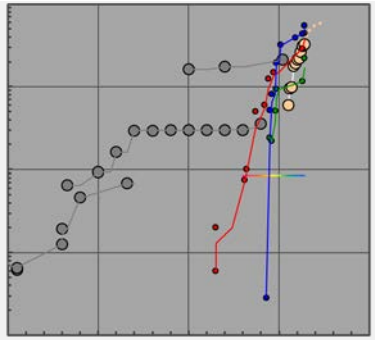
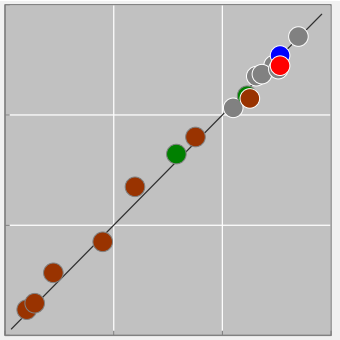
SAND2017-10809C

Exceptional service in the national interest

Sandia National Laboratories




$$\frac{P_o}{P_e} \quad \frac{LER_{CRI,CCT}}{MWLER_{CRI,CCT}}$$

$$\frac{\iiint \phi_{Min,Q}(x,y,t)dxdydt}{\iiint \phi_{Actual,Q}(x,y,t)dxdydt}$$


The New World of Engineered SSL

Past & Present, but mostly Future (5 SSL Grand Challenges)

Jeff Tsao

Acknowledgements

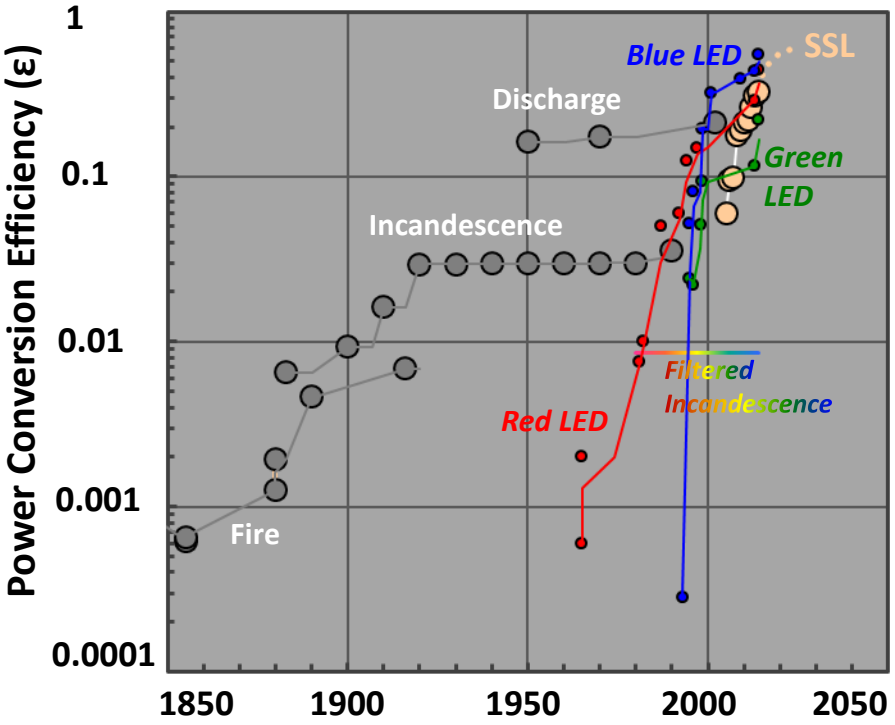
Morgan Pattison, Roland Haitz, Mike Coltrin, Jon Wierer, Jerry Simmons
Harry Saunders, Dmitry Sizov, Randy Creighton, Art Fischer, Yoshi Ohno, Mike Krames, Mary Crawford
Steve Brueck, Po-Chieh Hung, Wendy Davis, Sasha Neuman, Lauren Rohwer, Bob Steele, Igal Brener, George Craford
Dan Koleske, Steve Lee, Jeff Nelson, Tom Picraux, Julie Phillips, Rick Schneider, George Wang

U.S. DEPARTMENT OF ENERGY | NNSA National Nuclear Security Administration

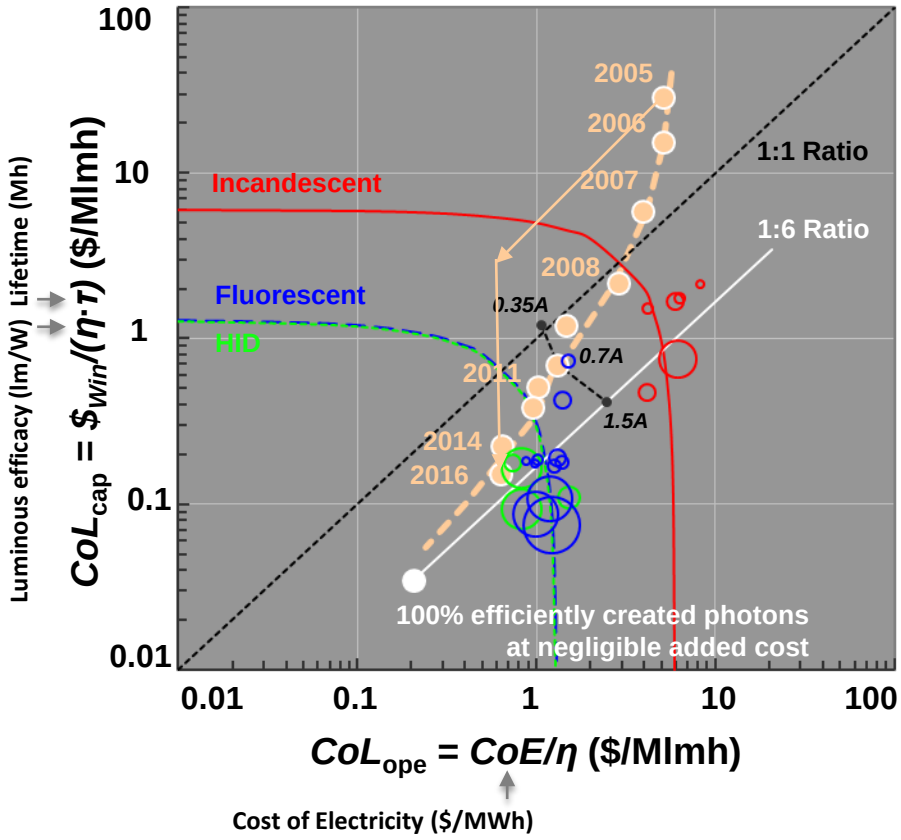
This work was supported by the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Building Technologies Office, Solid-State Lighting Program. Sandia National Laboratories is a multi-mission laboratory managed and operated by National Technology and Engineering Solutions of Sandia, LLC., a wholly owned subsidiary of Honeywell International, Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

SSL: two decades of technical progress

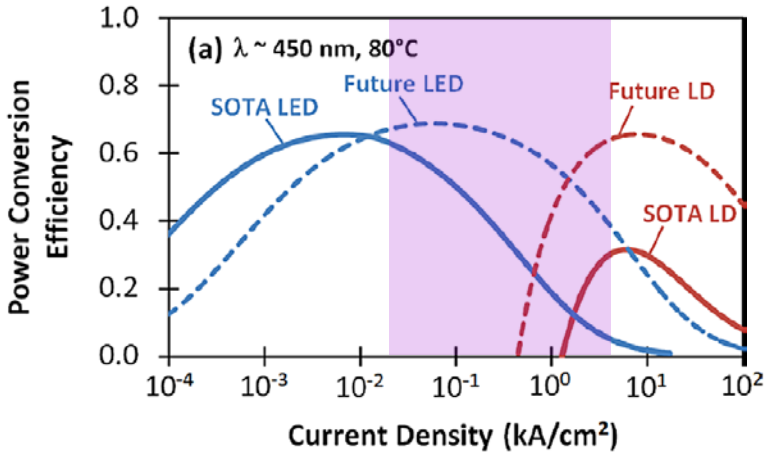
White & blue photons are now delivered by commercial devices at 30 & 60% efficiency, with 50% & 80% on the horizon



And the cost of the devices that produce those photons is becoming negligible

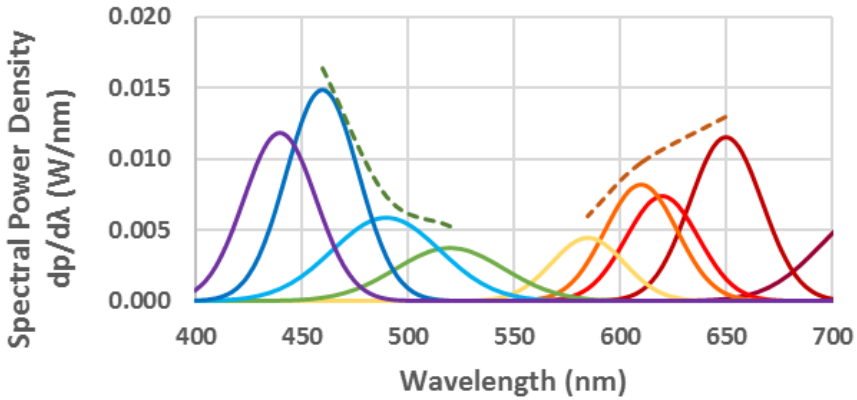


SSL GC 1: Valley of Droop



Courtesy, Jon Wierer, Lehigh University

SSL GC 2: RYG Gap



After 2017 DOE SSL R&D Plan

SSL GC 3: Expanded Functionality

Sony's *Multifunctional Light*

Actuation
- Color-Tunable and On/Off/Dim Light
- Speaker

Communications
- Wi-Fi

Sensors
- Temperature, Humidity, Presence
- Microphone

To Come?
- Local Intelligence and Alexa-like Interactivity
- Cameras
- Structured Light and 3D Mapping
- Chemical/Biochemical Sensing

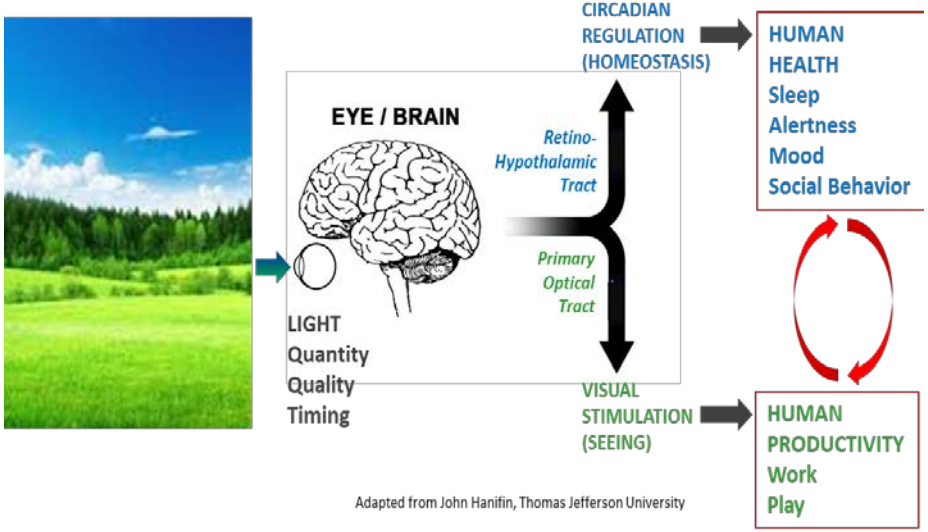
Augmented Reality and Illumination/Display Convergence

From Corning's "A Day in the Life"

After Extreme Tech (April, 2016)
https://www.extremetech.com/extreme/193402-what-is-night-vision-how-does-it-work-and-do-i-really-need-it-in-my-next-car

SSL GC 4: New Applications

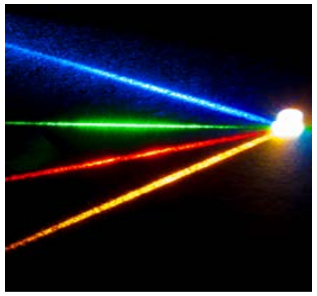
Human Health



Adapted from John Hanifin, Thomas Jefferson University

Indoor Farming

Co-Evolution



Plant Biology

Photons as
- *fuel*
- *morphology signalers*

Robotic Harvesting!

Plant Environment

Non-directional
- *Temperature*
- *Chemistry*

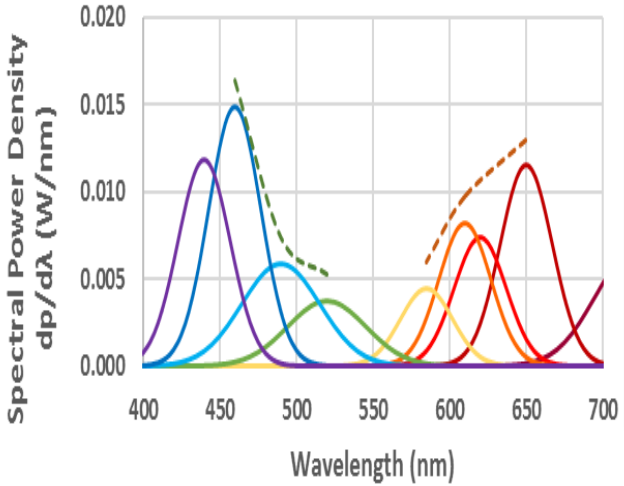
Directional
- *Gravity*
- *Photons!*

SSL GC 5: Application Efficacy

$$\eta_{Application} = \varepsilon_{Source} \cdot \varepsilon_{Distribution} \cdot \varepsilon_{Spectral} \cdot MWLER$$

ε_{Source}

$$\frac{P_o}{P_e}$$

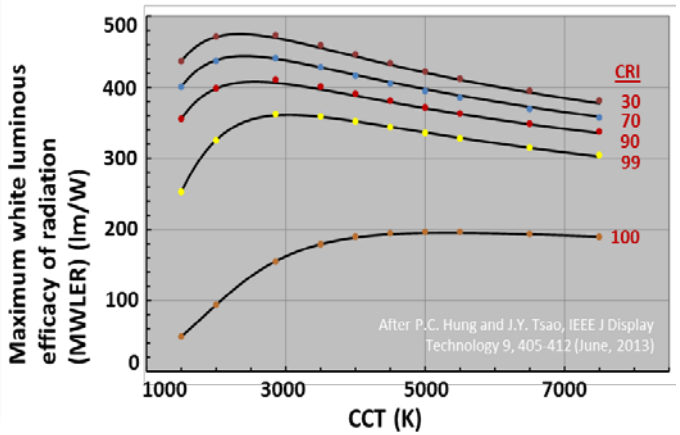


$\varepsilon_{Distribution}$

$$\frac{\iiint \phi_{Min,Q}(x,y,t)dxdydt}{\iiint \phi_{Actual,Q}(x,y,t)dxdydt}$$

$\varepsilon_{Spectral}$

$$\frac{LER_{CRI,CCT}}{MWLER_{CRI,CCT}}$$



If the future is like the past: more light = more productivity

Φ constant, less Ė

$$\dot{E} = \frac{\Phi}{\eta}$$

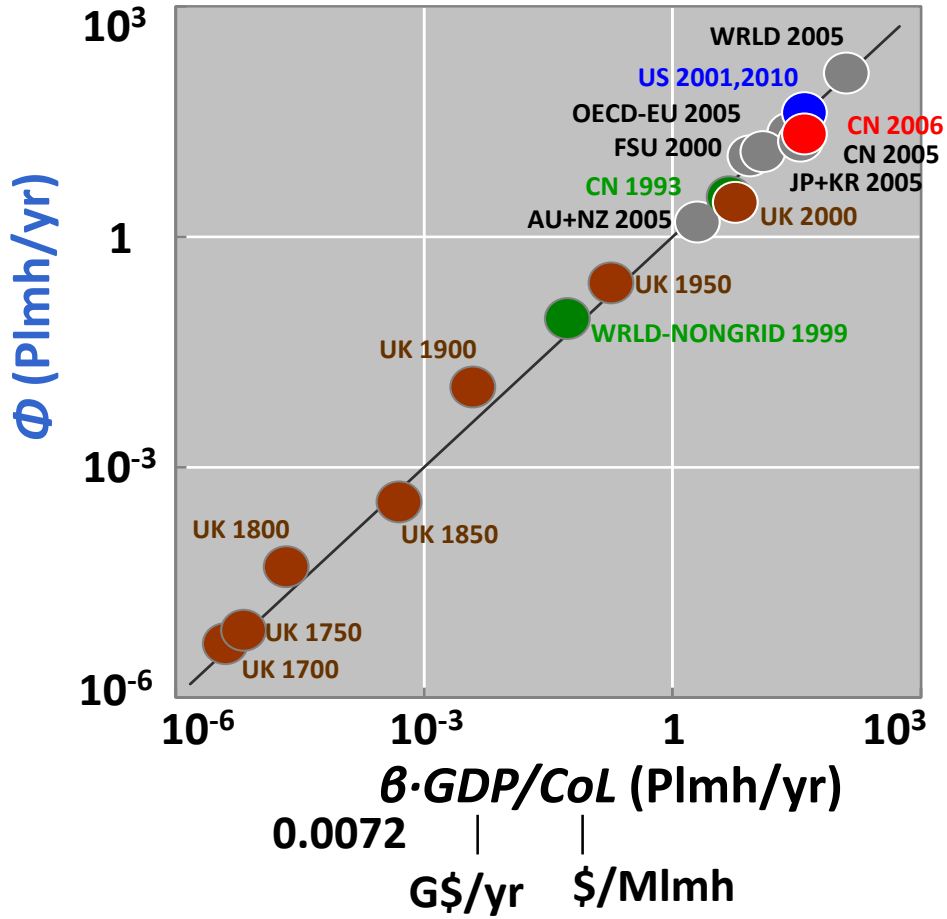
Energy consumption Rate (PWh/yr)

Light flux (Plmh/yr)

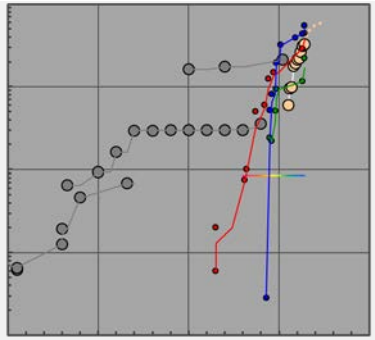
Luminous efficacy (lm/W)

Ė constant, more Φ

$$\Phi = \dot{E} \cdot \eta$$



Adapted from J.Y. Tsao and P. Waide, "The World's Appetite for Light: Empirical Data and Trends Spanning Three Centuries and Six Continents," LEUKOS **6**, 259-281 (2010).



$$\frac{P_o}{P_e} \qquad \frac{LER_{CRI,CCT}}{MWLER_{CRI,CCT}}$$

$$\frac{\iiint \phi_{Min,Q}(x,y,t)dxdydt}{\iiint \phi_{Actual,Q}(x,y,t)dxdydt}$$