AABC Commissioning Group
AIA Provider Number: 50111116

# Commissioning of Human Centric Lighting Systems

Course Number: CXENERGY1510

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# Course Description

- The world of lighting is in the midst of a multifaceted revolution.  Not only are light level controls being required by codes and standards such as California Title 24 and ASHRAE 90.1, but a new science called Human Centric Lighting also calls for controlling the Color Coordinated Temperature (CCT) of lighting.
- The next generation lighting technology can offer much more than just saving energy. This presentation will explore the **future use** of controls for dimming and CCT shifting, which is often called Kelvin changing or shifting, and how it can improve circadian rhythms, mood, visual acuity and performance in addition to providing substantial energy savings and sustainability.
- The presentation will address **future commissioning** of these new lighting systems and how it will require an understanding by all to think outside of the box.
- Emphasis will be placed on the need for expert commissioning guidance to determine optimal light levels and CCT at different times of the day based on the task optimize acceptance and reduce problems.

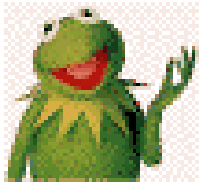
# Learning Objectives

At the end of the this course, participants will be able to:

1. Understand how light level controls are being required by codes and standards such as California Title 24 and ASHRAE 90.1.
2. Learn how the new science called Human Centric Lighting and its requirements for controlling the Color Coordinated Temperature (CCT) of lighting.
3. Understand how the proper use of controls for dimming and CCT shifting can improve occupants' circadian rhythms, mood, visual acuity and performance in addition to providing substantial energy savings and sustainability.
4. Learn why expert commissioning guidance is needed to determine optimal light levels and CCT at different times of the day based on the task optimize acceptance and to reduce problems.

# Being Green

- Who said “its not easy being green?



# Definition – Human Centric Lighting

- **Human Centric Lighting**
  - Lighting which can improve
    - circadian rhythms
      - alertness
        - sleep
          - mood
            - visual acuity
              - performance
                - etc.

http://humancentriclighting.com/

# What is Human Centric Lighting

HCL includes daylight, specialized fixed CCT electric light and tunable, which dimming and CCT or color changing, electric light.

Human Centric Lighting is based on predecessor and human evolution with daylight and night, substantial neuroscience research, especially since about 2000, when intrinsically photosensitive retinal ganglion cells (ipRGCs) were discovered, and practical case studies.

It is useful to know information about a person or people

- Age
- Sex
- Morning lark or night owl
- Work or activity schedule
- Times and quantity of drinking caffeine
- Eating patterns
- Mental and/or physical health
- Medications

Proper dosing of light for various tasks is usually very important. This includes:

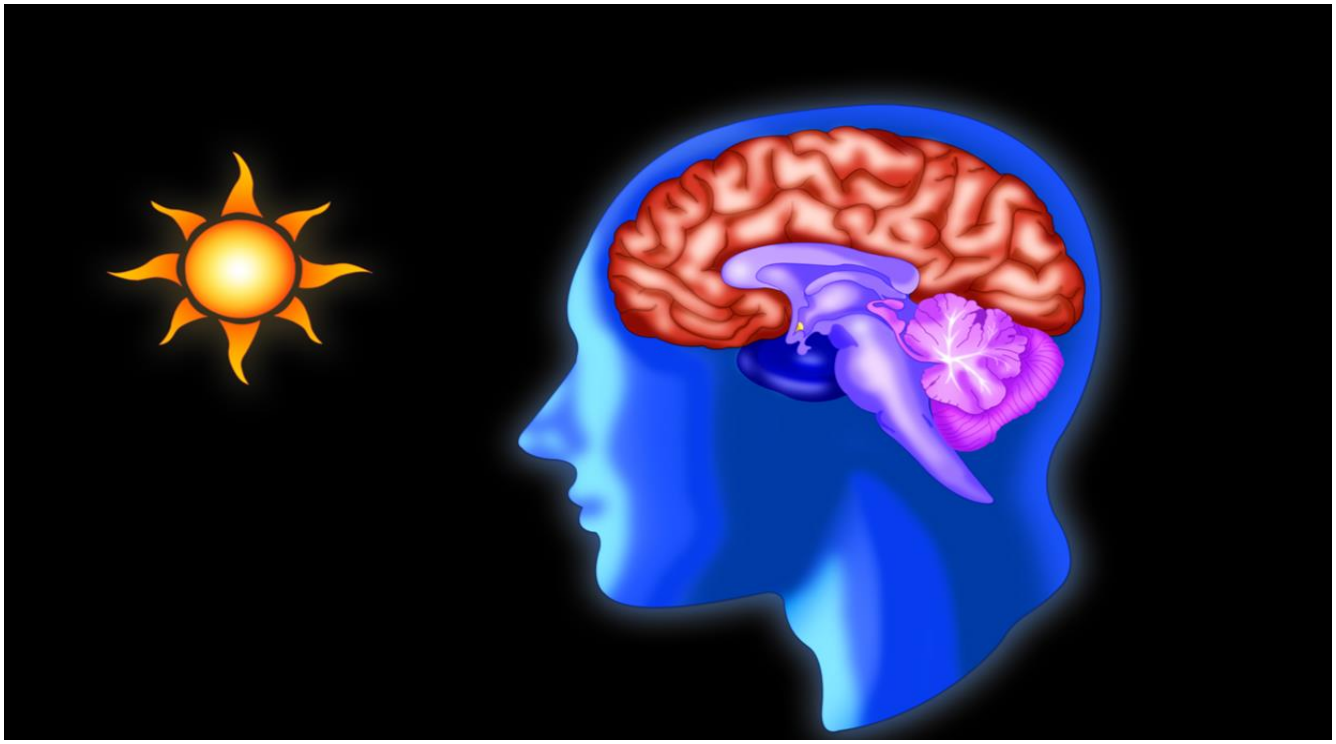
- Intensity
- Spectrum
- Duration
- Time(s) of day

# Human Centric Lighting

- HCL has a range of positive impacts on society, according to the new research and other studies on the topic
- At its simplest, such lighting allows us to sleep and rest best and perform with greater productivity during waking hours. Tunable lighting/color has also been shown to accelerate healing and help prevent chronic diseases
- HCL goes beyond the basic visual needs of people. Our populace is spending greater periods of time indoors and quality lighting is imperative for health
- “HCL solutions can actively support the circadian rhythm of human beings, thus promoting a person’s wellbeing, mood, and health.”

Source: Alfred Wacker, chair of LightingEurope’s Light and Health Working Group

# The Influence of Light

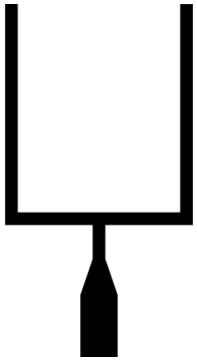


Light influences the biochemistry of the brain, endocrine systems, metabolic processes, and — well, who knows where it ends?

Source: Nat'l Institute of General Medical Sciences.

# Potpourri of Goals

- Lighting Community
- End user
- Builder
- Commissioning



# Lighting Community goal

To safely place the correct amount and type of light where it is needed, when it is needed, and for the lowest life cycle cost

Need:

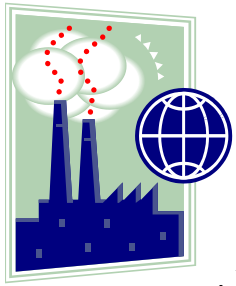
- Consistency in products
- Cost-effective products
- Quality in products
- Reliability in products

Then products will:

- Allow interchangeability of system components
- Provide “superior” lighting

# End User Lighting Goal

- Save money
  - First cost
  - Reduce power consumption
  - Reduce maintenance
- Provide “proper” level of illumination
  - Safe
  - Adequate light level
- Be environmentally friendly



# Builder Lighting Goals

- Spec builder
  - Minimize first cost
  - Maximize “appealability”
  - Maximize sales price
- Custom builder
  - Satisfy purchaser
  - Maximize profit

# Commissioning Goal

- Make it easy
- Get it done fast
- Get it done correctly the first time
- Satisfy the customer
  - Easy to use
  - Happy users

# Commonality of Goals

- Safe
- Correct amount of light
- Be green
- Money
  - First cost
  - Life cycle cost
- Ease of
  - Installing
  - Commissioning
  - Using

# Definitions

- Light Sources
- CCT (Correlated Color Temperature)
- CRI (Color Rendering Index)
- Lamp life
- Warranty

# Evolution of Light Lamps

# CCT (Correlated Color Temperature) - Kelvin (K)

- Color temperature – a measure of the "warmth" or "coolness" provided by the lamp, expressed in Kelvin (K).
  - Generally, sources below 3200K are considered "warm" while those above 4000K are considered "cool."
  - The higher the color temperature, the "cooler" or bluer the light.
  - Also called "Chromaticity"

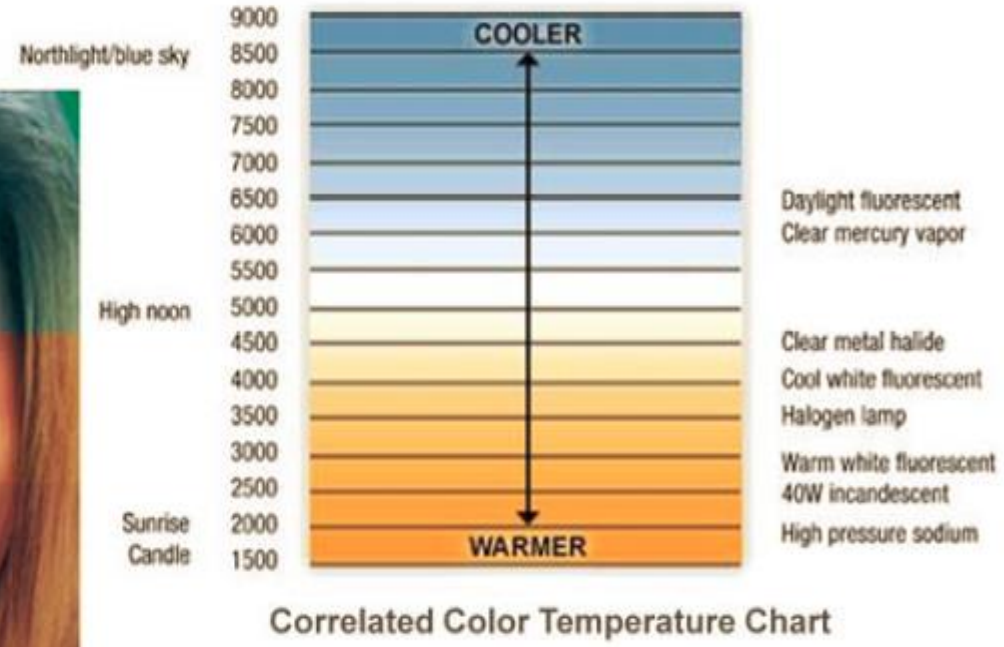
| Lamp CCT (Kelvin) | |
|---|---|
| <2500 | 3500–4100 "Cool" |
| 2500–3000 "Warm" | 4100–5000 "Very cool" |
| 2950–3500 "Neutral" | 5000–7500 "Cold" |

New concept – Human Centric Lighting

# CRI (Color Rendering Index)

- Color Rendering Index (CRI) - a scale from 0-100, is a measure of how well a lamp renders color.
  - A lamp with a CRI of 100 makes objects appear as they do in sunlight.
  - CRI can only be compared for lamps of similar color temperature.

# Lamp Characteristics – CCT and CRI

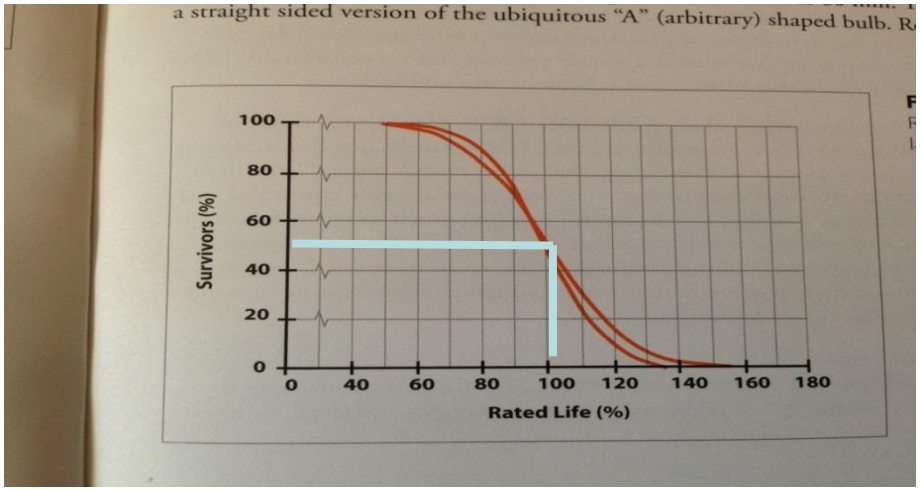



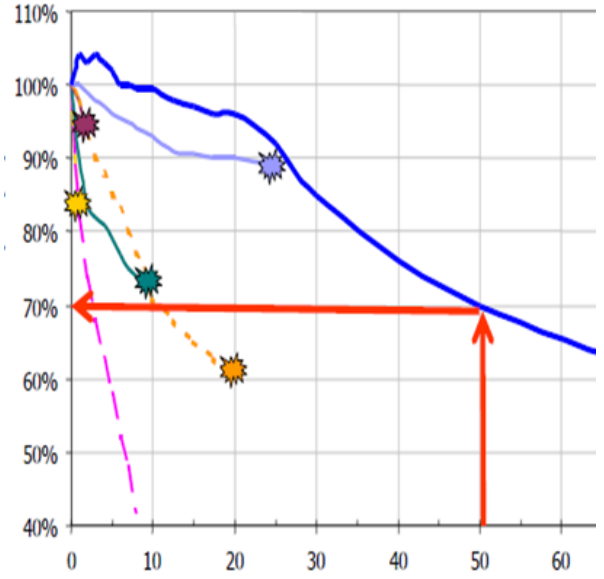

Correlated Color Temperature Chart

Source: IES

# Lamp Life

- Rated Life for **Incandescent, HID, and Fluorescent** is the point in time at which 50% of a large group of lamps have failed.
  - Ratings in catalogs are result of standard lab tests.
  - (Ex: Fluorescent lamps 20,000 hrs. @ 3 hrs./start)
- Rated life for **LED** is when lumen output has dropped to 70%, or $L_{70}$



# Warranties




- 10 years @ 24 X 7 X 365 = 87,600 hours
  - What is covered
- “Limited” warranty
  - What is not covered

Source: Stephen Naor Leapfrog Lighting

# LED dimming and Driver

LED drivers are low-voltage components that convert input-voltage power, such as 120V, 220V, or 277V, to the low voltage that LEDs need. These drivers can also interpret control signals to dim, brighten, and change the color of the emitted light (*Figure 1*).

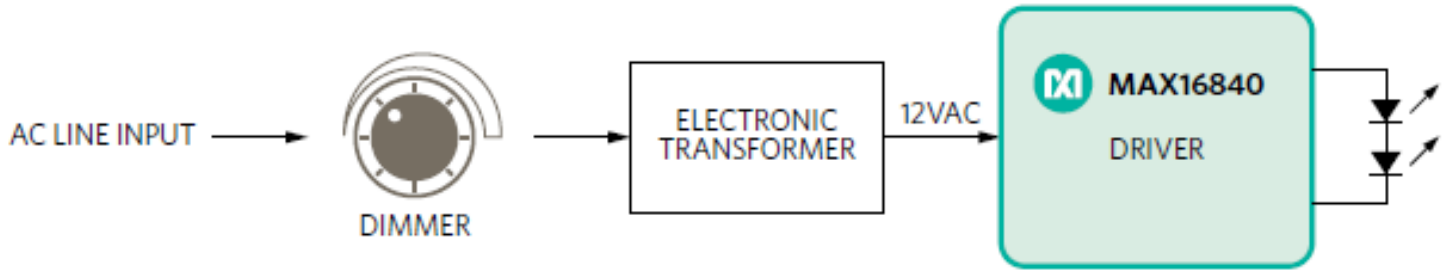


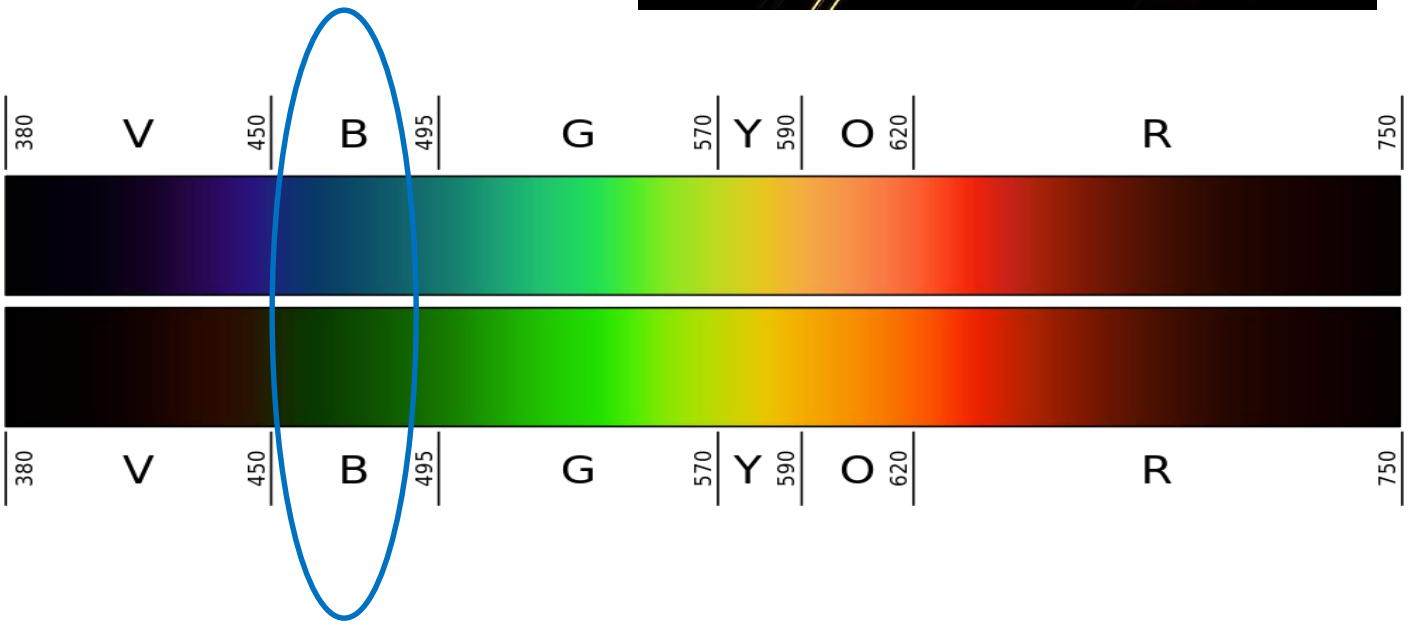

*Figure 1: The LED driver converts the input voltage to the level that the LED needs.*

Source: Maxim Integrated

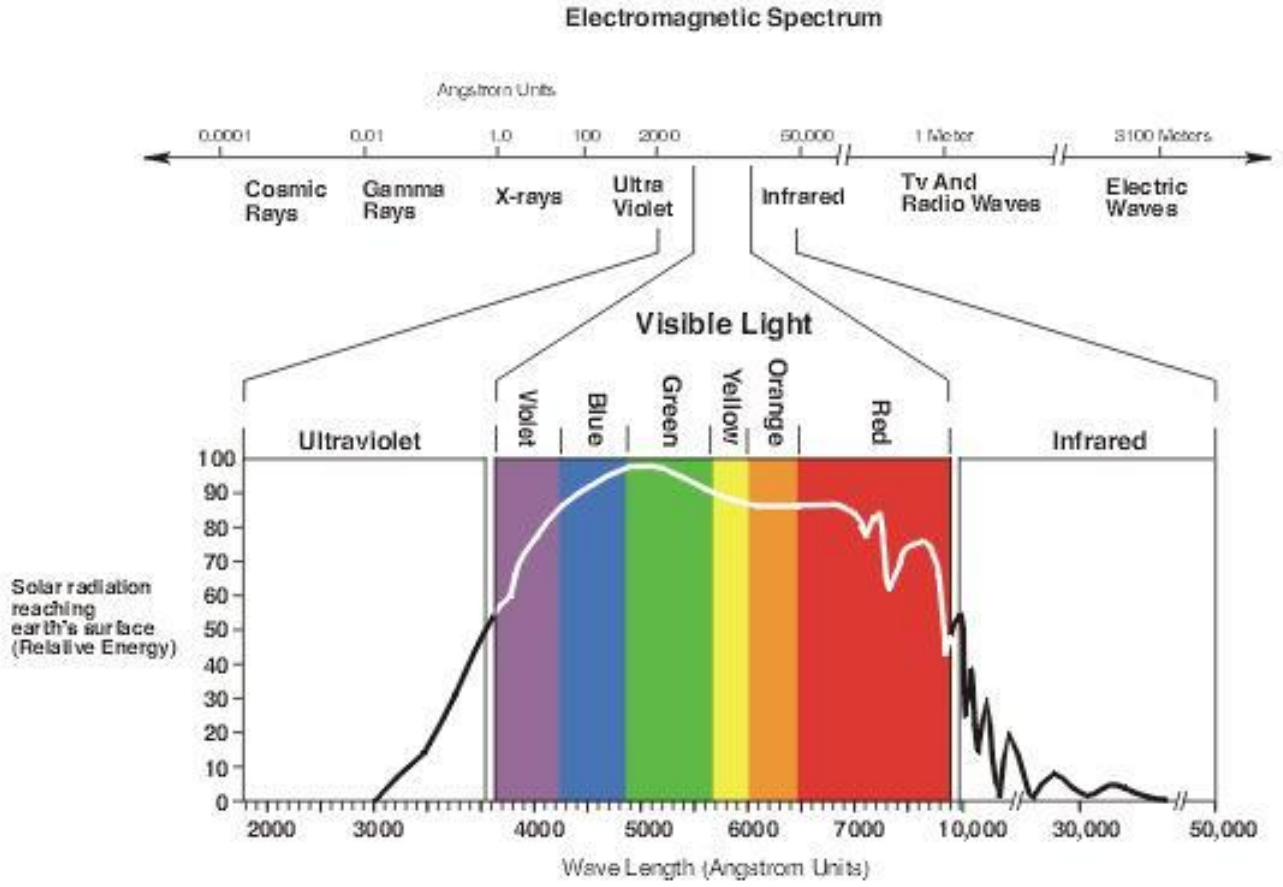
# Tunable

- For quite a long time some people have been calling dimming ballasts tunable, when they just dim. Tunable should include dimming with some type of white color tone changing or color changing.
- Although some systems cost less and are more efficient, based on photopic lumens, others can do a better job providing or not providing substantial 460 – 490 nm of light at various times of the day.
- Color tunable could be a RGB system, but each color LED is not totally independently controlled, so choices are limited.
- Spectrally tunable could be a RGB+ system with total independent dimming drivers and controls for each color to re-create any visual spectral condition, including on and off black body curve and degrees of saturation.

# Blue Light ~~Special~~ Hazard

# Visible Light Spectrum



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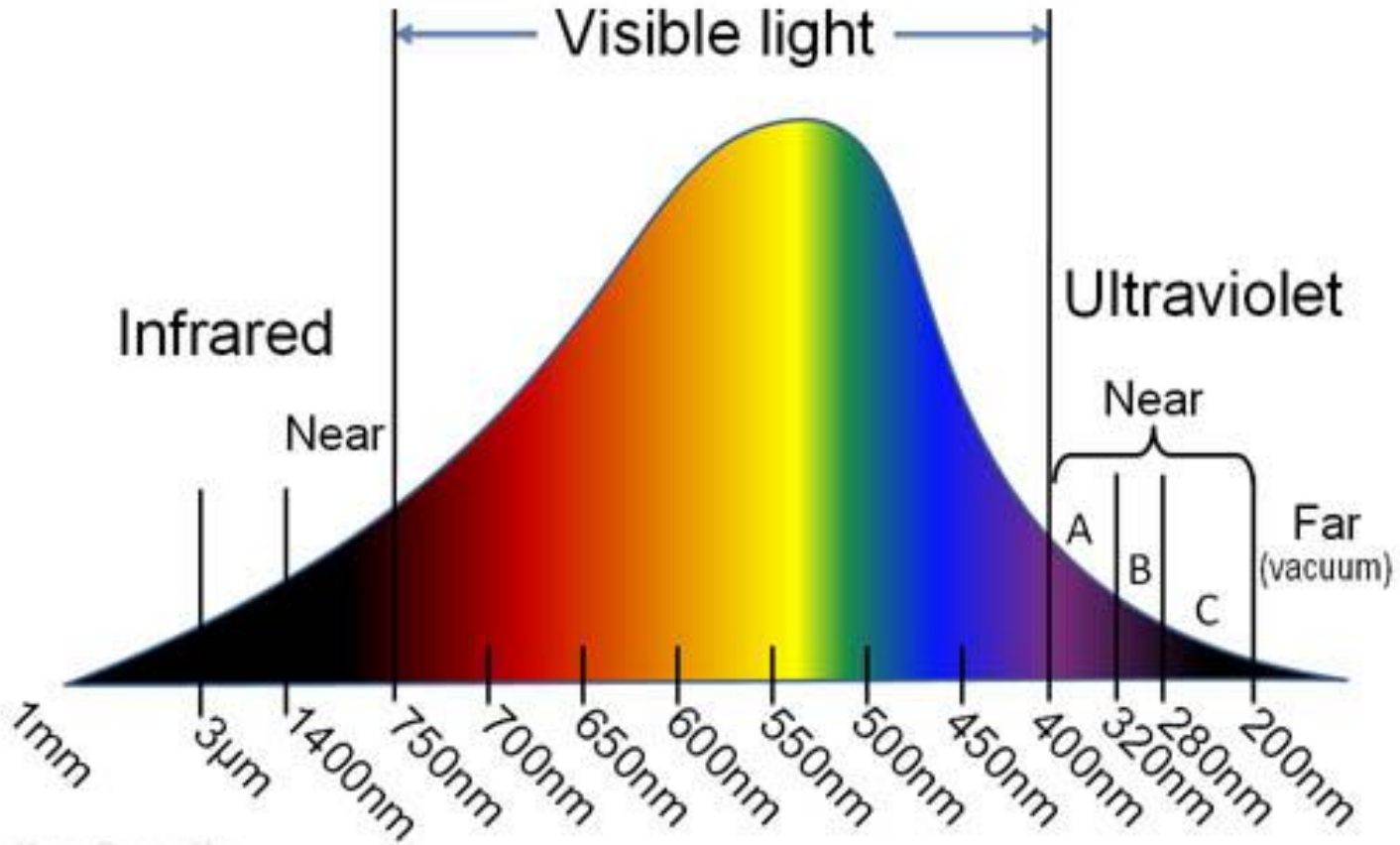


# LIGHT
# IS A
# DRUG

# ONE EXAMPLE IS LIGHT VS CAFFEINE

- Caffeine
  - 5 hour half life (some people state 4 or 6 hours)
  - Many coffees and some sodas have 200 mg of caffeine
  - If only one serving at 1 PM, which may be during post lunch dip
    - 100 mg at 6 PM
    - 50 mg at 11 PM, which can sleep delay in many people
  - If have more caffeine before and/or after 1 PM, problem can be compounded

Source: Stan Walerczyk, LightingWizards

# ONE EXAMPLE IS LIGHT VS CAFFEINE

- Light
  - 30 – 45 minutes of relatively high intensity and can be called high CCT, high Kelvin, blue enriched or 460 – 490 nm light can provide the same short term alertness benefit
  - Decision making may be better than with caffeine, because more calm
  - Effect goes away in about 2 hours

Source: Stan Walerczyk, LightingWizards

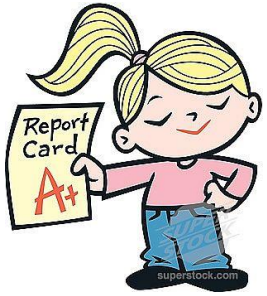
# ONE EXAMPLE IS LIGHT VS CAFFEINE

- Light
  - Especially working or studying before going to bed, this is better than than caffeine
  - Although we do not know the mechanism of this short term alertness boost, we know the effect

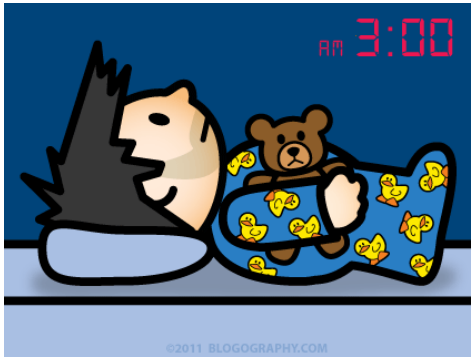

Source: Stan Walerczyk, LightingWizards

# HUMAN CENTRIC LIGHTING

- Basic guidelines
  - Substantial 460 – 490 nm content most of the day
    - ‘Day’ can be considered night if a night shift




  - Avoid 460 – 490 nm content 1 – 2 hours before going to bed




# BIG QUESTION
# &
# BIG ANSWER

# BIG QUESTION

- Will fixed CCT or Kelvin LED products, even if they are very efficient, be out dated within as short as 3 years?

Source: Stan Walerczyk, LightingWizards

# BIG ANSWER

- It sure looks that way as not only lighting professionals, but also commercial and residential end-users learn the significant visual and non-visual or biologic benefits on tunable (dimming and Kelvin or color changing) LED products
- There are already controls, which can provide optimal dosing of intensity and spectral distribution for various times and tasks through out the day
- People within 3 – 5 years will probably look back and wonder how they survived with today's lighting and outdated controls
- Remember before your first dumb phone and then smart phone!

Source: Stan Walerczyk, LightingWizards

# BIG ANSWER

- There are currently cost effective tunable LED products and controls for them
  - Some have about the same lumens, maximum wattage, lumens per watt (LPW), rated life and warranty as standard LED fixtures and they do not cost much more
  - So why accept fixed Kelvin LED products in many applications?
- Controls will get better down the road and it may be good to upgrade or replace them in a few years
- Lighting should no longer be considered just a commodity of energy savings and rebates

Source: Stan Walerczyk, LightingWizards

# SDG&E SCHOOL PROJECT

- A recently completed a dynamic CCT study for San Diego Gas & Electric's Emerging Technology Program
- In 1 4th grade classroom replaced 15 2x4 fluorescent troffers with 15 2x2 2700 – 6500K tunable LED troffers with smart wall controllers & 15 2x2 fixed 10,000K LED troffers with 30 minute wall timer
  - Both have typical blue pumped peak 450 nm LEDs

Source: Stan Walerczyk, LightingWizards

# SDG&E SCHOOL PROJECT

- Fixed 10,000K LED troffers with 2700 – 6500K LED troffers by themselves
  - Informed teacher that 10,000K LED troffers should be used first 30 minutes in the morning and if helpful also for post lunch dip and critical learning times also with tunable troffers set at 6500K at full output
- After being informed about how light can effect the non-visual or biologic part of the visual system, teacher and students have been using:
  - Tunable troffers at 6500K
  - 10,000K troffers while doing math second thing in the morning

Source: Stan Walerczyk, LightingWizards

# Test Scores Support Study

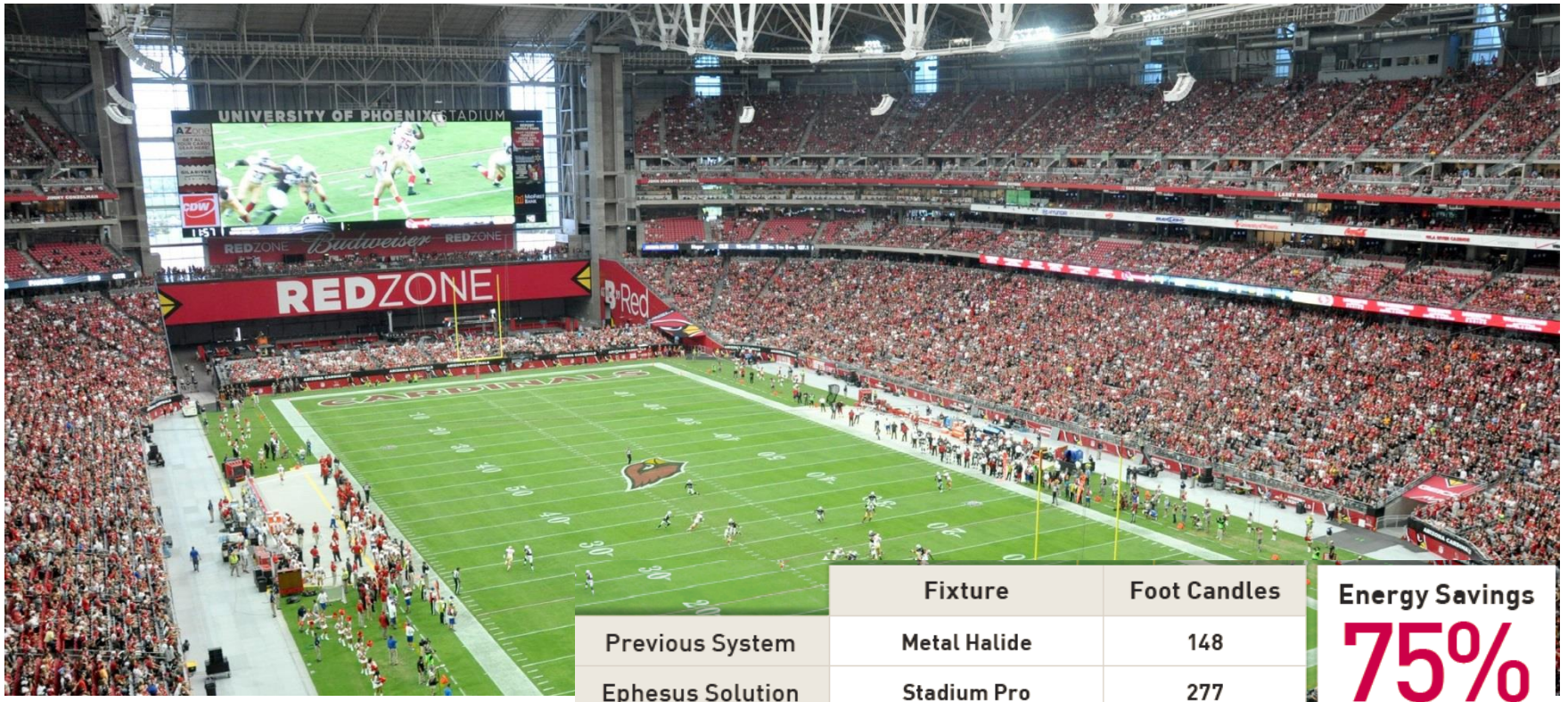
**PLANNED PARTICIPATION**
At Saltillo elementary School near tupelo, Miss., Philip's SchoolVision system was installed as part of a study by the university of Mississippi.

**LOW-KEY/UP-TEMPO**
Four different light settings were implemented, including "calm" (above), and "normal" (left). the study found that students exposed to the varying lighting experienced increases in performance 33%higher than students in the control group.

Source: Philips Lighting

# *UNIVERSITY OF PHOENIX STADIUM*

## *2015 Super Bowl Game*




| | Fixture | Foot Candles |
|---|---|---|
| Previous System | Metal Halide | 148 |
| Ephesus Solution | Stadium Pro | 277 |

**Energy Savings**

**75%**

An average of 277fc was generated on the playing surface, nearly doubling previous lighting levels. Light was precisely projected up to 620 feet from the source, while max/min uniformity improved to 1.2. System wattage was reduced by 929,000 watts

# Seattle Mariners' Locker room

New solid-state lighting at the Seattle Mariners' stadium — the first Major League Baseball stadium to make the switch — which includes (in the home team locker room only)features to tweak circadian rhythm for optimum alertness at game time.

Source: Stan Walerczyk, LightingWizards

# Effects of light beyond visual perception

## Visual effects

Image
Intensity
Contrast
Shape
Motion
Perception

## Biological effects

Hormones
Concentration
Chronobiology
Inner Clock
Alertness
Circadian Rhythm

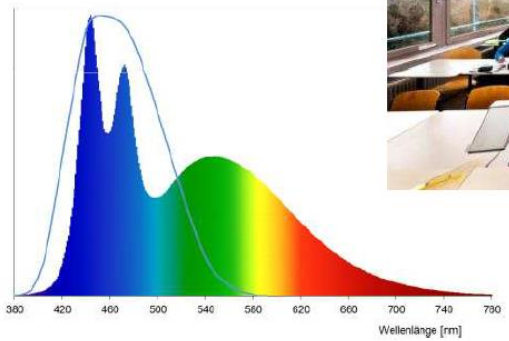

## Psychological effects

Comfort
Wellbeing
Mood
Relax

# LED Combinations

## Arranged to Excert High Melanopic Stimulation

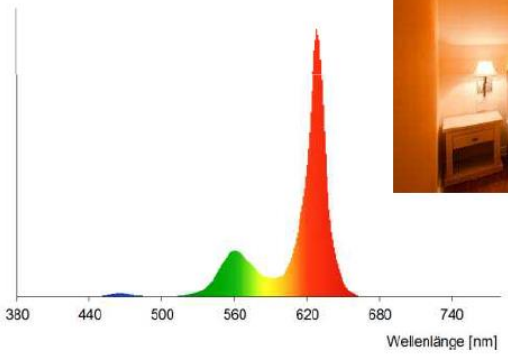
- LED Spectrum with coolwhite and blue
- 12000 K with Ra=80






## Arranged to Excert Low Melanopic Stimulation

- LED Spectrum with amber, green, blue
- 1500 K with Ra=90
- $a_{mel,v}$ = 0,05



# Regulations and Standards

- ASHRAE 90.1
  - Only interested in energy savings
- California Title 24
  - Attempts are being made to add to 2016 version
- Illuminating Engineering Society
  - Has started to recognize the potential of HCL
- US Department of Energy
  - Not in the Rulemaking pipeline to date
- Standards
  - None from IES, IEEE, UL, etc.

This is a Challenge

# The Future

Light therapy

Faster recovery

Nursing homes

Active day smooth night

Office


Stronger synchronization

School

Improved learning

aircraft

More comfort and relaxation

Wellness hotel

Sleep and recovery improved

Pain therapy

Study ongoing high acceptance

# The future

- LED prices
- Connectivity
  - Lamps
  - Luminaires
  - Sensors
- Control
  - On-off
  - Dimming
  - Color
  - Wave length
- Known as IoT


Human Centric Lighting

# Thirteen questions you need to ask when specifying LED products

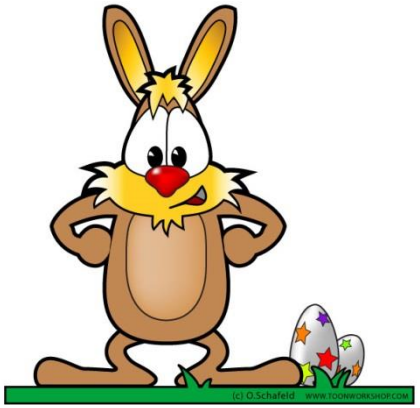
1) Is your LED supplier a reliable company?  How do you know?
2) Has your supplier provided an IES LM-80 test report from an accredited laboratory?
3) What is the operating temperature range specification and what is the maximum junction temperature
4) What is the expected $L_{70}$ lifetime of the fixture? How was it calculated – TM 21 or?
5) Can the manufacturer supply an IES LM-79 test report from an accredited laboratory as well as an .ies data file?
6) What are the delivered lumens and lumens per watt (LPW) of the fixture?

# Thirteen questions you need to ask when specifying LED products

7) What is the chromaticity of the fixture in the ANSI C78.377A color space and is it stable over time? How do you know?
8) Does the color of the light output vary from fixture to fixture or in different spatial locations for a single fixture?
9) What is the power factor of the fixture? How much power does it consume in the “off” state?
10) Do you have or have you applied for the EPA Energy Star or Design Lights Consortium listing?
11) Is the fixture lead-free, mercury-free and RoHS compliant?
12) What is the warranty and do you have the means to stand behind it?
13) If you use dimming LED’s - how do I know if the lamp and dimmer are compatible (will dim, no flicker)?

# *THAT'S ALL FOLKS*

## *any questions?*



This concludes The American Institute of Architects
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