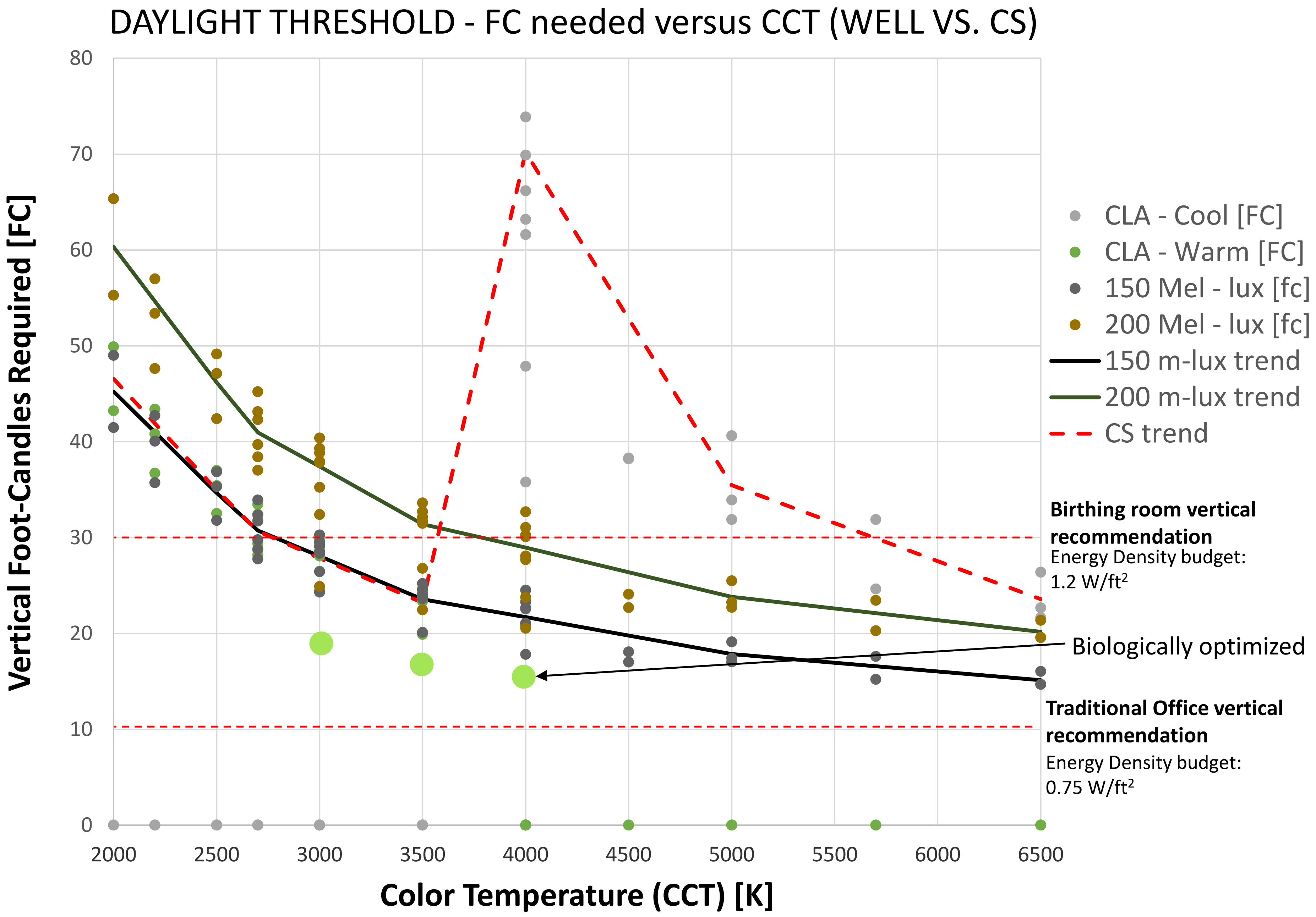
As a result: many people are failing to meet these circadian requirements

LRC MODEL

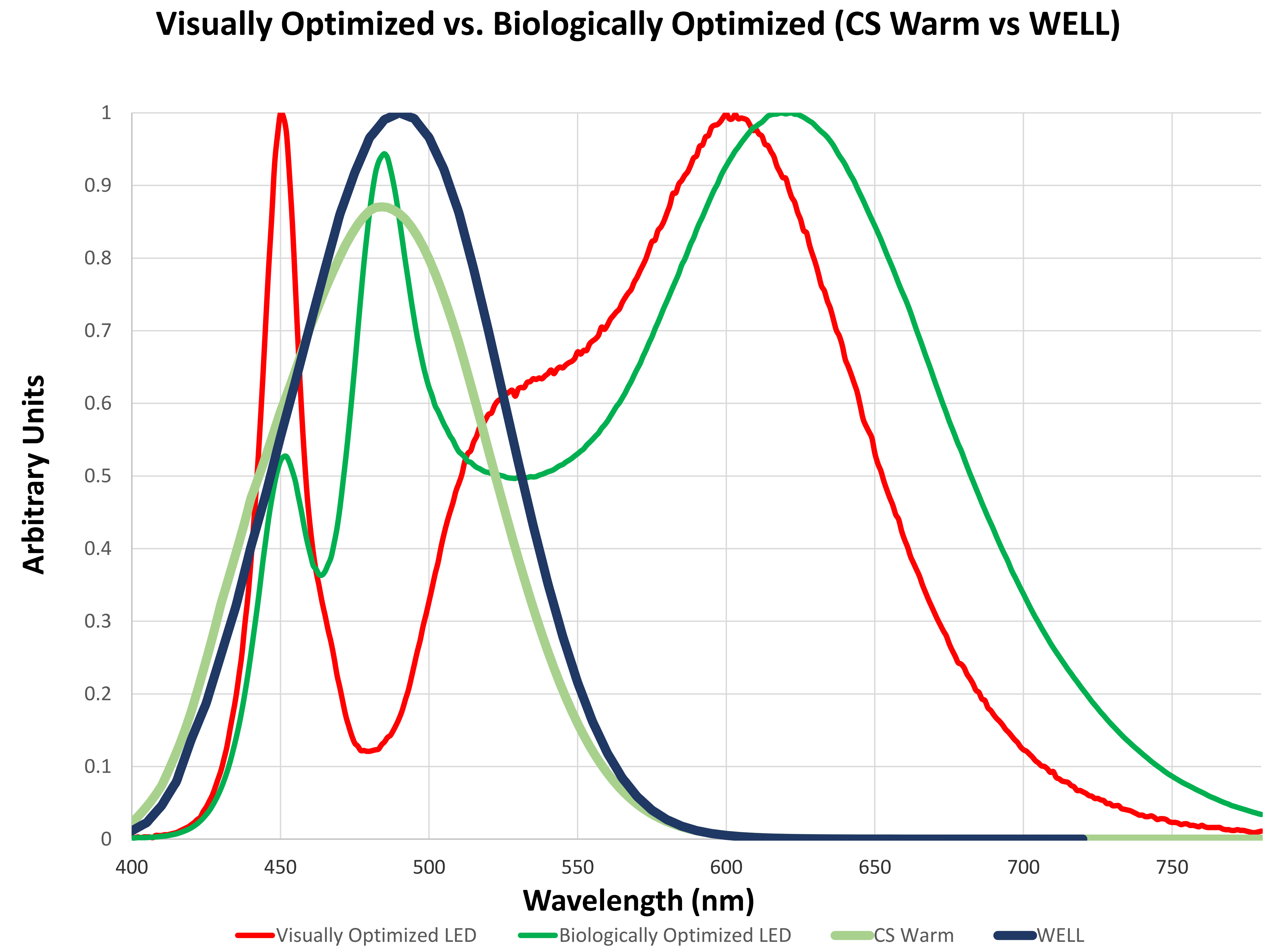
- Two-models in one
- The main difference here is it includes this idea of sub-additivity
- They basically agree at 3500K and warmer
  - 485nm peak versus 490nm
- Recommendation: CS of 0.3 or greater is a good daytime stimulus




CS @ 300 lux (LED)
CS Stimulation
0.4
0.35
0.3
0.25
0.2
0.15
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000
Color Temp (K)

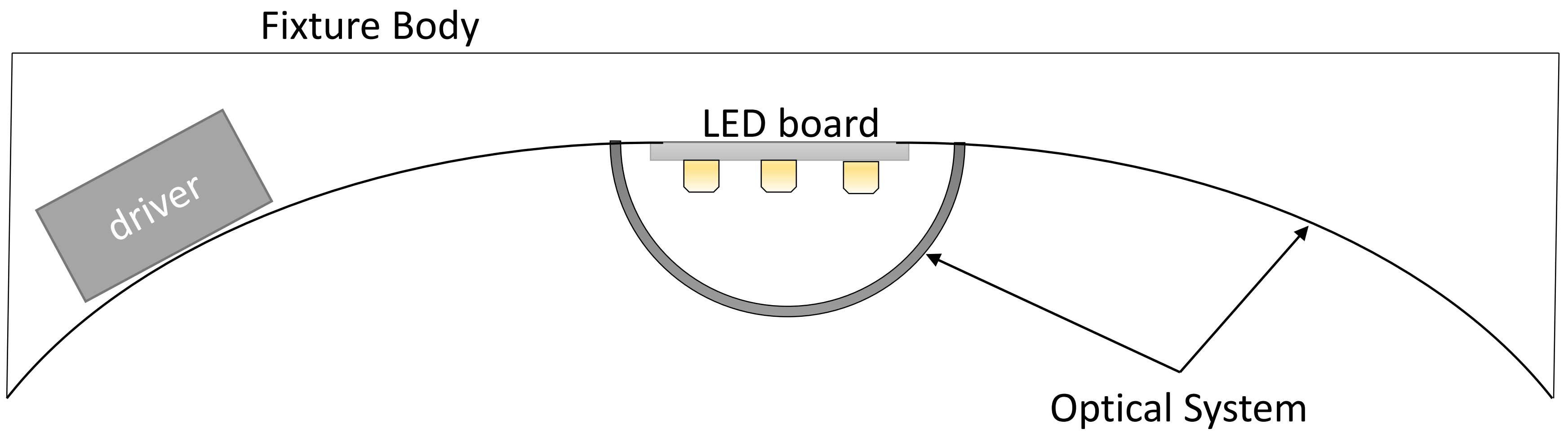


Generally, we need 2-3 TIMES more light in common CCTs


Visually Optimized vs. Biologically Optimized (CS Warm vs WELL)
Arbitrary Units
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
400
450
500
550
600
650
700
750
Wavelength (nm)
Visually Optimized LED
Biologically Optimized LED
CS Warm
WELL

SYSTEM EFFICIENCY

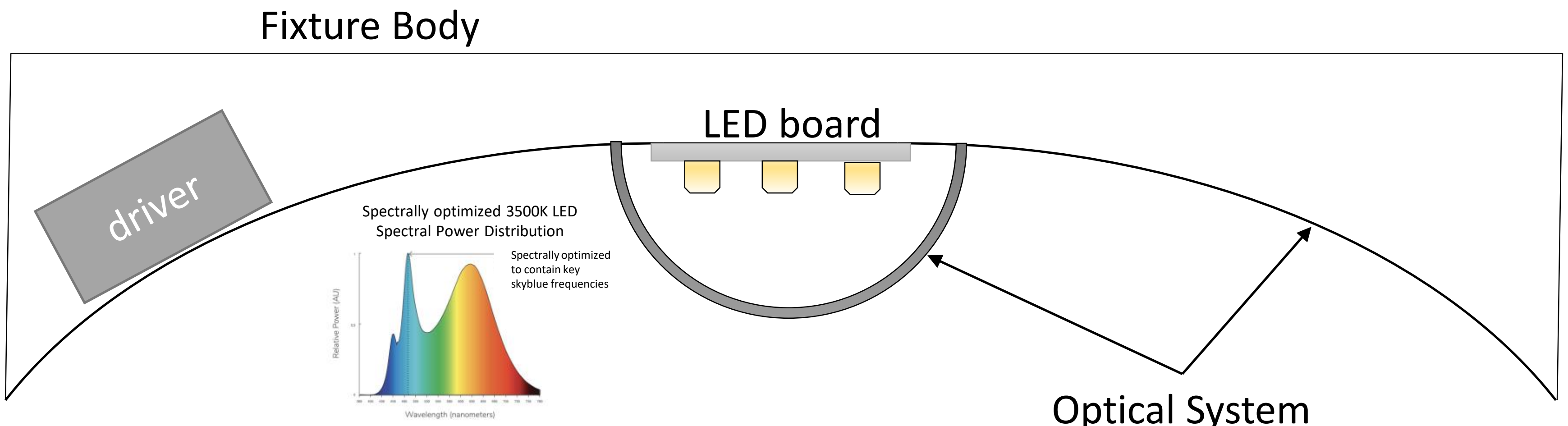
Troffer Example



- Components:
  - Power Supply/driver (PS)
    - ~87% efficient
  - LED board/light engine
    - 100-200 lumens per watt
      - Differences include color quality, biological potency, etc.
  - Optical System - reflector and diffuser (OS)
    - ~87% efficient

SYSTEM EFFICIENCY

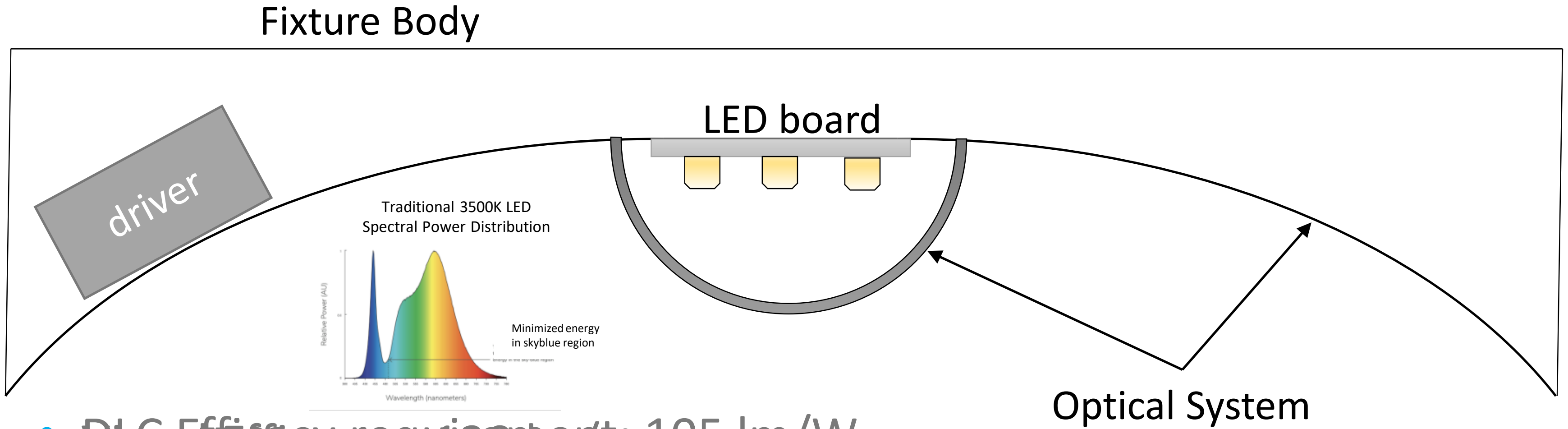
Biologically optimized



- Visual Efficacy = 130 lumens per watt
- 3500K with M/P = 0.83
- Fixture Efficacy = 130 * 0.87(PS) * 0.87(OS) = 98 lumens per watt
  - **DOES NOT MEET DLC REQUIREMENTS**
- Required vertical lux = 150/0.83(M/P) = 181 photopic lux (16.8 FC)

SYSTEM EFFICIENCY

Visually optimized



- DLC Efficacy requirement: 105 lm/W
- Visual Efficacy + 130 lm/w
  - 7% more efficient
- 3500K with M/P = 0.83
- Required vertical light = 150/0.56(M/P) = 267 photopic lux (24.9 FC)
- Fixture Efficacy = 98 lm/w
  - 48% more light needed
  - **DOES NOT MEET DLC REQUIREMENTS**
- 38% more energy required with a fixture that is DLC qualified
- Required vertical FC = 16.8 FC
- **If we only consider lumens per watt, we might be using more energy**

MORE TO THE EQUATION: BREAKDOWN OF IMPACT OF DIFFERENT WAVELENGTHS OF LIGHT IN DAYLIGHT

CONCLUDING POINTS

- There is a movement to provide more biological light in effort to promote health and wellness
  - This will require more energy
- Visually optimized spectrum may require more energy than biologically optimized spectrum
- We need to be looking at more than lumens per watt
- We need to report M/P ratios or more people will fail

Discussion Session
Commercial Break