4th Annual 2015 ESC Market Transformation Conference:

Achieving Higher Savings through Innovative ESPC Projects

Innovations in TLED Technology – A driving force for ESPC Projects:

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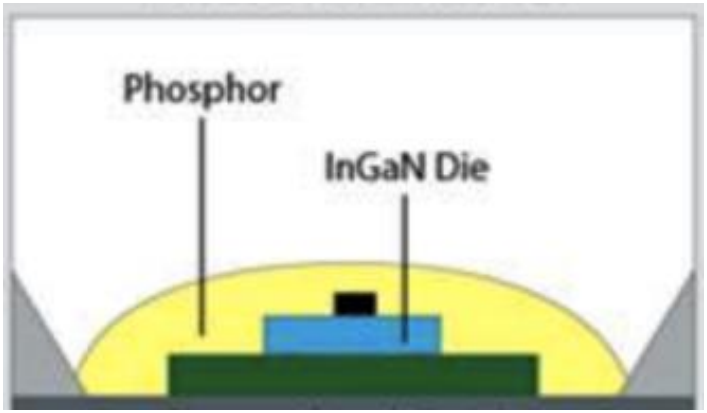
chief scientist
Energy focus

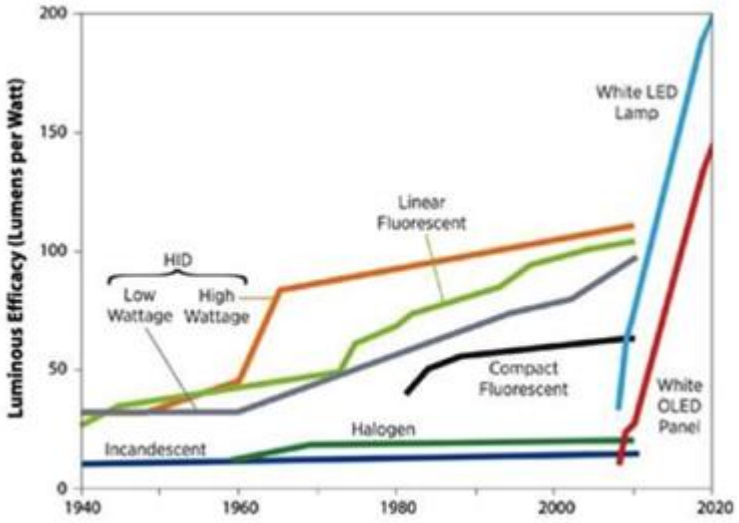
TLEDs - A driving force for ESPC Projects

- Unparalleled Energy Savings
- A new standard for reliability and life
- Are simple to install
- Promote health and wellness

T-LEDs are not only “the next best thing” in lighting, they take lighting to the next level

“Blue LED” Noble Prize Winning Breakthrough





Shuji Nakamura demonstrates the first practical blue **“direct band gap” LED** in 1993

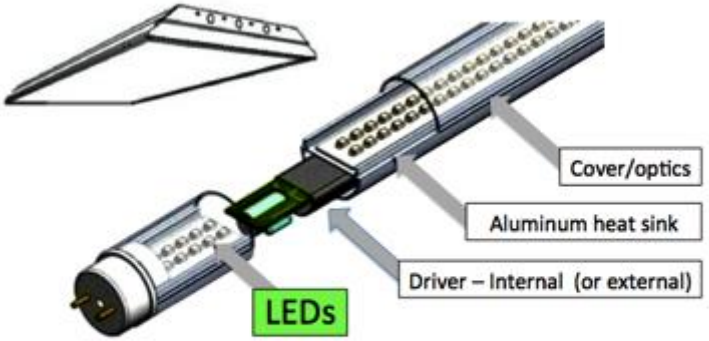
2014 Nobel Prize

Direct band gap LED

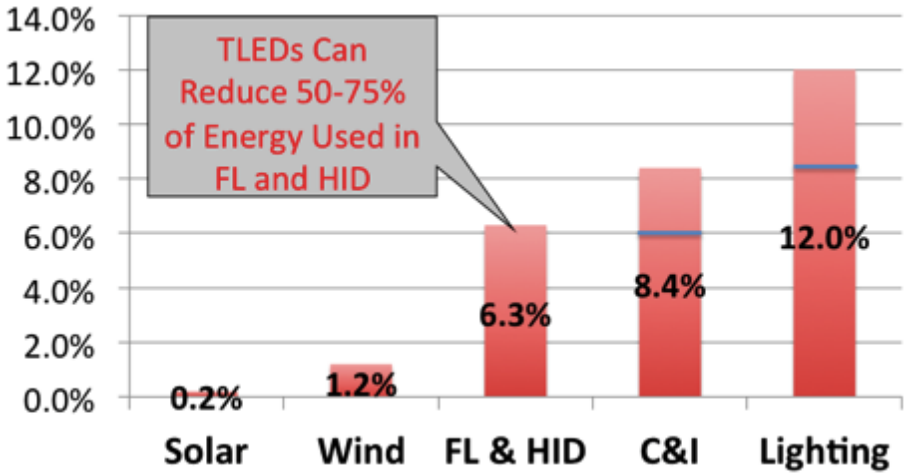
- Can (in principle) produce blue light (photons) without loss
- An efficient path from blue to white existed using phosphors

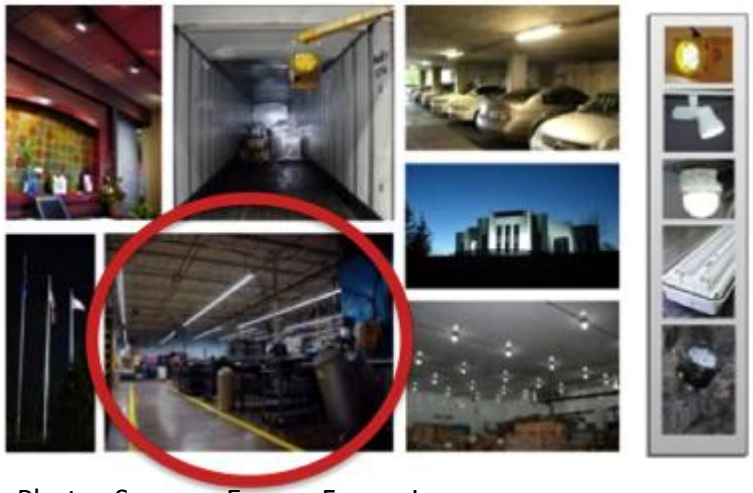
The possibility for making very efficient LED light sources “suddenly” existed

TLEDs have potential to reduce energy use 3% TODAY



TLED are Tube LED Retrofits for Fluorescent
(TLED = "Tubular" LED, also called "LED Tube")





Photos Source: Energy Focus, Inc.

The investment for substituting incandescent or fluorescent lighting with LED is **a fifth of the investment for installing solar power** based on CO_2 reduced*

Source: Smil, V. 2014. The long slow rise of solar and wind. ,*Scientific American* 282 (1):52-57*; EIA 2013 Energy Book; "Lighting The Way 2013", McKinsey Inc.*

TLEDs - A perfect fit for ESPC Projects

TLED Products

High quality, TLED tubes available **now** for land and sea with LPWs at 120, 130 and 150 LPW!

US Navy – TLEDs meet energy/ performance

US Navy's Requirements

- No risk – ships not dependent on "new" technology working. Easy to return to fluorescent if necessary.
- Easy to mix conventional fluorescent/LED
- Lowest first cost - sailors can install
- Easy efficiency/ reliability upgrade path, just wire around ballast or omit ballast at major ship retrofit
- "Obsolescence proof" – just plug new/ more efficient bulbs in as they become available (have already seamlessly improved efficiency > 25%)

TLED approach selected – after extensive testing

The result - 166 ships now use TLEDs

SSN-774
11 of 11

SSN-698
3 of 41

LCS
4 of 4

MCM
11 of 14

PC
8 of 12

LED implementations aboard Navy vessels has been so successful that Secretary of the Navy Mavis has accelerated their adoption

Commercial TLEDs

The Motivation for for a land based TLED lamp is similar to the Navy's:

- No risk: Installation (e.g. special needs classroom) not dependent on "new" technology working. Easy path to return to fluorescent if desired.
- Lowest up front cost - maintenance crew can install
- Easy to mix conventional fluorescent/LED
- Easy efficiency/ reliability upgrade path, just wire around ballast or omit ballast
- Obsolescence proof: Easy efficiency/ reliability upgrade path, just wire around ballast once the application is proven.

TLEDs have reached the Payback Tipping Point*

LED tubes can save customers $35/year with about a 70% reduction in power which can qualify a project for even more savings with rebates

	Existing Fixture 4 Fl Tubes	3 TLED 120 lpw 15W Tubes	2 TLED 130 lpw 18W Tubes
Upgrade Approach	N/A	Retrofit – 3 LED Tubes	Retrofit – 2 LED Tubes
Fixture Watts	118	45	36
Product Cost	NA	$60	$55
Annual Energy Cost[1]	$50	$19	$15
Annual Savings	**NA**	$31	$35
Simple Payback[2]	NA	1.9 years	1.6 years

- *All energy savings calculated using $0.10per kilowatt-hour and 4200 lighted hours; does not include installation costs*

Source: Energy Focus, Inc.

TLEDs make economic sense

Many Successful non-military TLED Installations

Meeting ESPC Performance, Reliability and Payback Hurdles

Osceola High School, AR

US Coast Guard

City of Louisville Garages

Houston County Gov., AL

Corrpro Industries

Simple installation

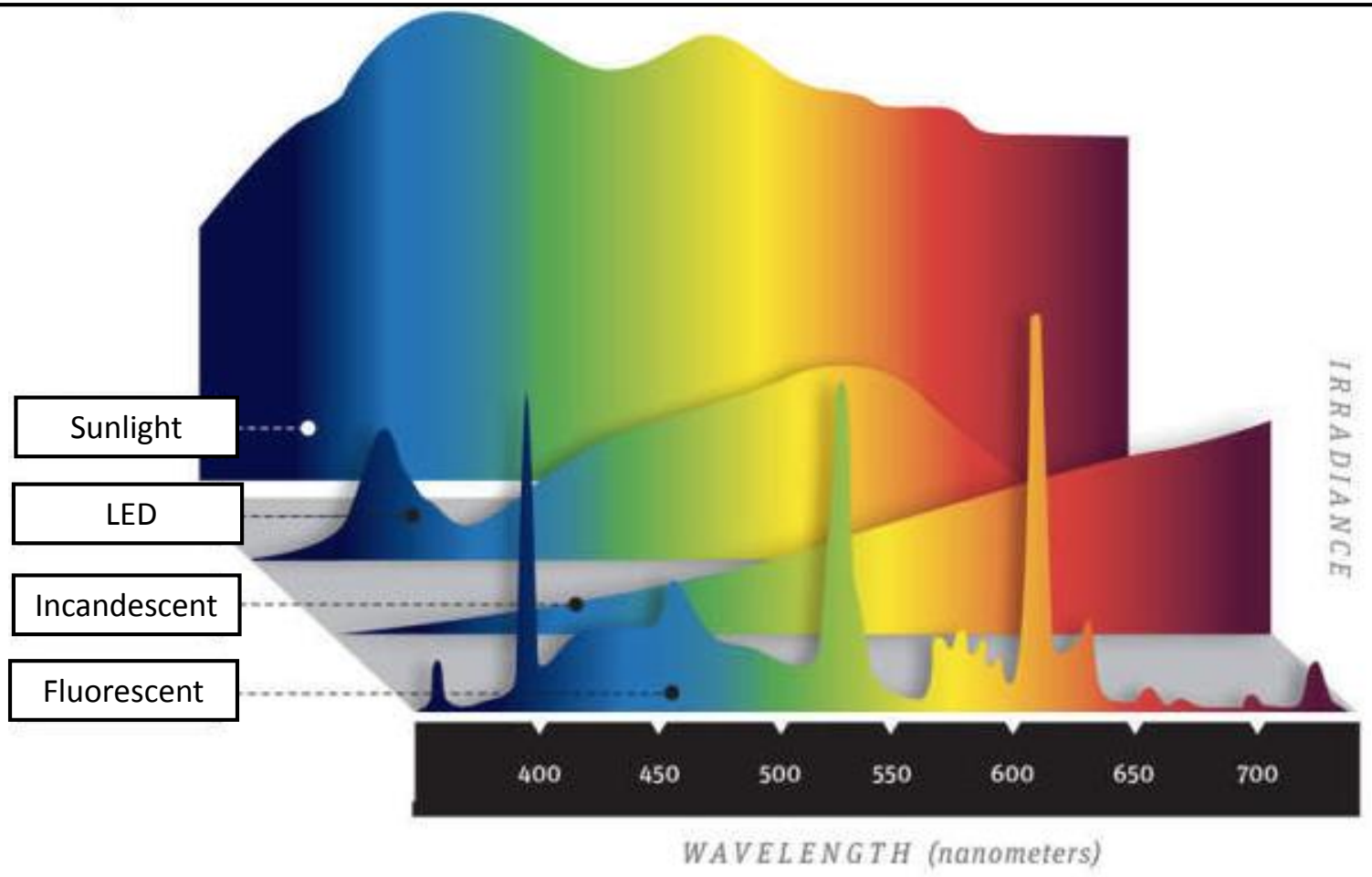
Benefits of TLED Replacement: Lower First Costs, Better Performance, Highest Energy & Operating Savings, and Aggressive Paybacks

Hospitals – a perfect fit for TLEDs*

- Energy savings drives payback
- Better electricals – lower THC & EMI
- Long life reduces maintenance
- Simpler to install than fluorescent
- **LEDs – promote health and wellness**

* Cleveland Clinic's main campus will install 250,000 TLED lamps in an initial phase - announced August 20, 2015

LEDs are the Best Spectral Match to the Sun



LED products can have the highest efficacy, **best quality of light** and longest life of any (artificial) light source

LEDs improve color visualization – which is the opposite of what the current CRI scale indicates!

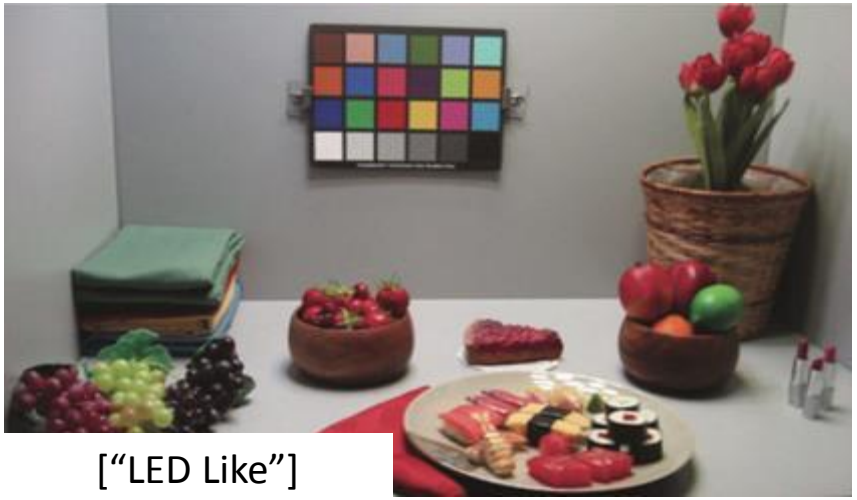
1. ***NIST proposed the new CQS measure – still a single number***

["Fluorescent Like"]

a: *Color-desaturating light*

CRI=82 ➔ ***CQS = 74***

Replacing 8 muted color referent



["LED Like"]

b: Color-enhancing light

CRI=71 ➔ ***CQS = 83;***

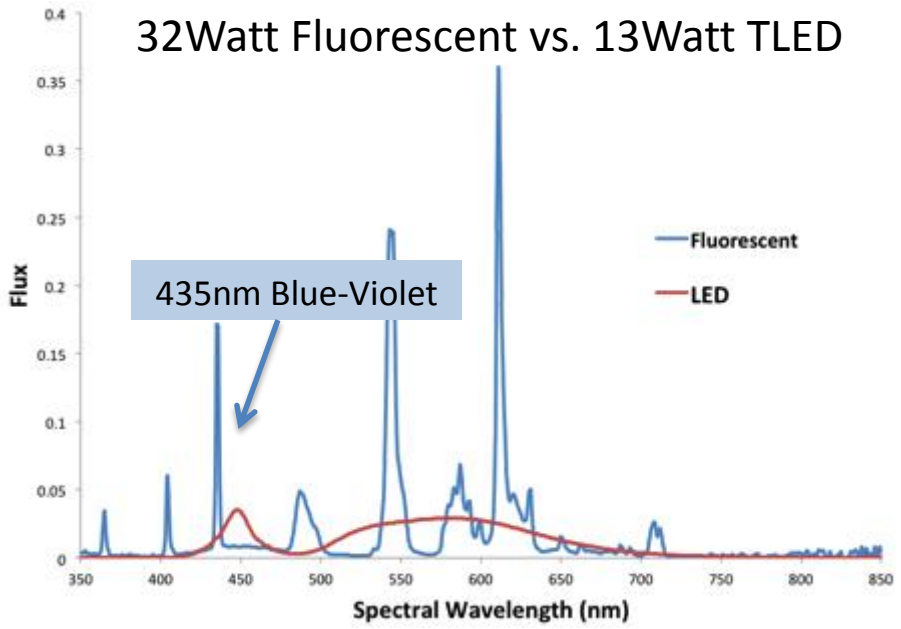
with new 15 colors referent

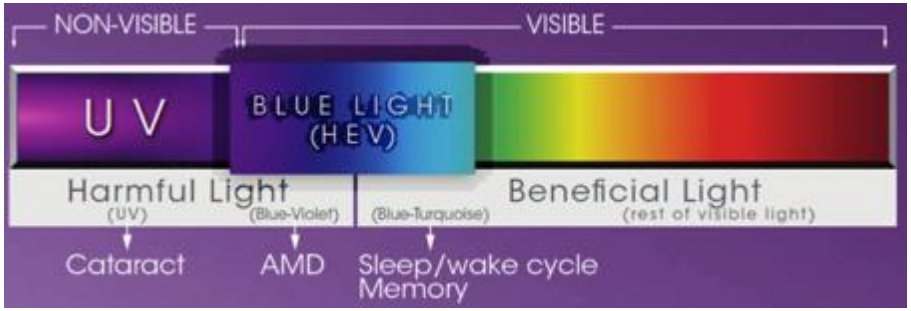
2. ***IES has proposed a "two-measure" standard***
3. ***The CIE is considering #1 and #2 above (as well as others)***

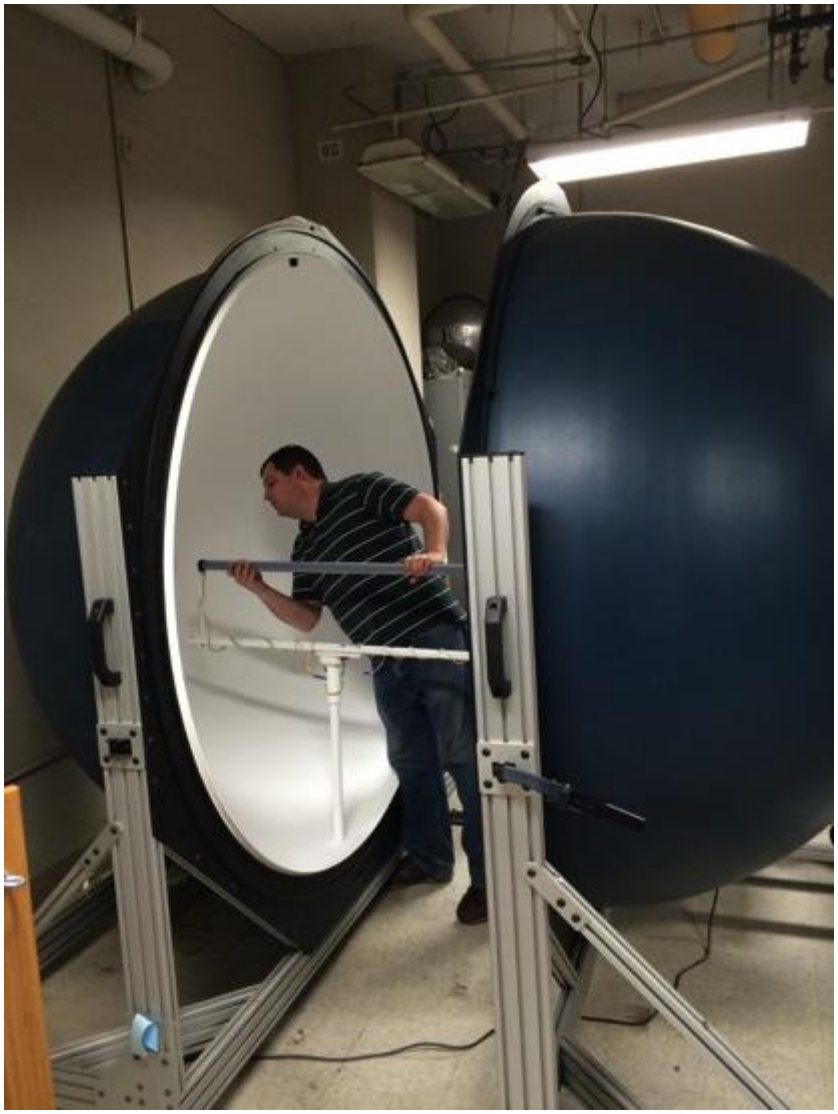
New color standard will remove "unfairly" penalize for LEDs

** "Rational of Color Quality Scale," Dr. Yoshi Ohno and Dr. Wendy Davis, National Institute of Standards and Technology*

LEDs promote heath and wellness – no UV or deep blue, but do emit beneficial longer wavelength blue



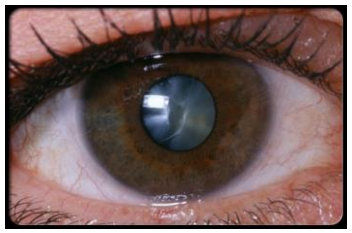


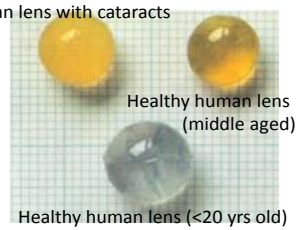


Fluorescents emit radiation
In the near UV and deep blue

Health Issues and Fluorescent – *near UV / deep blue*

Cataracts:

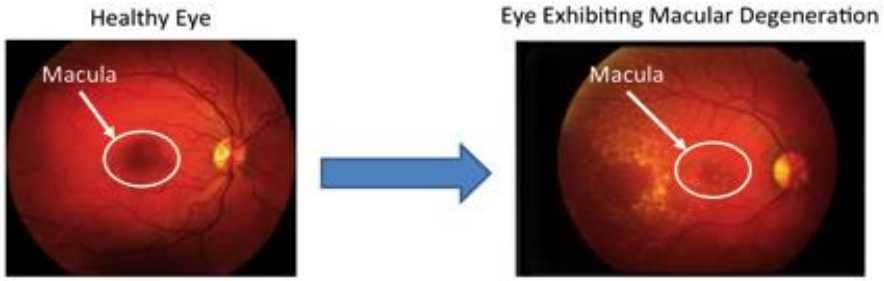




A clouding of the lens inside the eye which leads to a decrease in vision. It is the most common cause of blindness. Visual loss occurs because opacification of the lens obstructs.

Protection: UV Blocking Glasses.

Age-Related Macular Degeneration (AMD):



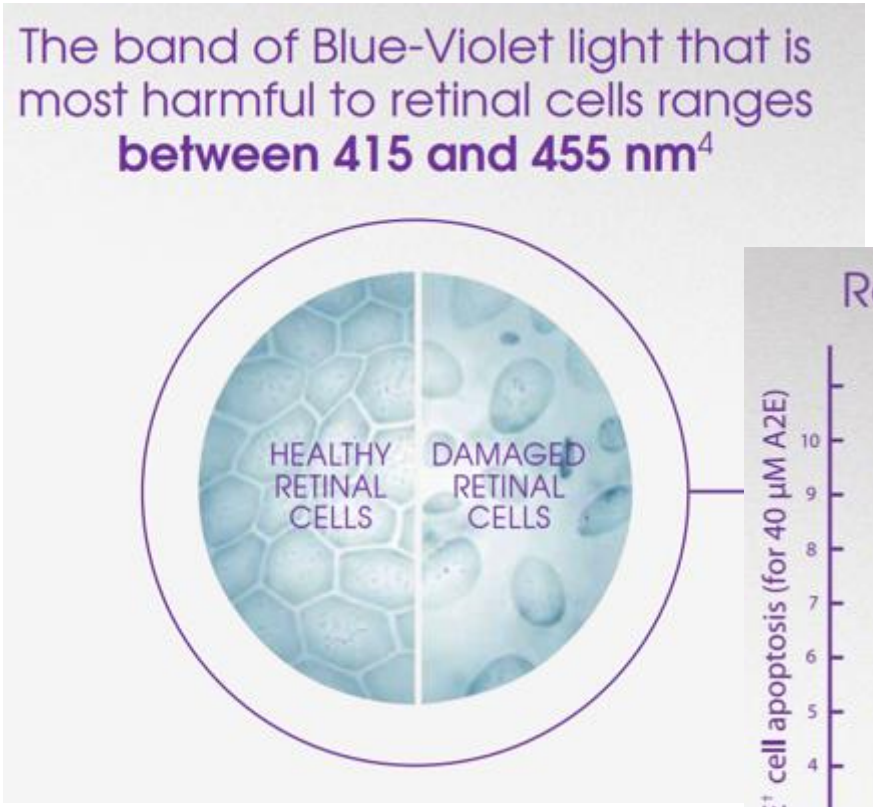
A medical condition that usually affects older adults and results in a loss of vision in the center of the visual field (the macula) because of damage to the retina. It occurs in "dry" and "wet" forms. It is a major cause of blindness

Protection: Blue Blocking Glasses.

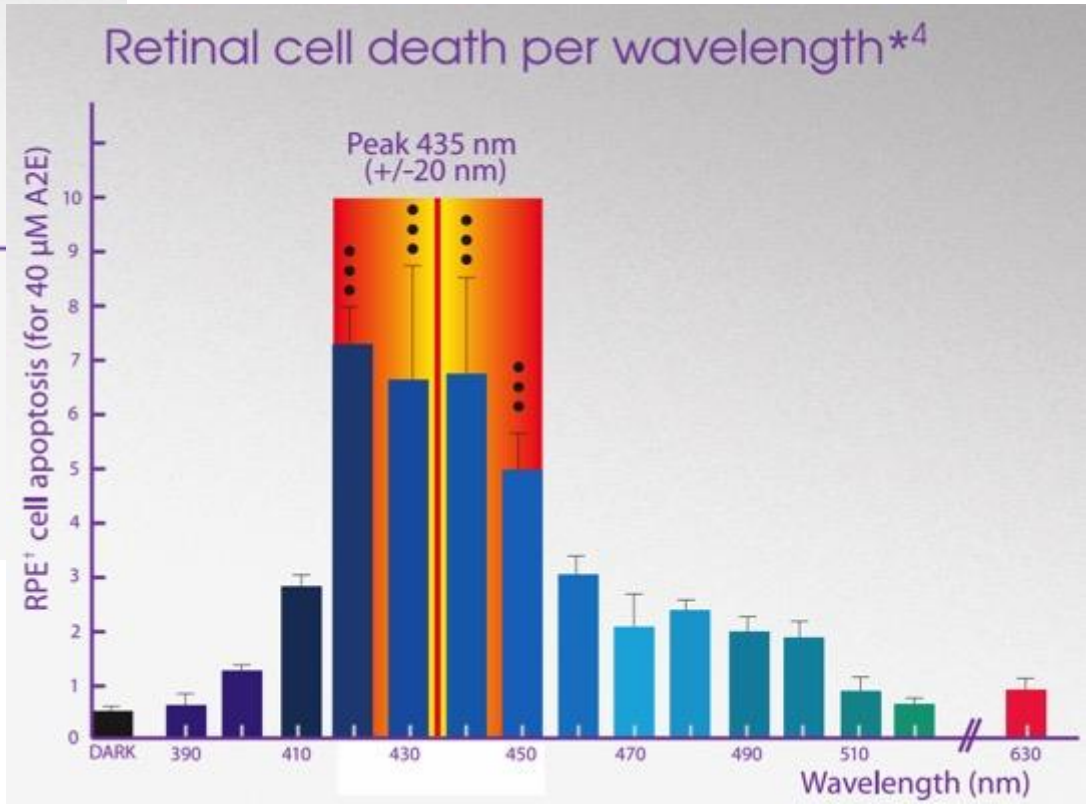
Wide range of symptoms and diseases claimed to be impacted by artificial light

- **cataracts**
- **age-related mac. degeneration (AMD)**
- **Circ. rhythm sleep disorders (CRSD)**
- migraine
- epilepsy
- autism/asperger syndrome
- xeroderma pigmentosum
- lupus
- myalgic encephalomyelitis ("chronic fatigue syndrome")
- Irlen-Meares syndrome ("scotopic syndrome")
- fibromyalgia
- electrosensitivity
- dyspraxia
- chronic actinic dermatitis
- solar urticarial

Eye Health Issues and Fluorescents

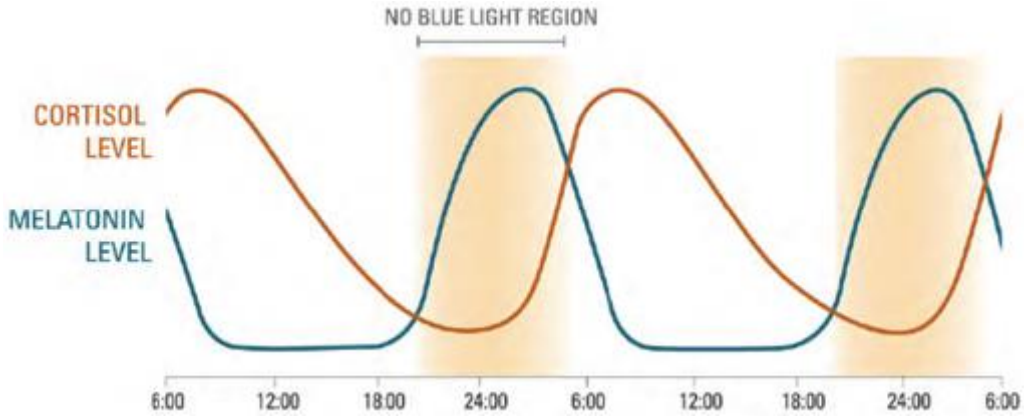


Age-Related Macular Degeneration (AMD) Caused by Retinal Cell Damage from Blue-Violet Wavelength!!



*Based on *in vitro* tests on swine (pig) cells.
†RPE = Retinal Pigment Epithelium.
Source: IDV/Essilor R&D 2011

Melatonin & Cortisol Circadian Rhythms – some longer wavelength blue is needed *



Biological adaptation to the sun has evolved over billions of years.

The **power to artificially override the natural cycle** of light and dark is a **recent event** and represents a **man-made self-experiment on the effects of exposure to increasingly bright light during the night** as human societies acquire technology and expand industry.

Among the latter (health effects) are potential **carcinogenic effects** related to melatonin suppression, especially **breast cancer**. Other diseases that may be exacerbated by circadian disruption include **obesity, diabetes, depression** and **mood disorders**, and **reproductive problems**.

LEDs provide the right spectral balance

*Adverse Health Effects of Nighttime Lighting Report 4of the Council on Science and Public Health (A-12) of The American Medical Association, June 2012

TLEDs – how "future proof are they?

- **Efficacy will double** – from todays about 150 LPW to ~300 LPW in the next 5-10 years

- **Quality of light** – excellent now, will continue to improve – from todays CRIs in the 80s (CQS of 90s) to CRIs in the 90s (CQS ~100) with improved phosphors

- **Controls** not typically cost effective today, will be widely used to futher enhance, **quality of life, health and wellness** rather than to save more energy. (The controls energy requirements may well be comparable to the savings.)

- **And, yes we'll continue to still see bi-pin sockets**. Like the A-19 screw in socket they will have staying power – for all the right reasons!

TLEDs - A driving force for ESPC Projects

… now and in the future