A proposed method for estimating regional and global changes in energy consumption for outdoor lighting

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$$\Delta E = \frac{s\mu_{s1}L_{s1}K_{s1} + (1-s)\mu_{p1}L_{p1}K_{p1}}{s\mu_{s2}L_{s2}K_{s2} + (1-s)\mu_{p2}L_{p2}K_{p2}}$$

Thanks to …

Remote Sensing

of

Energy Consumption for Outdoor Lighting

Light spectrum carries information

Visible Infrared

NASA/JPL-Caltech/R. Hurt (SSC)

Broadband radiance/reflectance

Marlith, Wikimedia Commons

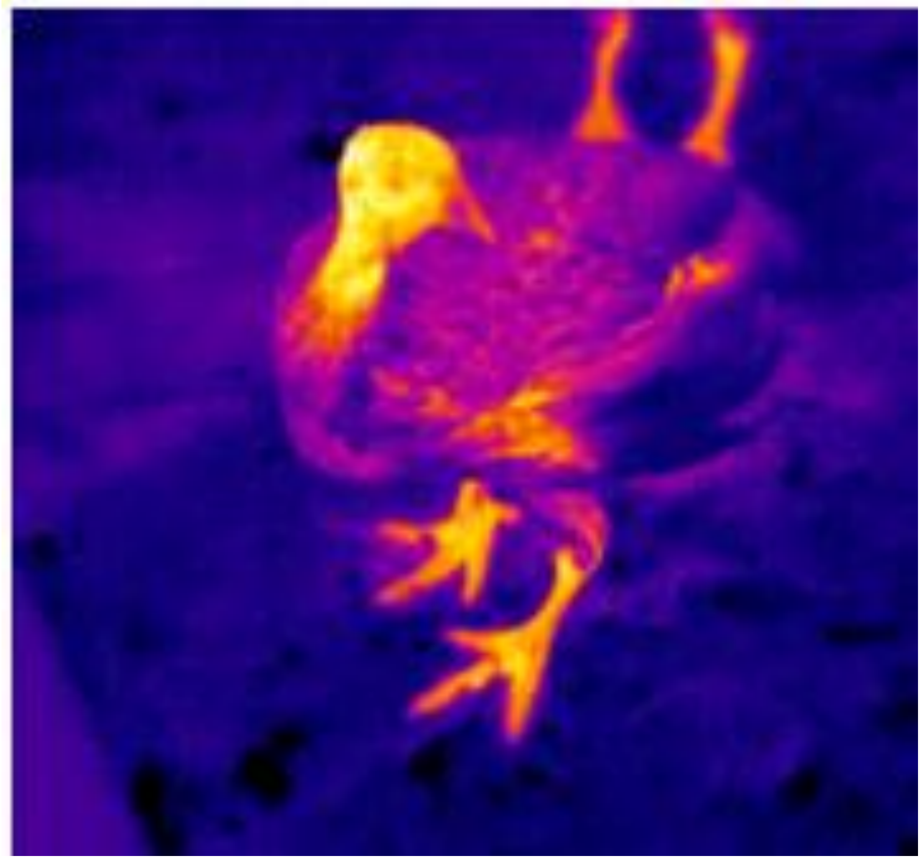
Remote sensing

Marlith, Wikimedia Commons

Remote sensing

“Remote sensing is the acquisition of information about an object or phenomenon without making physical contact with the object…”

-Wikipedia

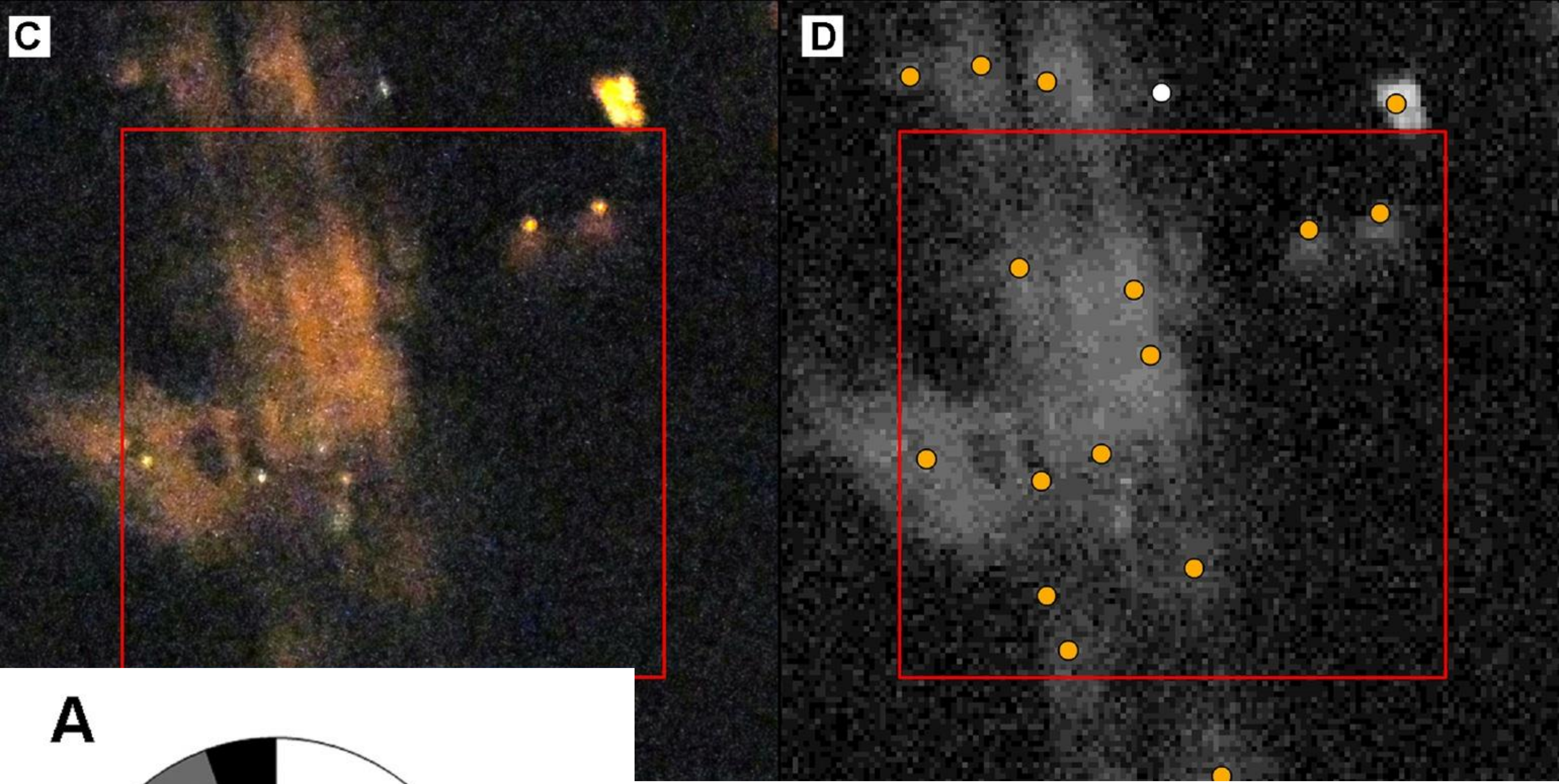


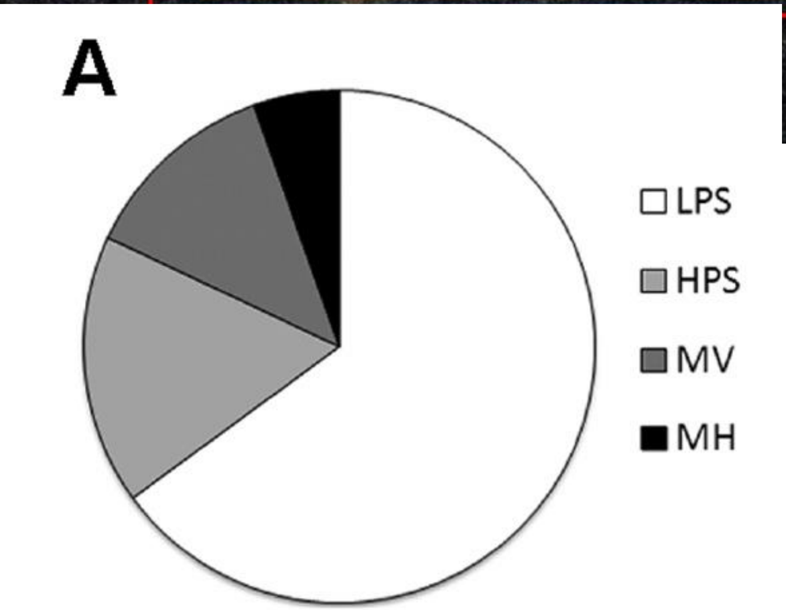
John Snell, Fluke blog
www.thesnellgroup.com

Remote sensing

“In current usage, the term ‘remote sensing’ generally refers to the use of satellite- or aircraft-based sensor technologies to detect and classify objects on Earth”

-also Wikipedia





Hale et al. 2013

Remote Sensing

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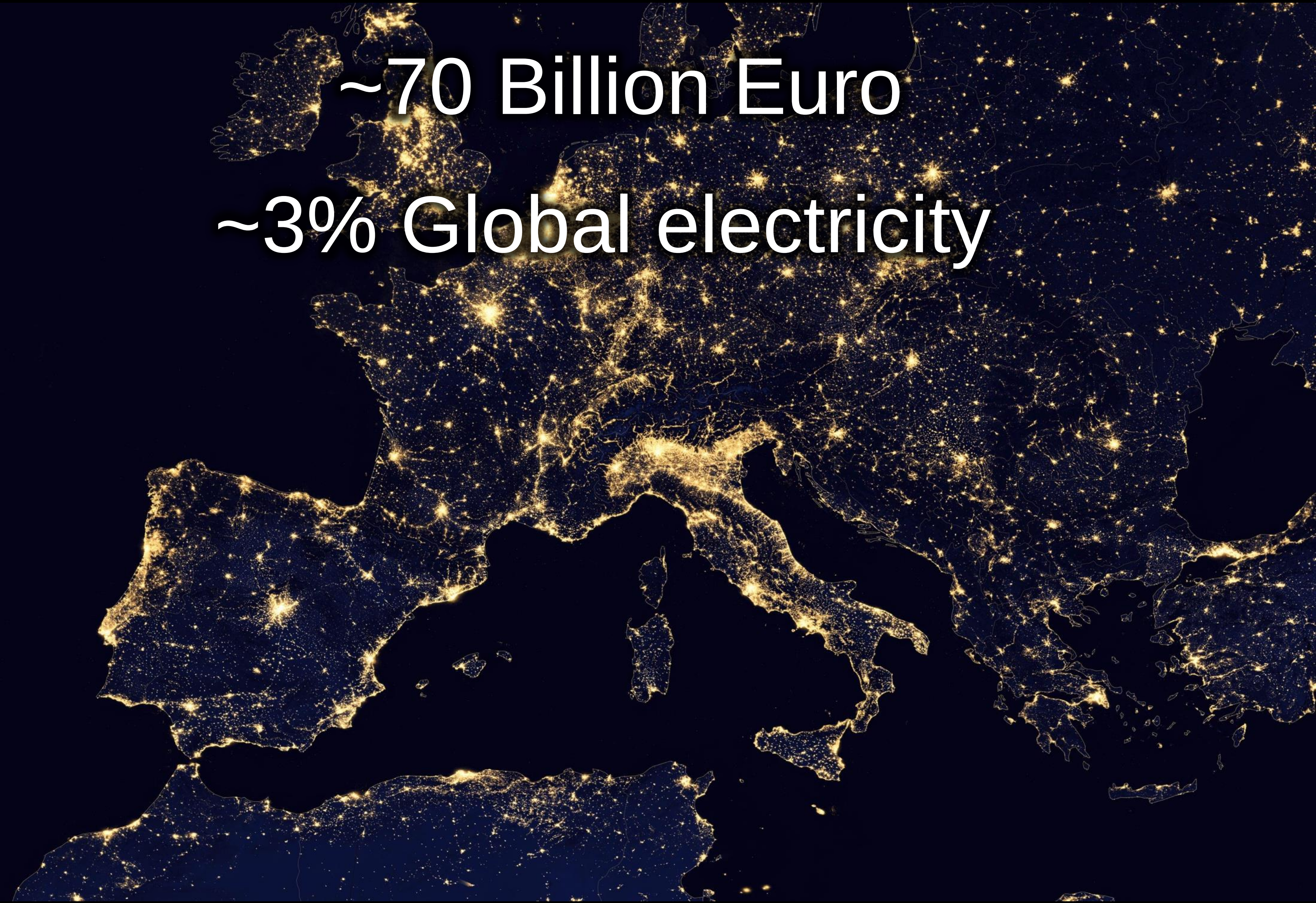
Energy Consumption for Outdoor Lighting


~70 Billion Euro
~3% Global electricity

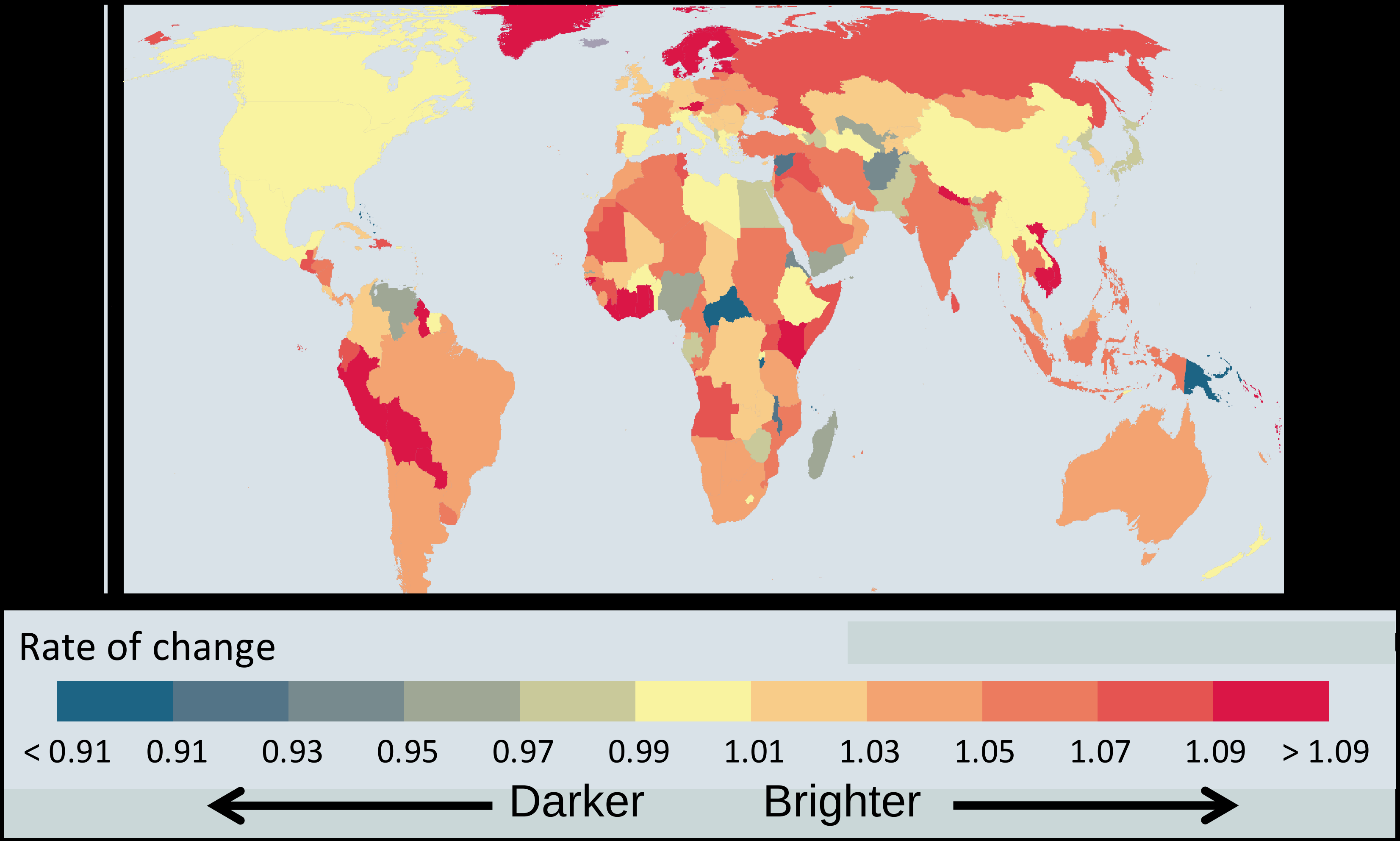
Do LEDs save energy,
or just enable brighter lights?

White LED

Sodium vapor

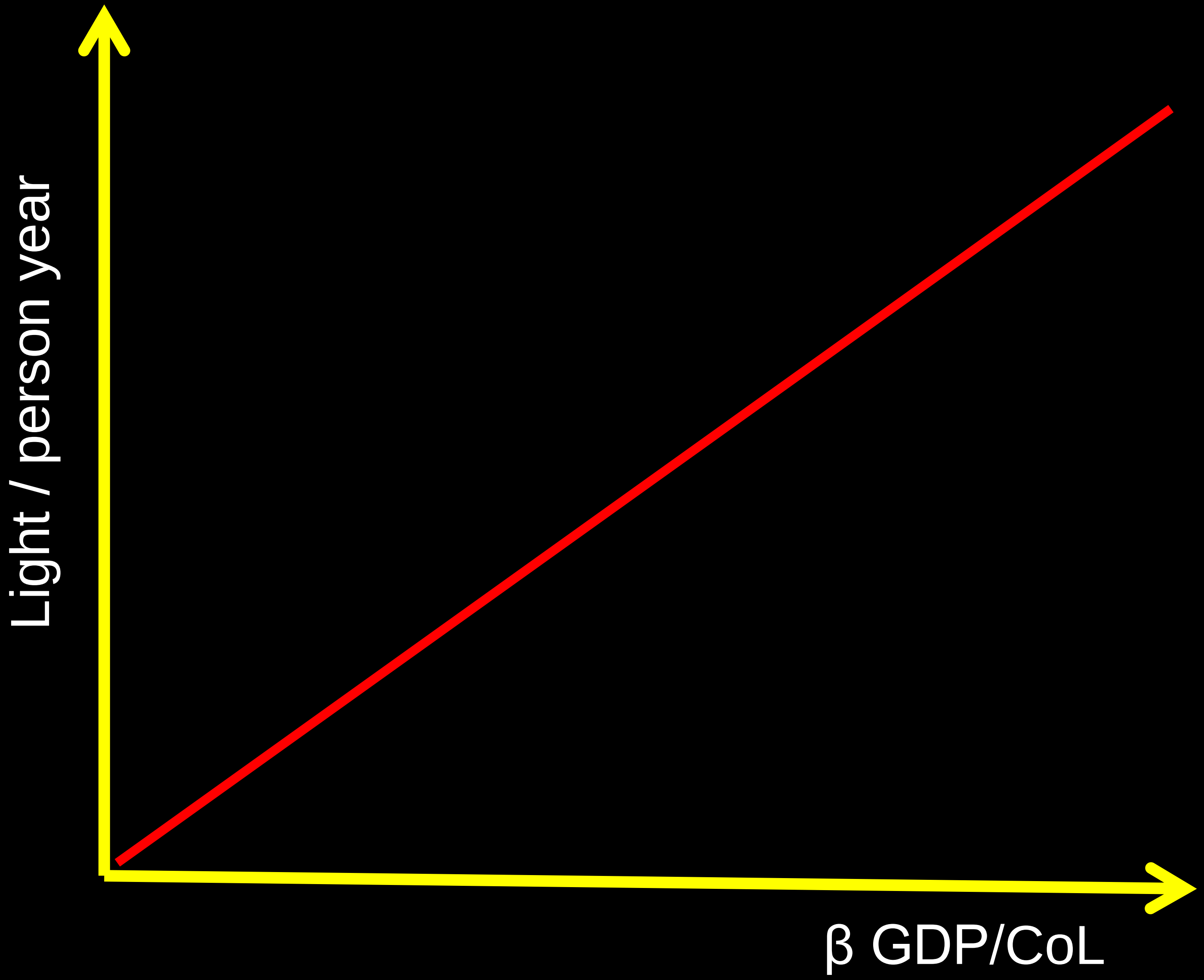
Image by redit user “alreadytakenusername”

Annual change in radiance (brightness), 2012-2016



Kyba et al. (2017) Science Advances

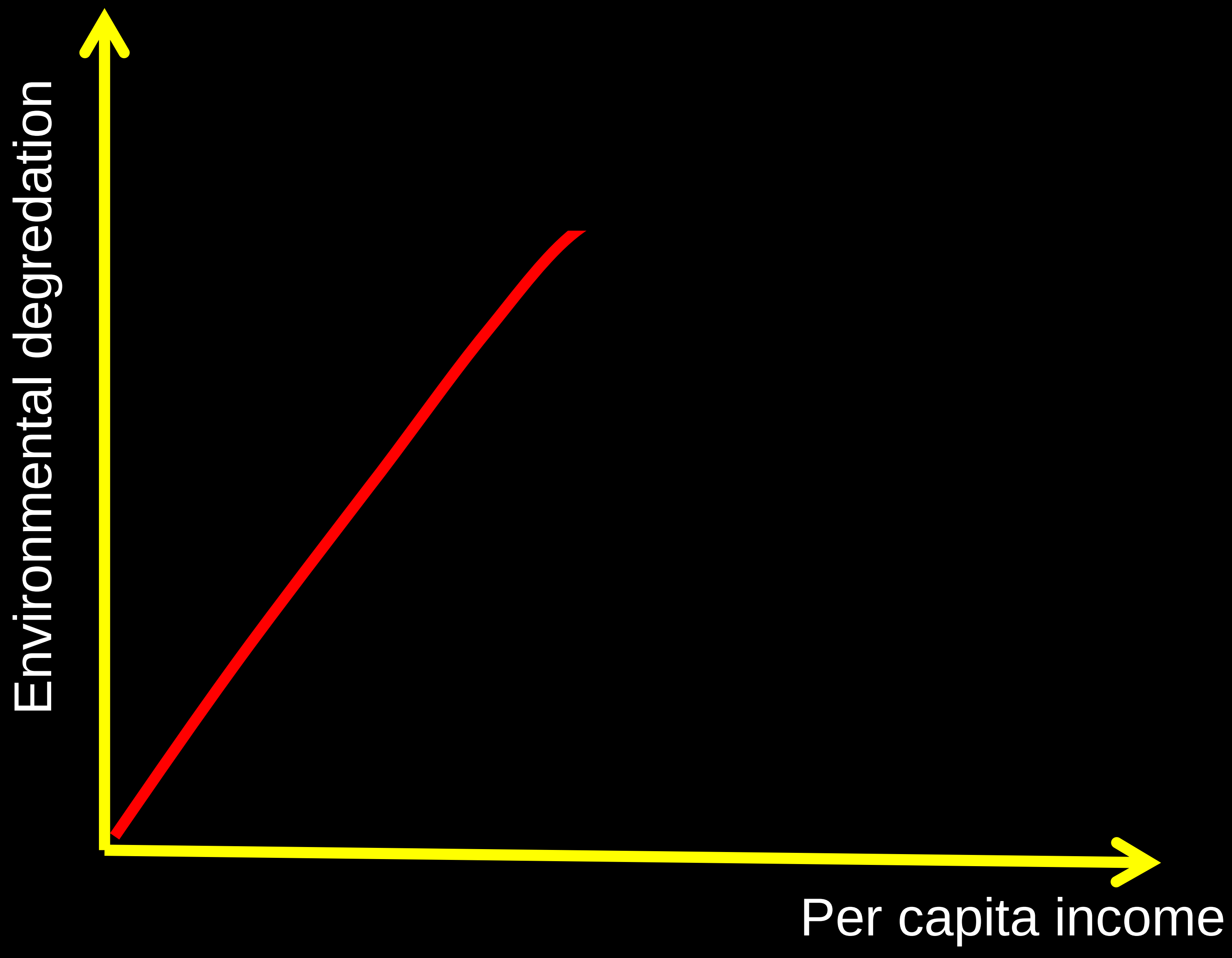
Demand for lighting



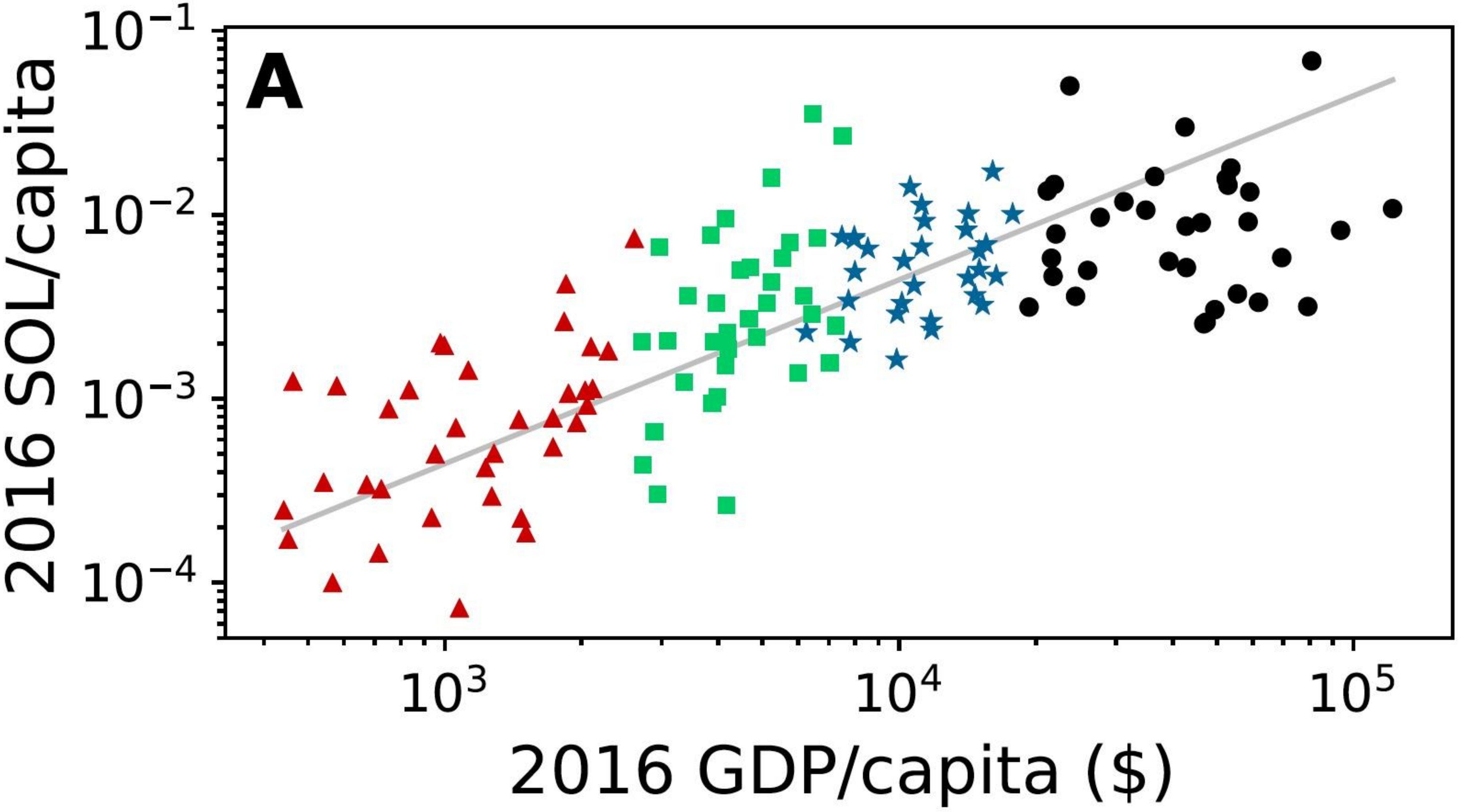
Demand for lighting

Tsao & Waide, 2010

Environmental Kuznets curve



Light/capita vs GDP/capita



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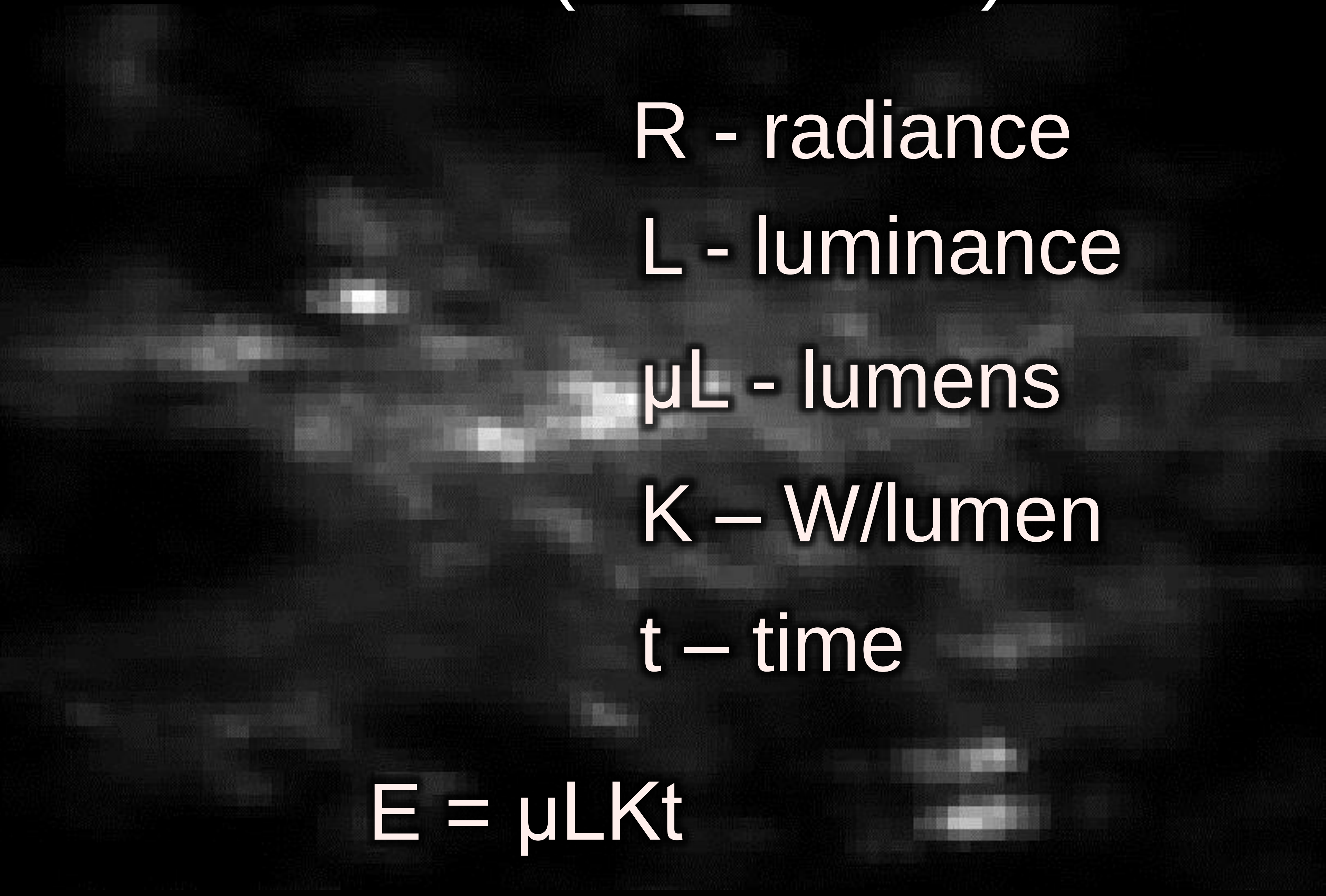
Simple model

- All light is public outdoor area lighting
- Only one lamp type

Berlin (VIIRS DNB)



R - radiance

L - luminance

μL - lumens

K – W/lumen

t – time

$E = \mu L K t$


E = μLKt

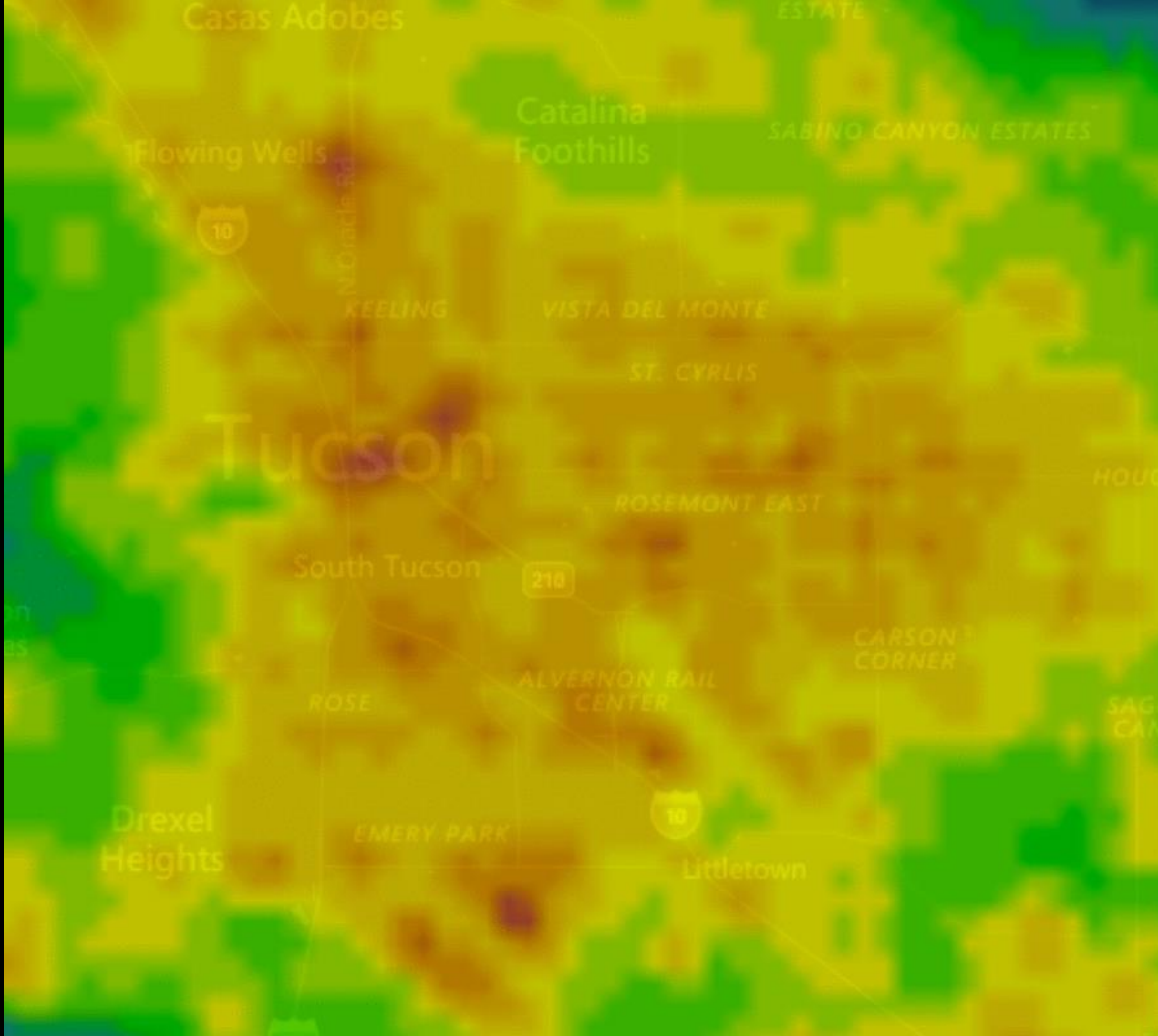
Private lighting

City lighting change experiment

Full power

50% Dimmed

Photos of Cambridge, MA
WSP | Parsons Brinckerhoff


Casas Adobes
ESTATE
Catalina Foothills
SABINO CANYON ESTATES
Flowing Wells
10
KEELING
VISTA DEL MONTE
ST. CYRLIS
Tucson
ROSEMONT EAST
South Tucson
210
CARSON CORNER
ALVERNON RAIL CENTER
ROSE
Drexel Heights
EMERY PARK
10
Littletown

R - radiance

L - luminance

μL - lumens

K – W/lumen

s – fraction streets

$$E = \mu L K t$$

$$E = s\mu_s L_s K_s t + (1-s)\mu_p L_p K_p t$$


$E = s\mu_s L_s K_s t + (1-s)\mu_p L_p K_p t$

$$\Delta E = \frac{s\mu_{s1}L_{s1}K_{s1} + (1-s)\mu_{p1}L_{p1}K_{p1}}{s\mu_{s2}L_{s2}K_{s2} + (1-s)\mu_{p2}L_{p2}K_{p2}}$$

You’re welcome!

$$L_{s1} = \frac{L_1 - L_2}{1-d} \quad , \quad L_{s2} = \frac{dL_1 - dL_2}{1-d} \quad , \quad L_o = \frac{L_2 - dL_1}{1-d} \quad , \quad s_1 = \frac{L_1 - L_2}{(1-d)L_1} \tag{3}$$

$$L_p(\hat{\Omega}) = \sum_n \alpha_n \sin\theta_n L_{p,n}(\hat{\Omega}, \theta_n) \tag{5}$$

These predictions can be compared to observations $L_o(\hat{\Omega})$ from an eVscope or all sky camera photograph:

$$\Delta(\hat{\Omega}) = L_o(\hat{\Omega}) - L_p(\hat{\Omega}) \tag{6}$$

A full eVscope acquisition or all-sky camera photo contains many observing directions $\hat{\Omega}$, so the overall agreement between the model and an observation can be assigned a test statistic, for example a likelihood $\mathcal{L}_i$

$$\mathcal{L}_i = \prod_{\hat{\Omega}} p\Big(\Delta(\hat{\Omega})\Big) \quad , \quad \mathcal{L} = \prod_i \mathcal{L}_i \tag{7}$$