



Viva la Revolution!
An outlook on LED lighting in
performance contracting

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Who Is Energy Focus?

Besides myself, here today are:

Rhonda
Courtney



Joe
McGowan



Jeff
Kuhl

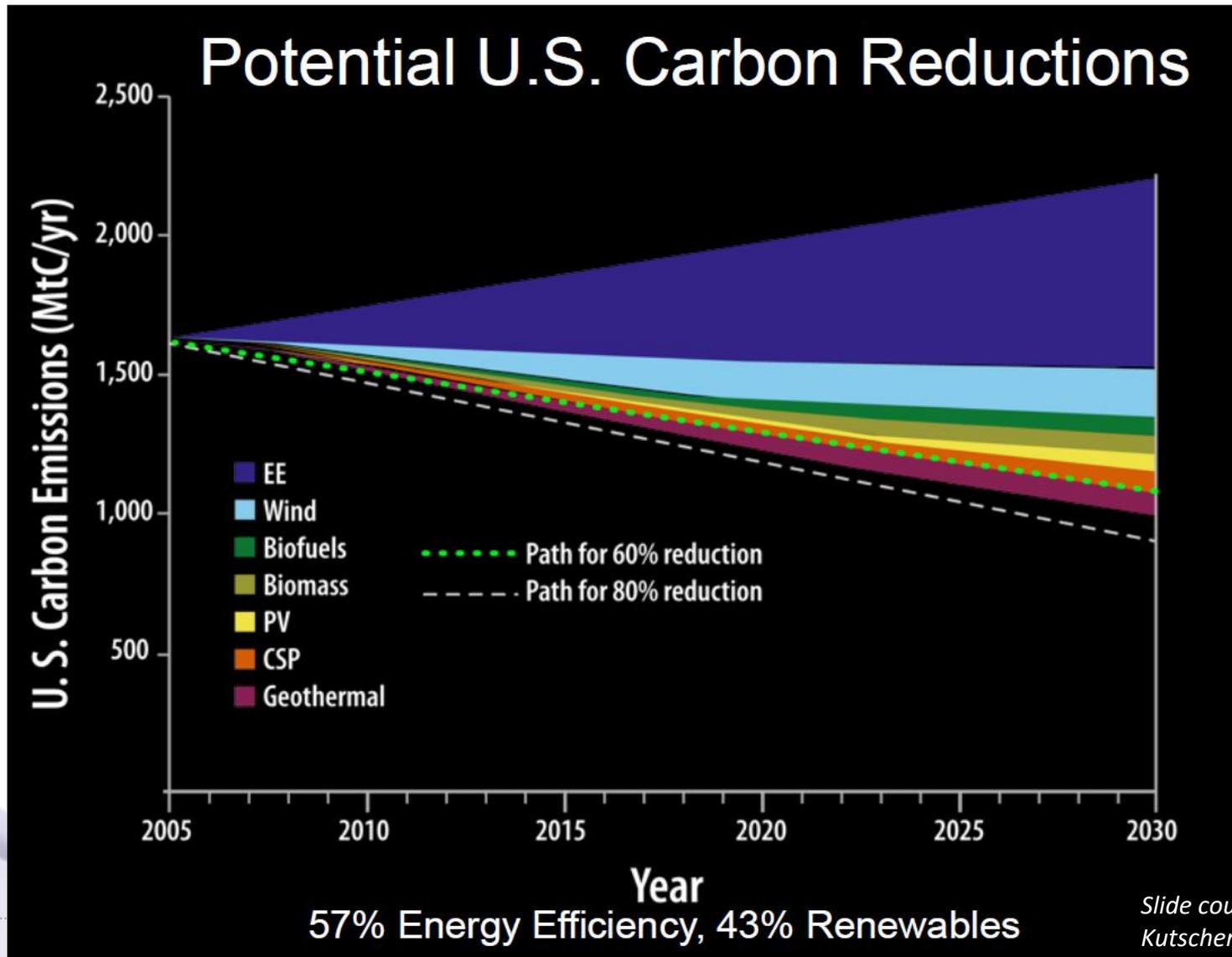


- Energy Focus is a leading LED lighting manufacturer
- Founded 1985 / NASDAQ
- Focus on LED retrofits (TLEDs)
- Intense LED R&D effort starting in 2002
- Developed the unique “Intellitube®” TLED solution for the US Navy
- Has offered commercial TLEDs since 2010 – for office buildings, schools, hospitals, military bases, retail stores ...
- Approach to market – ESCOs & LRCs, direct, GSA and, now available in CA, via the CMAS award vehicle



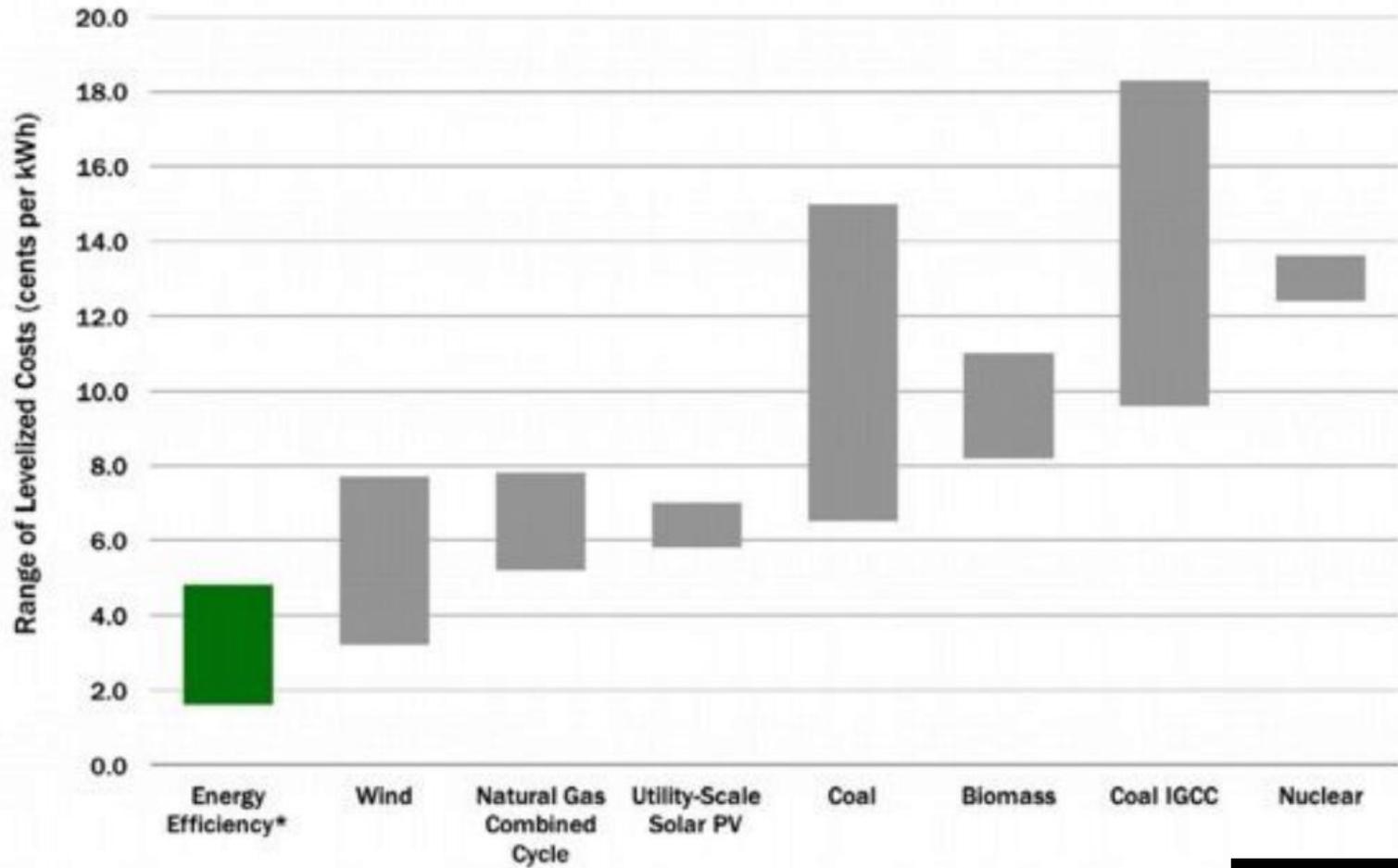
Focus on providing TLED Retrofits for Fluorescent

Energy Efficiency: Lions' share of savings



Slide courtesy of Chuck Kutscher, NREL

“Negawatts” are cheaper than Megawatts



Slide courtesy of Chuck Kutscher, NREL

Energy use by the numbers

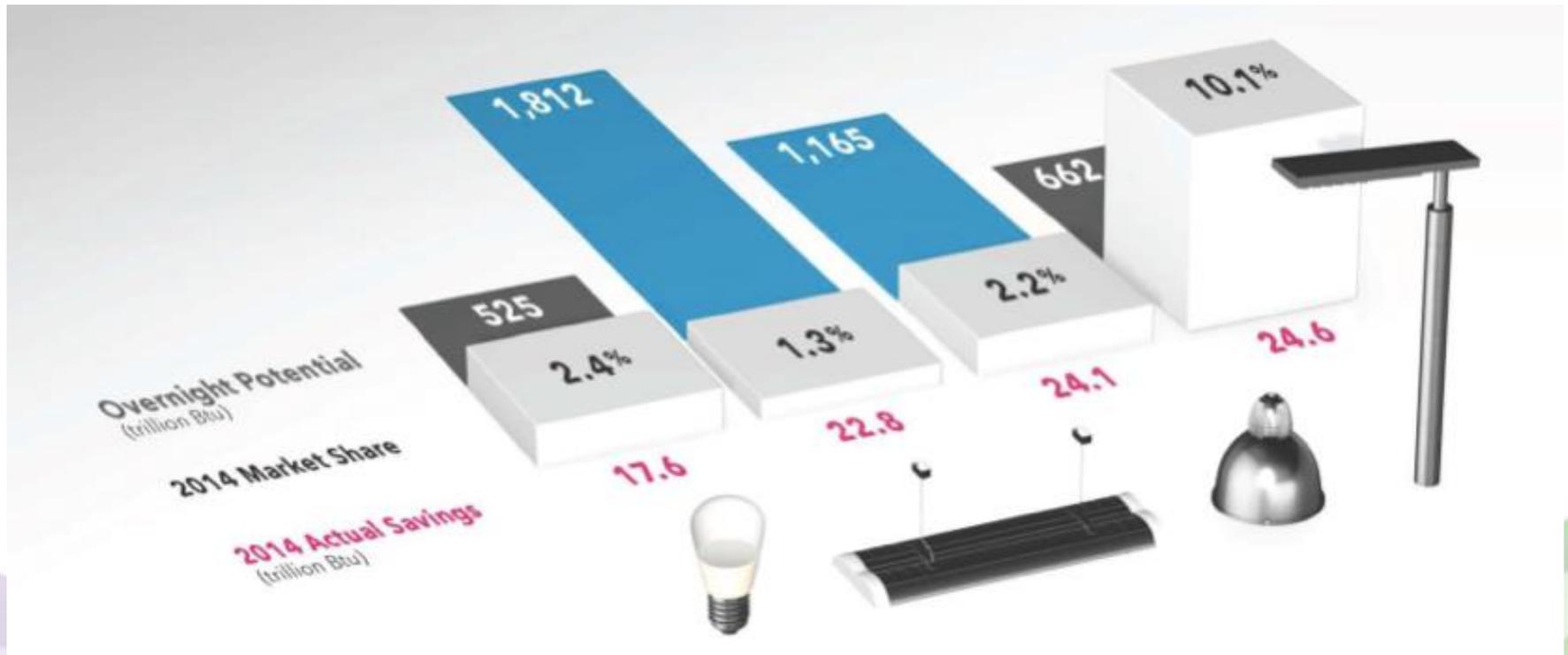
Buildings use **74%** of all electricity produced

Lighting accounts for **19%** of a building's energy consumption.

Source: US Energy Information Administration

Why LEDs are important

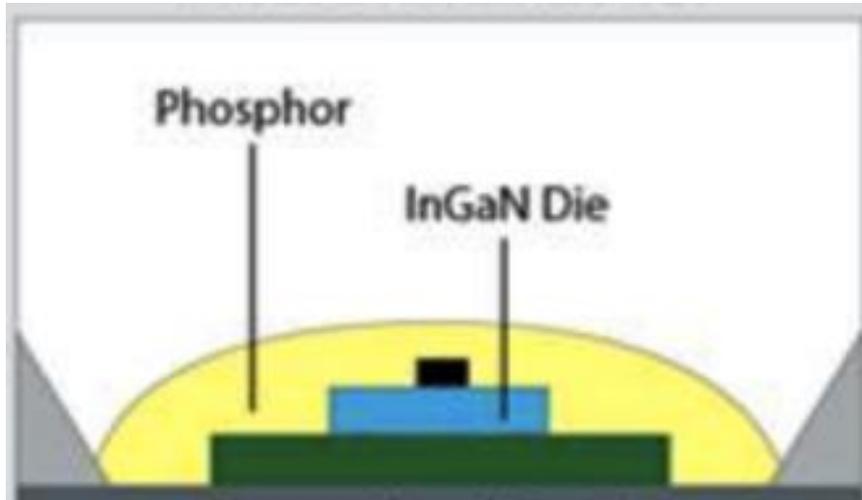
LEDs can save a tremendous amount of energy – an estimated 4,000 Trillion BTUs* – and conversion has really only just begun



* Data presented at Strategies in Light, March, 2016 by James Broderick, Ph.D., U.S. DOE

Nobel-worthy LED breakthrough

The “Blue LED” Breakthrough



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

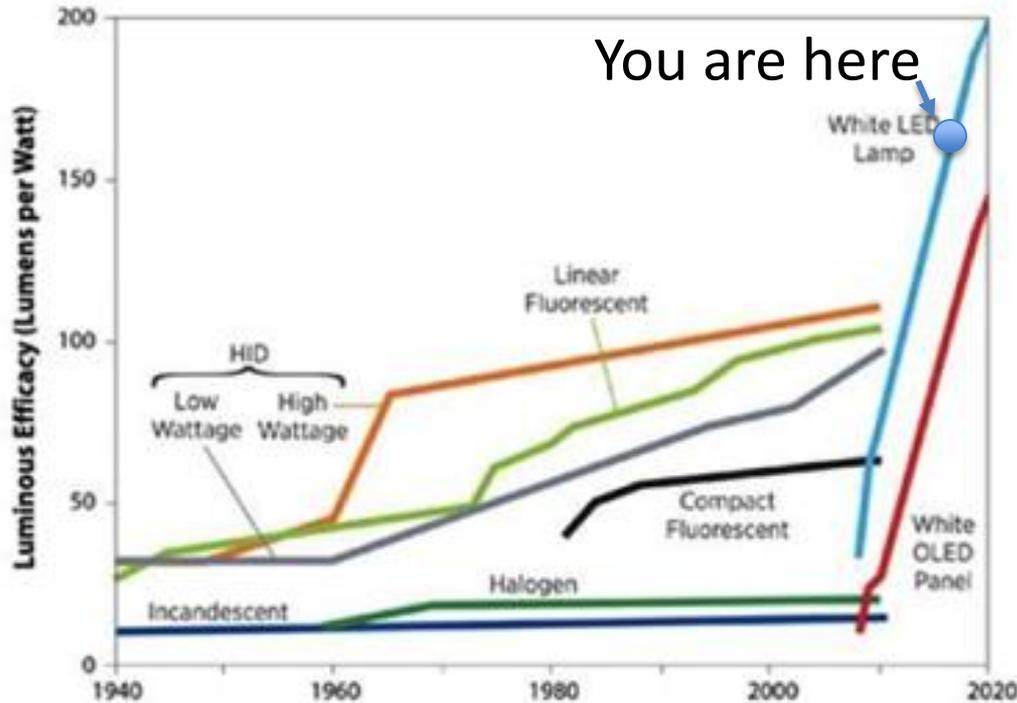


2014 Nobel Prize

Direct band gap LED

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

Haitz law: Moore's law for LED



Haitz Law

“Every 10 years, the cost per lumen will decrease 10x, while the light density will increase 20x.”

-Roland Haitz, 1935-2015

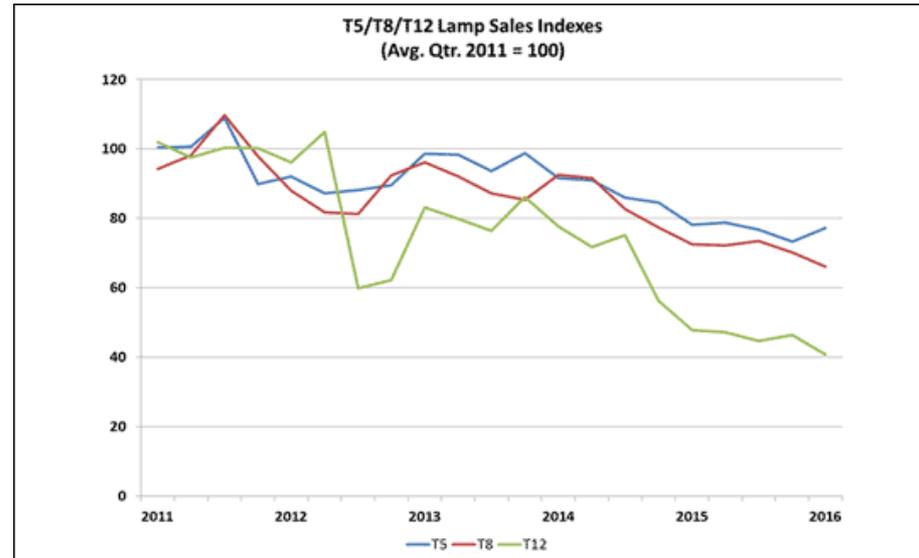
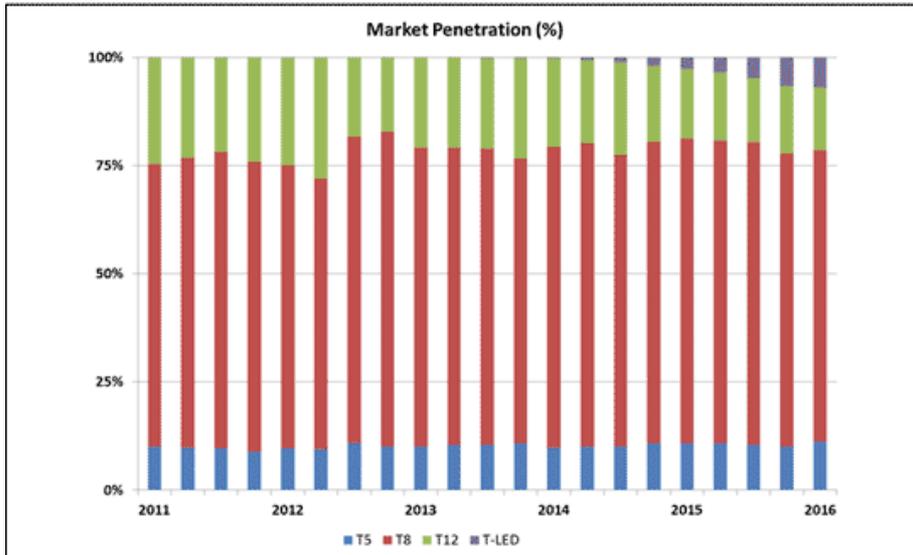
In LEDs today, 25% of electrical energy is converted to light, 75% to heat.

2016: 170 lm/W, 2x more efficient than FL, HID, 10x over INC

2026: 250lm/W, 2x more efficient than today (incl control, heat)

2030: All other light sources will be obsolete (Source: DOE LED Adoption, 2015)

What does “obsolete” mean?



T12: Still 20% of install base, 20% of unit sales.

Technology is not the barrier!

Why do they not see the value?

How do we convince “laggards” to upgrade?

Summary: if LED was sold on late night TV

- What if I told you this revolutionary lighting technology...
- ... can cut existing lighting power in *half*...
- ... (shaving off about 10% of a building's current electricity bill)...
- ... (not counting reduced HVAC load)...
- ... is most cost effective, typical payback less than 5 years...
- ... and is essentially maintenance-free for a 10 years...
- ... and basically NOBODY has it, EVERYBODY needs it...

BUT WAIT, THERE'S MORE!!

Artificial light can positively affect well-being?!

Intrinsically photosensitive retinal ganglion cells (ipRGCs) → melanopsin receptors.⁶

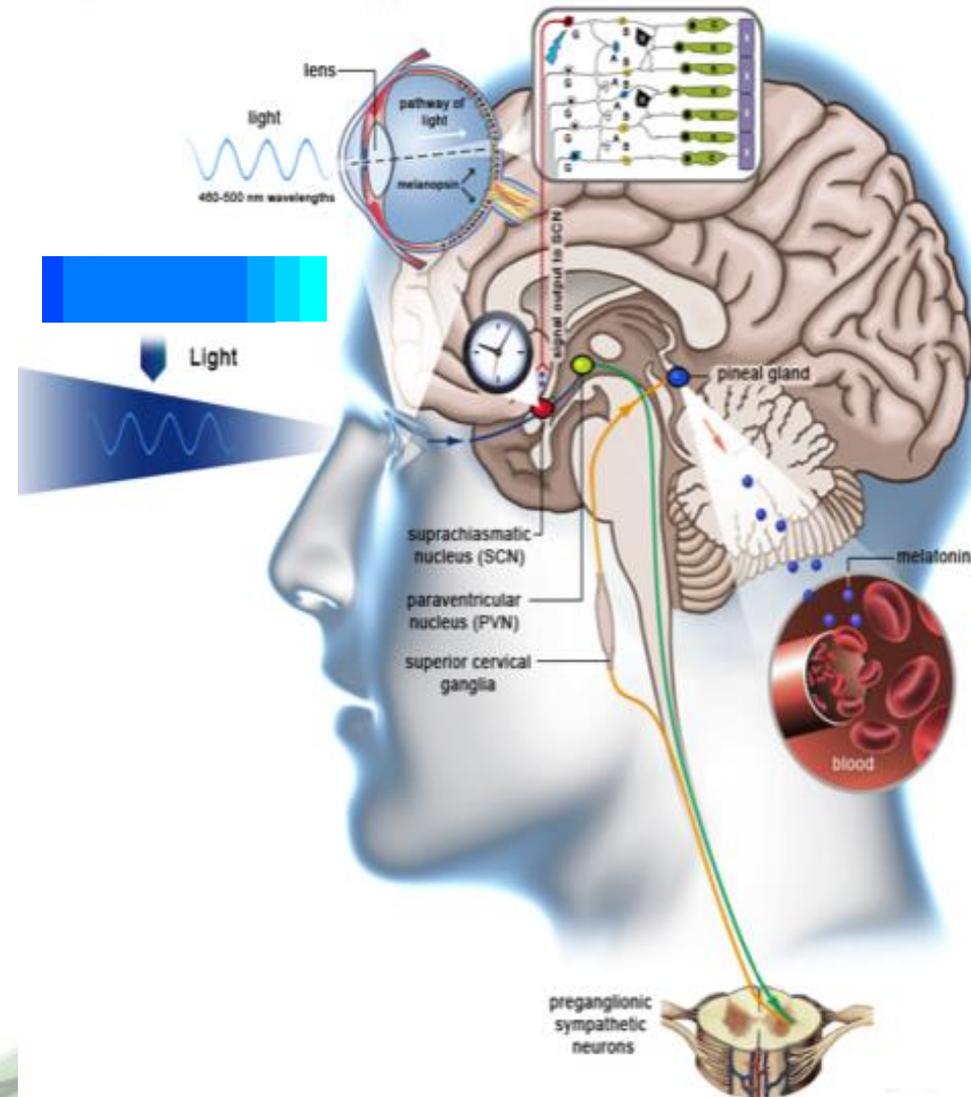
Immediate alerting affects and long term sleep cycle regulation.^{4,5}

We can measure the amount to which a white light contributes to this, called melanopic lux.

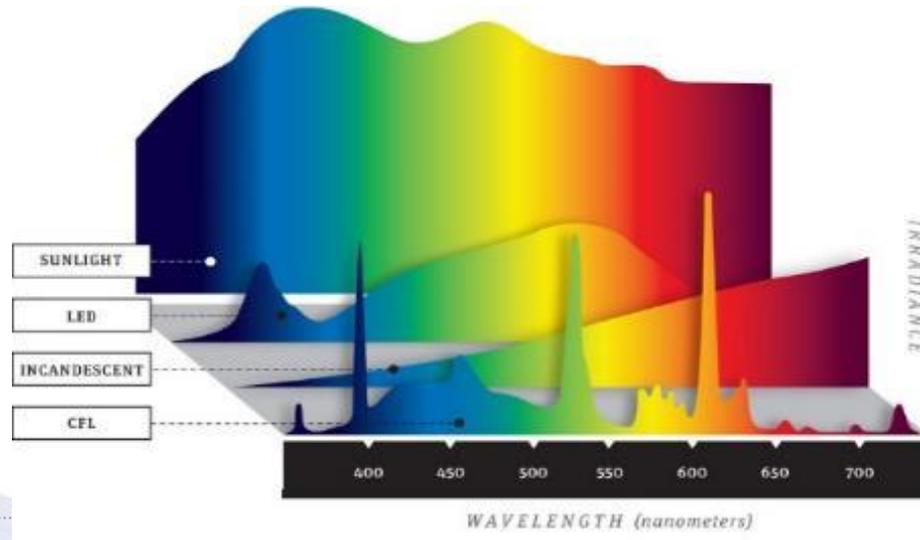
Benefits can range:⁷

- Offices: increased productivity, job satisfaction
- Schools: absenteeism, test scores, teachers
- Manufacturing: mistakes, longevity
- Hospitals: patient recovery, 3rd shift workers

ALSO LINKED TO LOWER BMI, HEALTHIER METABOLISMS, etc.^{18,19}



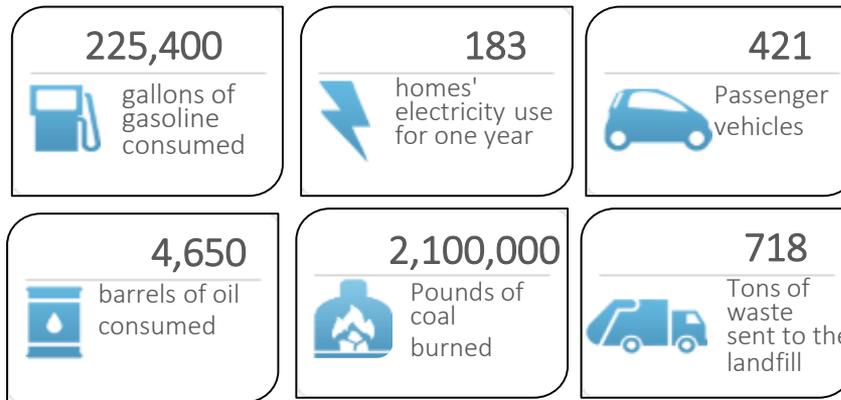
Appearance of color is improved?!



Changing lightbulbs is good for the environment?!

DOE estimates by 2030, all artificial lighting will be replaced with LEDs.¹⁰

Replacing 35,000 lamps has the ability to reduce carbon dioxide emissions by 2,100 metric tons per year, the same as:



This is WHY we do it.
So why not do it WELL?

Energy is simple.

Can we sell added-value
to promote adoption?

Sustainability: Beware the diminishing return

Plan on doing this all over again in 10 years.



Reap what you sow.

LED solutions



Fixture retrofit

- Convert existing troffer
- Lower cost
- Less material waste
- Easy to maintain



New fixture

- Replaces existing troffer
- Aesthetic appeal
- Higher rebates
- Broad photometric and sensor options

LED's blind side (literally, what you can't see)

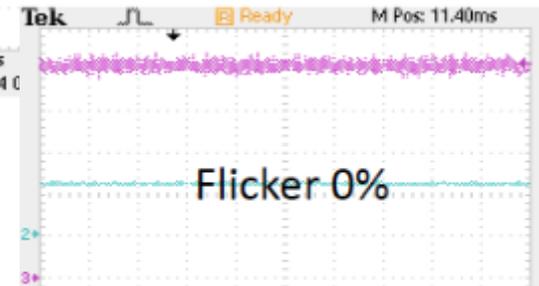
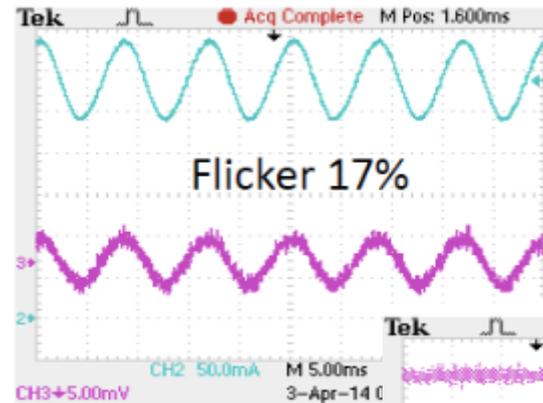
Beyond spectrum, how the light is produced affects our comfort and wellbeing.

Flicker: modulation of light output.^{8,12}

- Human threshold: ~90Hz
- If faster than that, eye cannot tell, but brain can

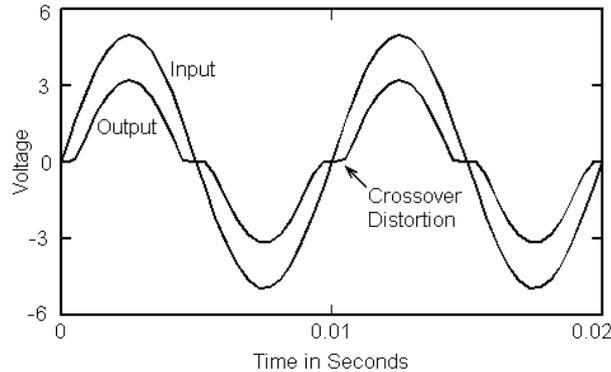
Everyone is affected. Some are more sensitive than others.⁹

- Visual Sensitivity/ Irlen Syndrome/ Scotopic Sensitivity Syndrome
- Visual Processing Deficit where sharp peaks in light and light modulation can jumble the signal sent to the brain, resulting in:
 - Dizziness, Headaches¹¹, Nausea
 - Difficulty reading small font
 - Difficulty concentrating
 - Possible misdiagnosis of learning disabilities



Off the road to righteousness

THD and PF:
Not stand-
alone
metrics!



Some of our evaluation metrics
and roadmap do not lead to our
final destination.



Don't turn light
sources into glare
sources.

Interoperability standards (or lack thereof)

Single-end direct wire, double-end direct wire, dual mode, ballast compatible, full fixture, external driver, NEMA-this, IES-that, constant current, constant voltage, type A, type B, type C, Type P, wired, wireless, Zigbee, 6lowpan, Thread, proprietary, lions, tigers, and bears...

OH MY!

Material cost
Labor cost
Safety

Standards

Energy savings
Net value
Future

Energy Performance Codes



Unified Facilities Criteria* (“UFC”)

- Applies to 1000+ US Bases and/or Military Installations, used by base personnel as guidelines for specifying and approving projects, including ESCO UESC/ESPC projects



Facilities Standards for the Public Buildings Service* (“P-100”)

- establishes design standards and criteria for the over 9600+ buildings it owns and leases (376.9+ million ft²)



California Energy Code (“CEC”) / Title 24, Part 6

- Provides Energy Efficiency Standards for California’s Residential and Nonresidential Buildings

Focus on TLED retrofits

US DoD, Federal, and CA installations 2015

Thou
Shalt Not
RETROFIT
With
TLED

UFC – 2015

“Do not use LED lamp replacements”

UFC 3-530-01 2-4.1.1 (2015)

GSA P-100

“LED lamps must not be retrofitted into existing luminaires”

- 6.3.2.2 P100-2016

CEC – Title 24 (2013) multilevel prescriptive language effectively requires controls for compliance*

- Prior to April 2016

*With the exception that "Lamp replacements alone and ballast replacements alone shall not be considered a modification of the luminaire ..."

Early TLEDs influenced UFC, GSA and CEC

Characteristic	2010 TLEDs	Fluorescent	Comments
Efficacy	85 lpw	80 lpw (includes ballast)	Not much better than fluorescent
Quality of light	CRI > 70	CRI > 80	Lower than 80 CRI generally available from fluorescent
Power Savings	>25% (includes optics)	> 20% with replacement of 32W with 25W	Positive, but comparable to other fluorescent alternatives
Reliability	< 5 years	Very little depreciation over life	Significant LED depreciation seen, particularly in early 2000's installations
Affordability	~ \$80	~ \$10 (includes a portion ballast)	Reasonable payback times only for high electricity rates and/or 24 hour operation

In 2010 TLEDs were only incrementally more efficient than fluorescent

Substantial TLED performance gains over the past six years

TLEDs	2010	2016	
Efficacy	85 lpw	150 lpw	About 2X Fluorescent
Quality of light	CRI > 70	CRI > 80	Continuous spectrum, no UV, much better light
Power Savings	>25%	>50%	Up to 75% for some installations
Reliability	< 5 years	> 10 years	Significant LED chip level improvements; life now >4X fluorescent
Affordability	~ \$80	< \$20	“Hardware” payback often <3 year, total <5yr

Where are the UFC, GSA and CEC today?

UFC and GSA now permit TLEDs - with some restrictions



Unified Facilities Criteria* (“UFC”)

Changes of Feb 1 Mar 3, Jun 1, 2016

- Expanded detail on “luminaire conversion”
- Removed prohibition on TLED
 - Allow if ≥ 120 lpw
 - Requires a ballast



Facilities Standards for the Public Buildings Service* (“P-100”)

- Permits use of TLEDs via waiver process
- Will likely incorporate a change in P-100 to permit



The California Energy Commission creates a new “performance path” April 2016

Table 1: Control Requirements for Luminaire Alterations

Applicable Section 130.1 control requirements:	Resulting lighting power, compared to the lighting power allowance in Section 140.6(c)2, Area Category Method		
	EXISTING OPTION 1 Lighting power density is > 85% of allowance	EXISTING OPTION 2 Lighting power density is ≤ 85% of allowance	NEW OPTION Existing lighting power is reduced by 50/35%
Section 130.1(a)1, 2, and 3 Area Controls	Yes	Yes	Yes
Section 130.1(b) Multi-Level Lighting Controls - only for alterations to general lighting of enclosed spaces 100 square feet or larger with a connected lighting load that exceeds 0.5 watts per square foot	Yes	Bilevel Switching - for each enclosed space, minimum one step between 30-70 percent of lighting power regardless of luminaire type, or meet Section 130.1(b)	Not Required
Section 130.1(c) Shut-Off Controls	Yes	Yes	Yes ¹
Section 130.1(d) Automatic Daylight Controls	Yes	Not Required	Not Required
Section 130.1(e) Demand Responsive Controls - only for alterations >10,000 sq. ft. in a single building, where the alteration also changes the area of the space, or changes the occupancy type of the space, or increases the lighting power	Yes	Not Required	Not Required

¹ As bilevel controls are not required for this option, partial off controls are not required to be installed in place of “full off” automatic shutoff controls; this difference is included in the analysis of anticipated energy savings.

Source: California Energy Commission staff

“[The retrofit] reduction must result in at least **50% lower** compared to existing rated power at full light output for **hotel, office, retail** occupancies, and at least **35% lower** rated power ... for **all other** occupancies.”

LED retrofits should no longer be an issue in CA – provided performance goals are met

The California Energy Commission's rational

“These changes were made in response to stakeholders’ concerns with the [existing] 2013 language:

- The language was **too complex** ...
- Running new wiring for multilevel and bilevel controls made some otherwise cost-effective **projects no longer possible**.
- It was **expensive to accurately determine** lighting power densities and difficult to do so for nonrectangular spaces.
- the newly adopted ... **percentage reduction... pathway that saves as much or more energy than the [prior] 2013 language”**

Performance, as opposed to prescriptive, regulations make sense for rapidly evolving technologies



What's in the future – “global” controls requirements for retrofits: via 90.1 - 2013

- “Global” controls requirements for lighting alterations for interior and exterior applications (9.1.2)
- Similar to Title 24 (2013 and 2016)
- Allow Retrofit – as long as the performance is there

Section 9
Lighting General – Alterations

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

- Applies to these retrofits:
 - where luminaires are added, replaced, or removed
 - Replacement of lamp plus ballast in luminaires
- Requires BOTH interior and exterior alterations to comply with Lighting Power Density (LPD) limits and basic after hours automatic shutoff requirements

Exception
Spaces where alterations involve < 10% of connected lighting load and the LPD for the space is not increased



BUILDING ENERGY CODES www.energycodes.gov

Parting sentiments

- ESPC funding: if it's 54% of the saving potential, how about we get 54% of the MONEY?!
- Educate first. Sell later.
- Help us form the standards! Be prepared to reap what you sow: With a lack of interoperability standards in lighting today, consider how you want to do business now, and again ten years from now.
 - Protect your marketplace: don't let the easy way out turn in to the only way out.
 - Don't rest on your laurels: improve continuously, and expect lighting packages are obsolete in 2 yr

What's after LED, in 2040?

A large, clear crystal ball sits on an ornate, silver-colored metal stand. The crystal ball is the central focus, and inside it, the text '?????' is written in a large, white, sans-serif font. The background is white, and there are decorative wavy lines in shades of purple and green at the bottom of the slide.

?????



THANK YOU!

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