

Impact of LED lighting on Worldwide Energy Saving and Role of Optical Metrology

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LED Lighting (Solid State Lighting)
– the Third Revolution in Lighting –

Incandescent

10~ 15 lm/W
(lumen / watt)

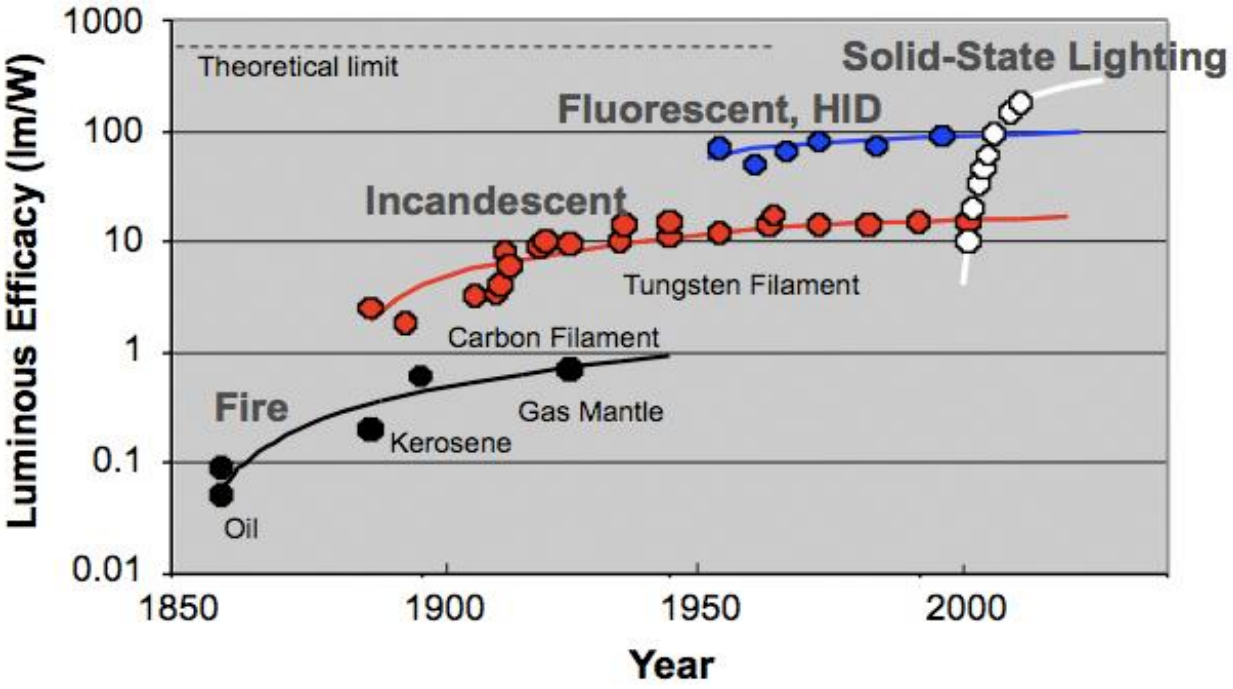
Fluorescent

(Hg)

50~ 90 lm/W

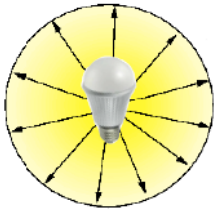
Solid State (White LEDs)

Potential 250 lm/W



- 200 lm/W product already available
- 3~5 x Longer lifetime than fluorescent lamps

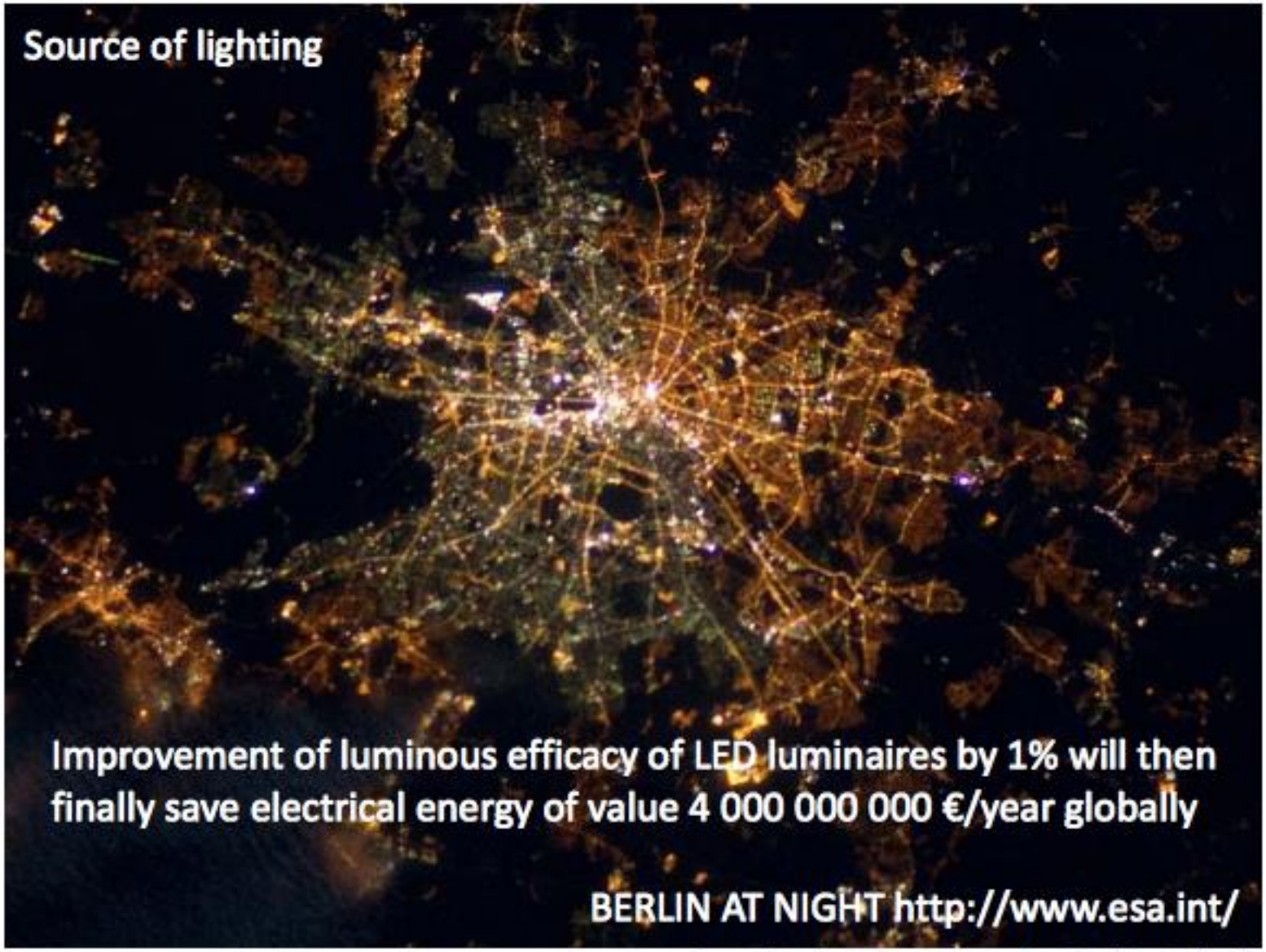
Lumen (lm): unit for total amount of light



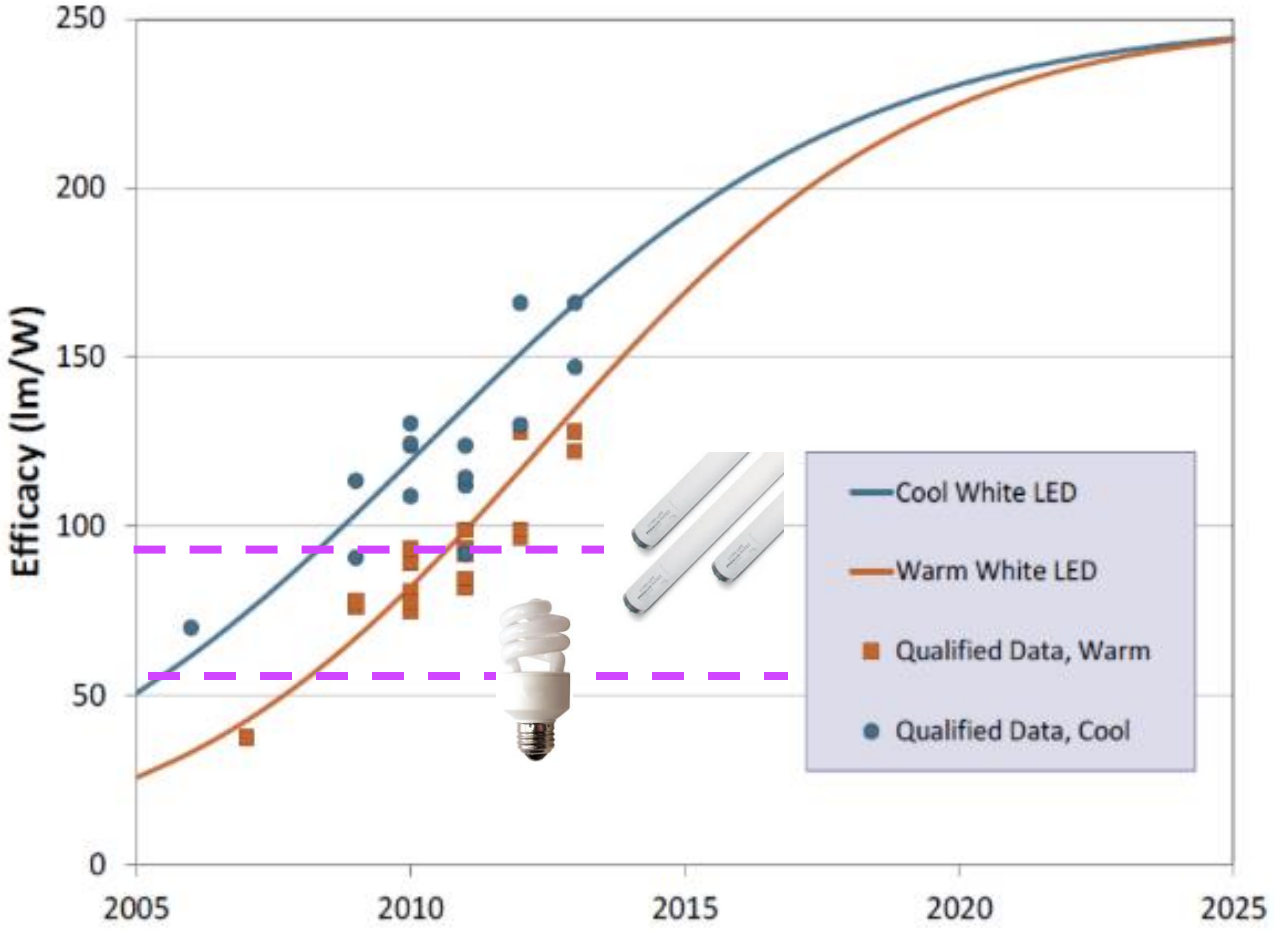
Huge Energy Savings Potential

Lighting consumes 22 % of electricity
8 % of total energy
(statistics of USA)

Solid State Lighting, by 2027
50% reduction of energy consumed by lighting
Customer savings of *$30 billion annually in USA*
Reduction of greenhouse gas emissions
(U.S. Dep. Energy)


Source of lighting
Improvement of luminous efficacy of LED luminaires by 1% will then finally save electrical energy of value 4 000 000 000 €/year globally
BERLIN AT NIGHT http://www.esa.int/

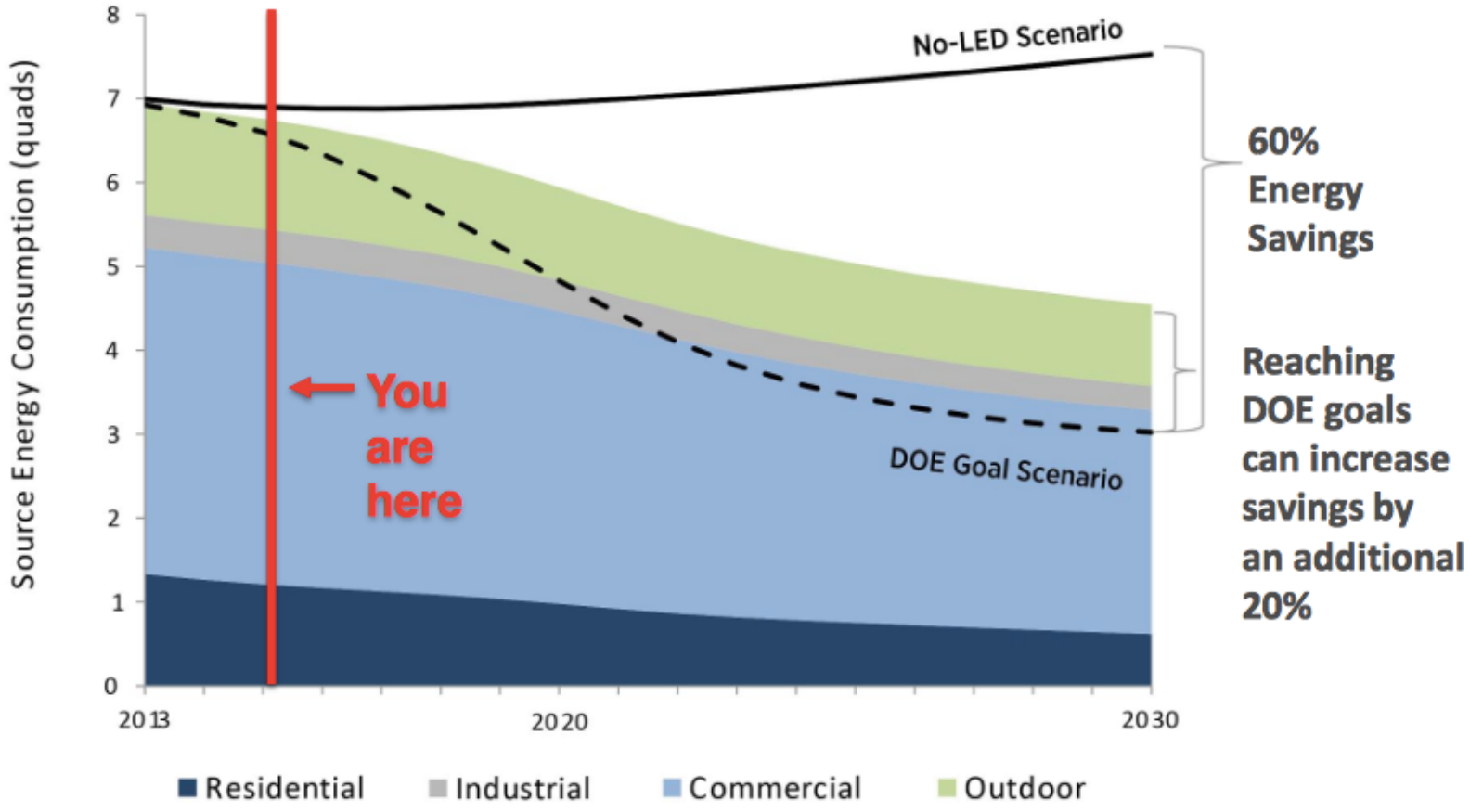
White LED lm/W improvements



Source: DOE 2014 SSL Roadmap

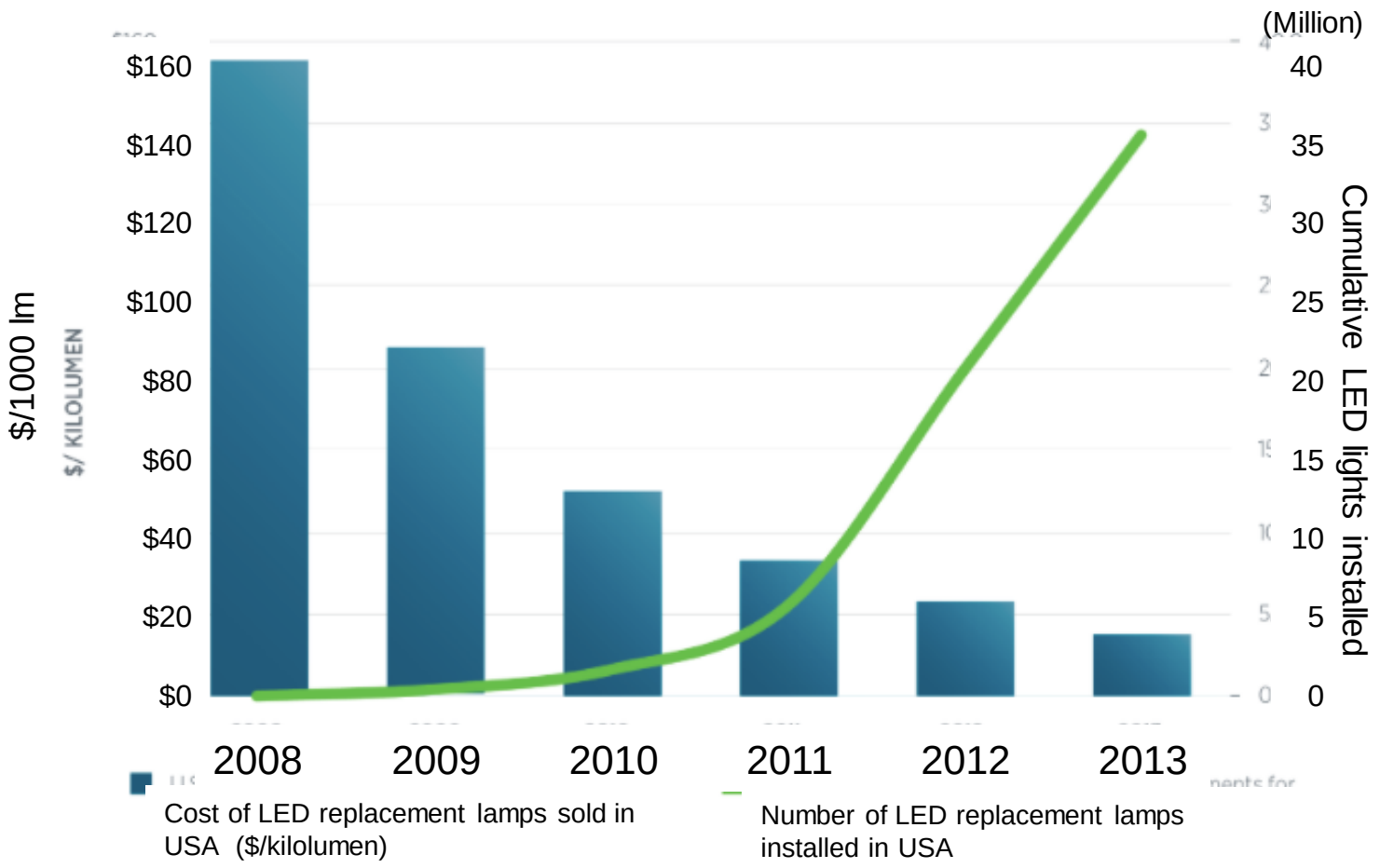
http://www.energy.gov/sites/prod/files/2015/02/f19/craford_innovation_sanfrancisco2015.pdf

Energy Savings Forecast for SSL



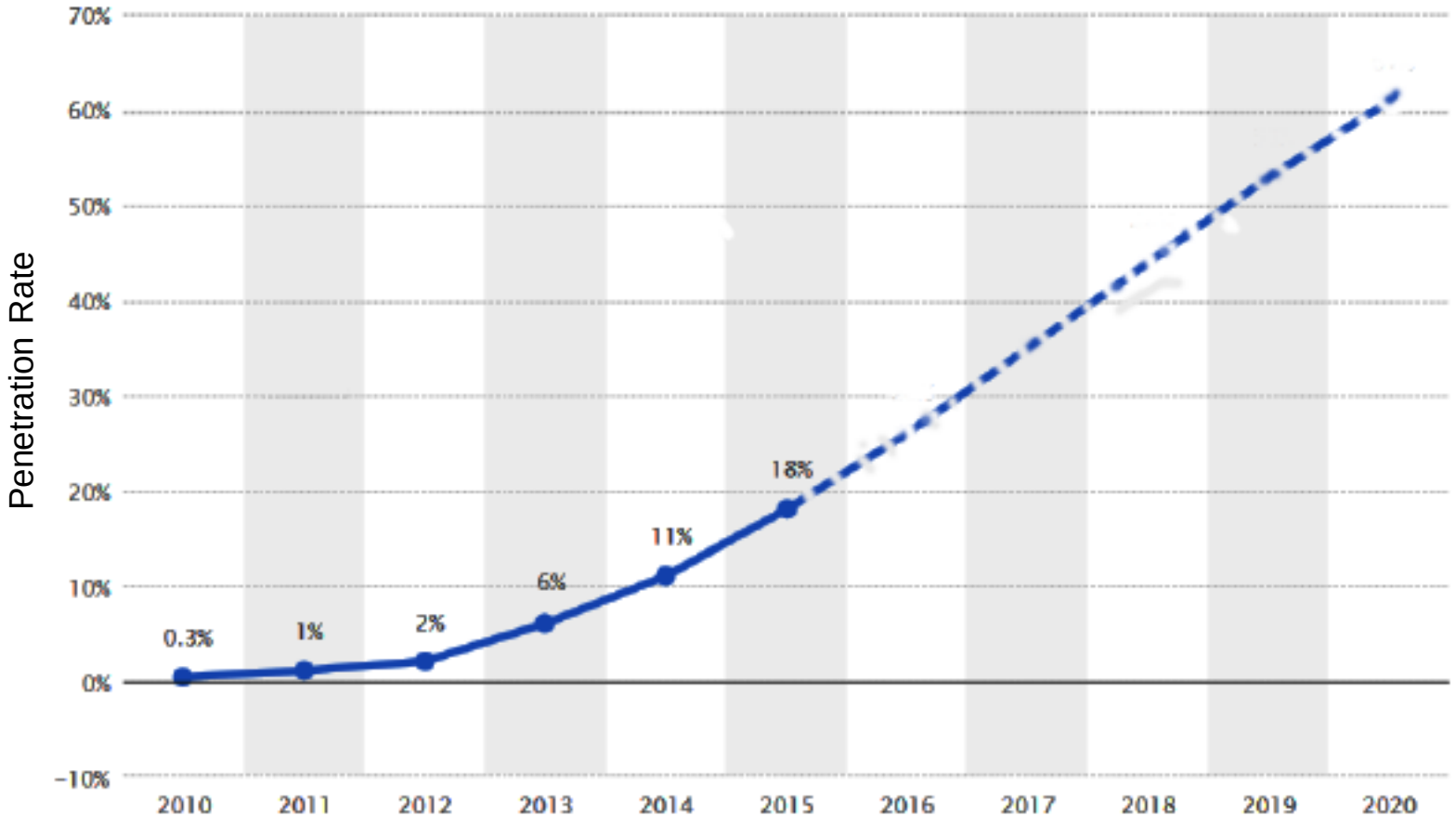
http://www.energy.gov/sites/prod/files/2015/02/f19/brodrick_welcome_sanfrancisco2015.pdf

U.S. Deployment and Cost for A-Type LED Lights 2008–2013



http://www.energy.gov/sites/prod/files/2015/02/f19/carr_keynote_sanfrancisco_2015.pdf

Global LED penetration in lighting



http://www.statista.com/statistics/246030/estimated-led-penetration-of-the-global-lighting-market/

CALiPER

Snapshot Indoor LED Luminaires

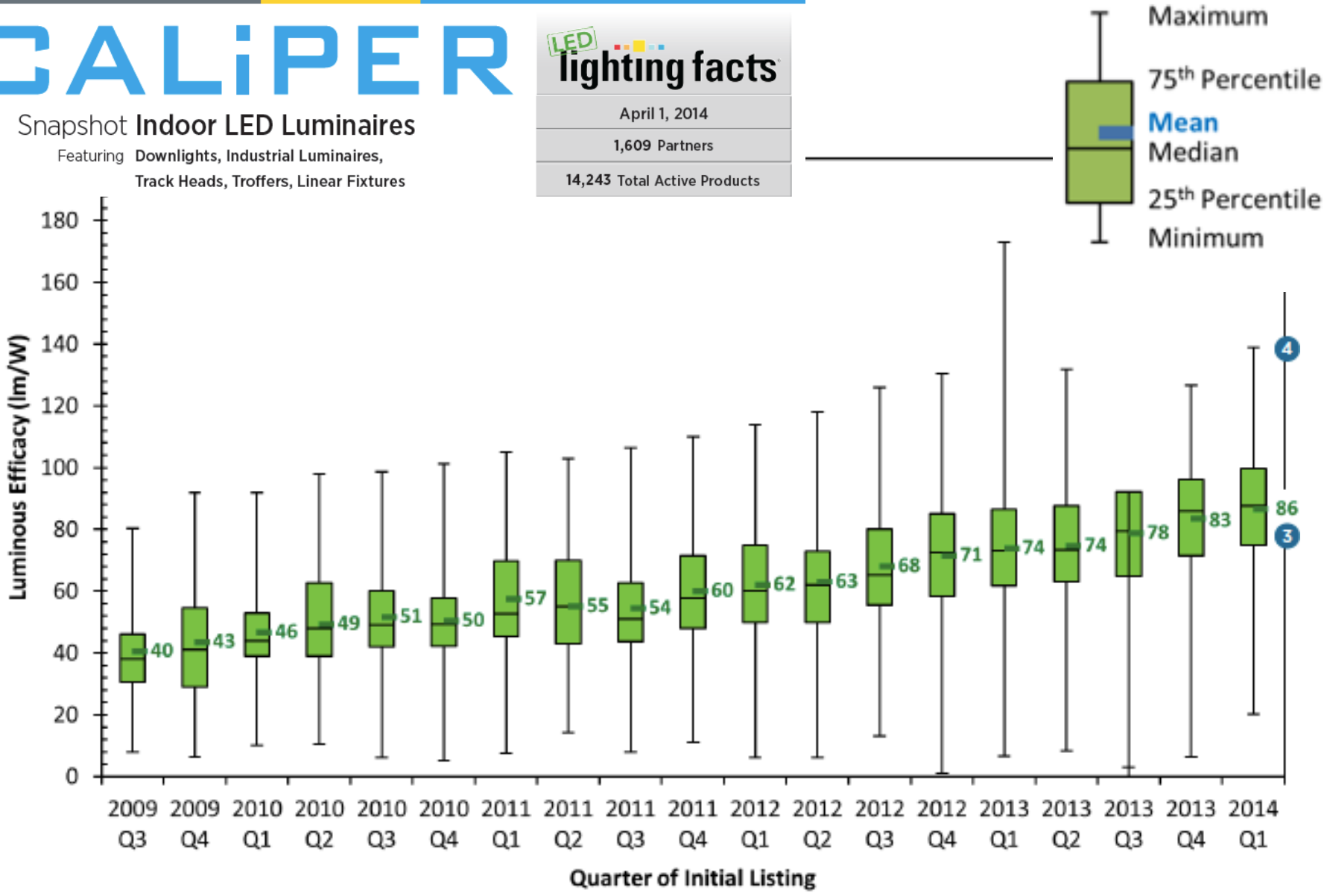
Featuring **Downlights, Industrial Luminaires, Track Heads, Troffers, Linear Fixtures**

LED lighting facts

April 1, 2014

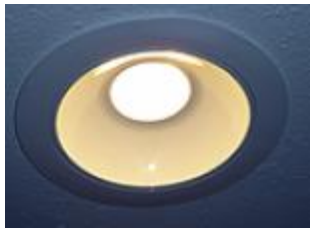
1,609 Partners

14,243 Total Active Products



Problems

Many different SSL products of various qualities are spreading to the market



- Some very **low quality** products in the market (dim, short life, bad color).
- **Inaccurate performance claims**
- **Insufficient information** on product labels

- **Disappoint customers.**
- **Delays adoption of LED products.**

Big concerns worldwide

- Many new manufactures, some have little knowledge on lighting.
- Standards and measurement proecdures for traditional lamps often do not apply.

Quality Assurance of SSL products (USA)

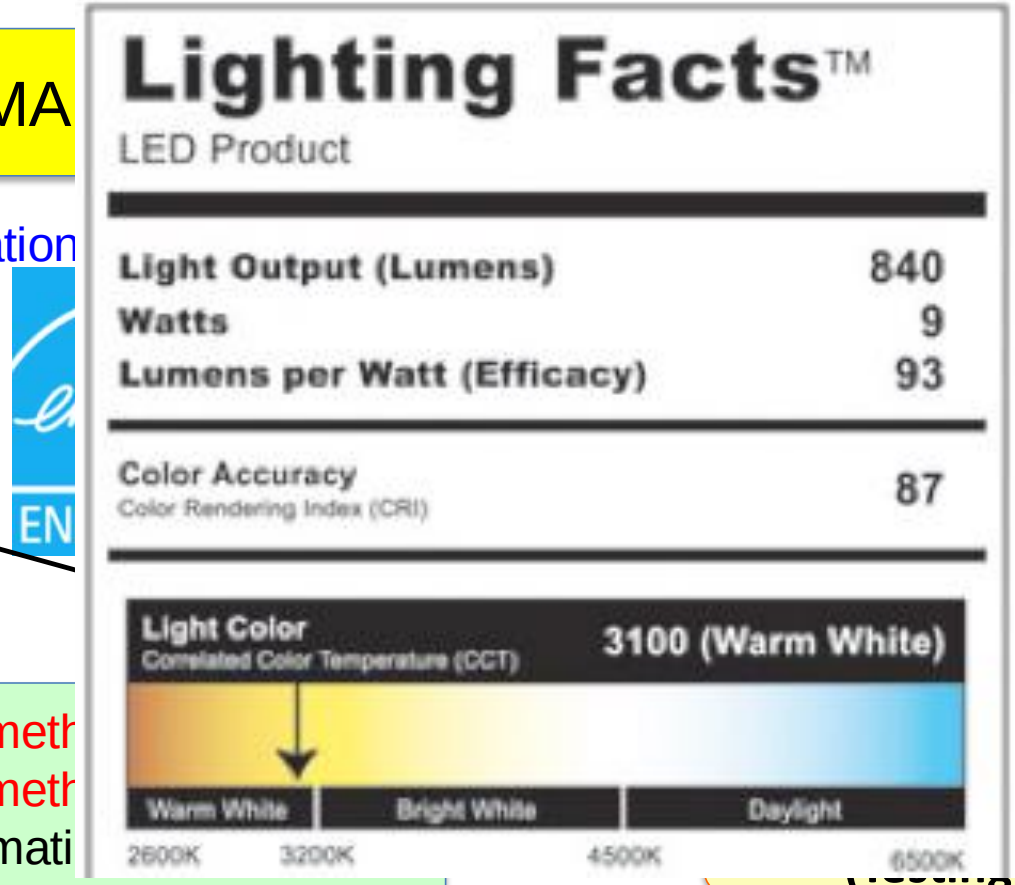
MA

Regulation

CALiPER
BENCHMARK REPORT

(Products monitoring)

EN



2007 Energy Independence and Security Act

Standards

Standards
- Test meth
- Test meth
- Chromati
- Safety of products

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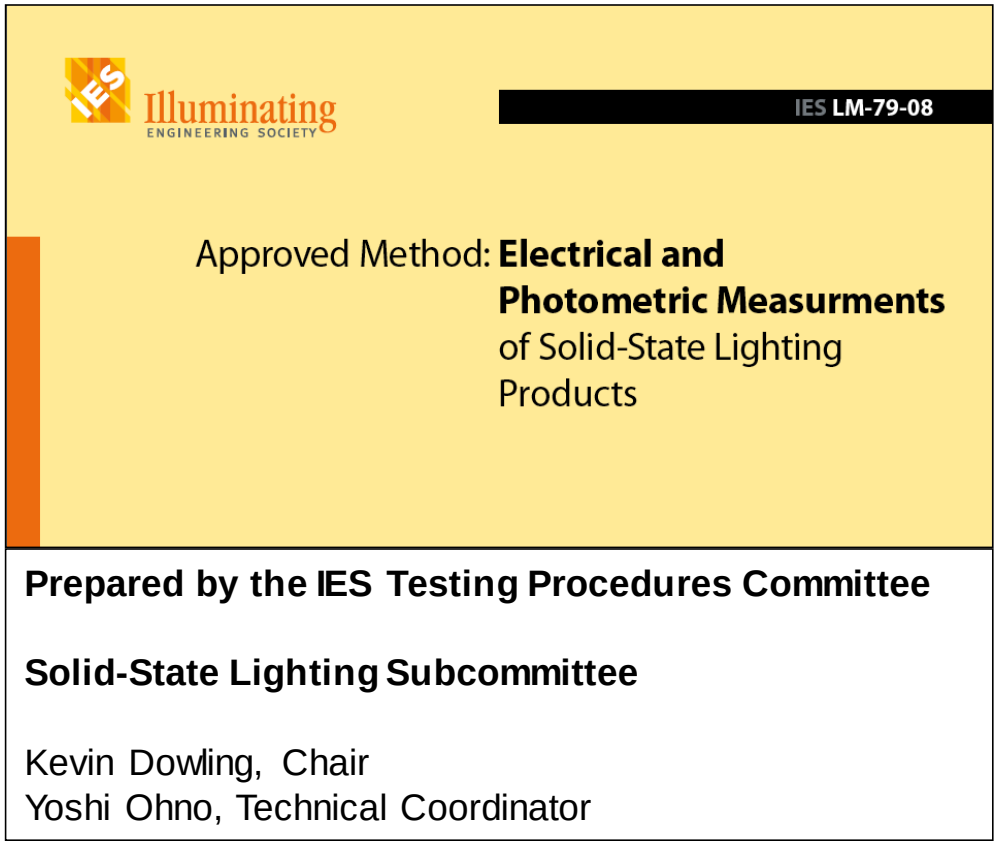
Research

industry, academia, national labs

NIST-NVLAP
(over 100 SSL labs)

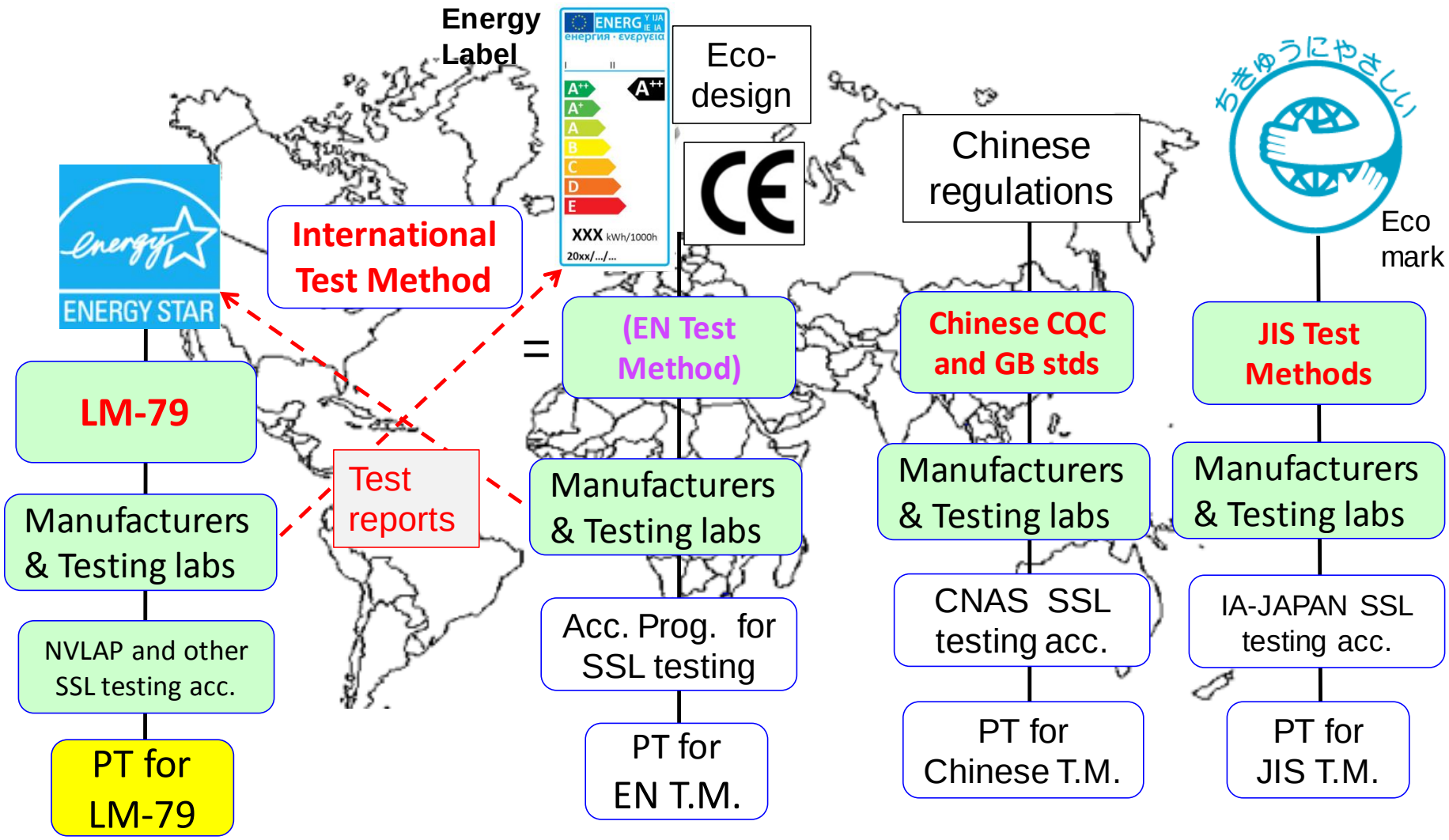
IESNA LM-79-08 Approved Method for Electrical and Photometric Measurement of SSL Products



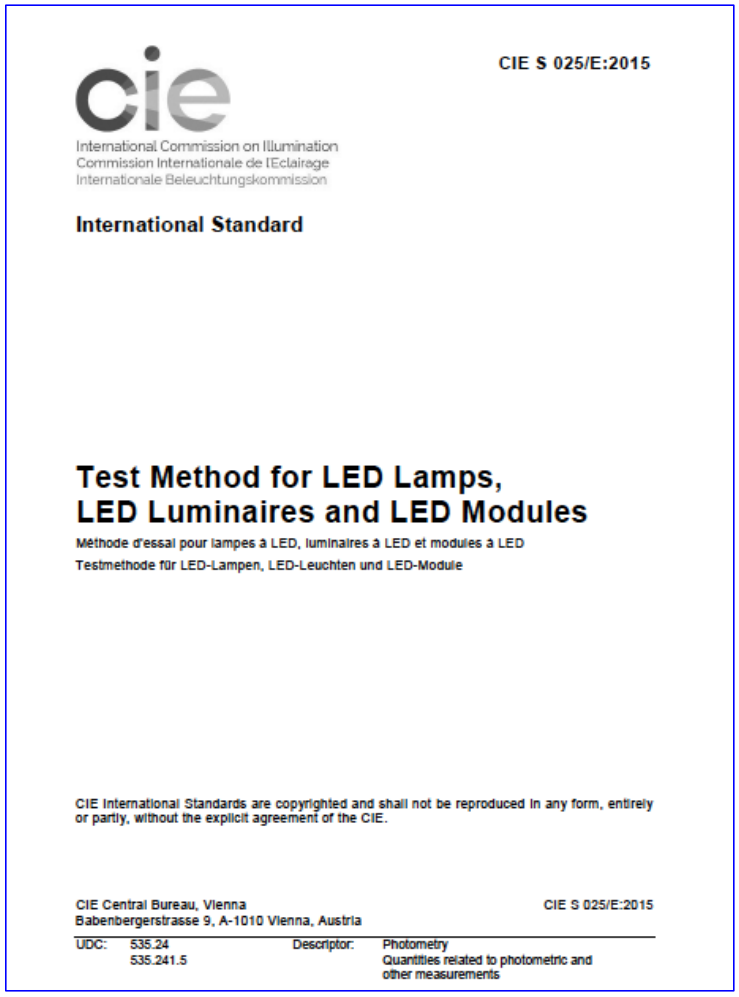
Published 2008.

- Used by **Energy Star**, **Lighting Facts, and many other government programs**.
- Used in accreditation (**NVLAP SSL Testing)**
- Covers LED luminaires and LED lamps.
- Covers measurements of
  - Total luminous flux (lumen)
  - Luminous efficacy (lm/W)
  - Chromaticity, CCT, CRI
  - Luminous intensity distribution

Needs for International Harmonization in SSL Testing and Accreditation



CIE S025 Test Method for LED lamps, LED modules, and LED luminaires



CIE S 025/E:2015

cie

International Commission on Illumination
Commission Internationale de l'Eclairage
Internationale Beleuchtungskommission

International Standard

Test Method for LED Lamps, LED Luminaires and LED Modules

Méthode d'essai pour lampes à LED, luminaires à LED et modules à LED

Testmethode für LED-Lampen, LED-Leuchten und LED-Module

CIE Central Bureau, Vienna
Babenbergerstrasse 9, A-1010 Vienna, Austria

CIE S 025/E:2015

UDC: 535.24
535.241.5

Descriptor: Photometry
Quantities related to photometric and other measurements

Published in March 2015.

This standard took 4 years to develop.

International Standard CIE S 025 provides a unified global test method for harmonisation of testing of LED lighting products worldwide.

Collaboration of
CIE TC2-71 (Y. Ohno, chair) and CEN TC169 WG7 (G. Vandermeersch, chair)

European standard published:
EN 13032 Lighting Applications — Measurement and presentation of photometric data of lamps and luminaires — Part 4: LED lamps, modules and luminaires

Measurement challenges

An example

Flux Characteristics at 700mA, Junction Temperature, T_J = 25°C

Table 1.

	Minimum Luminous Flux (lm) or Radiometric	Typical Luminous Flux (lm) or Radiometric
Rc		

Manufacturers measure LEDs using a short current pulse. Data are given at junction temperature25° C.

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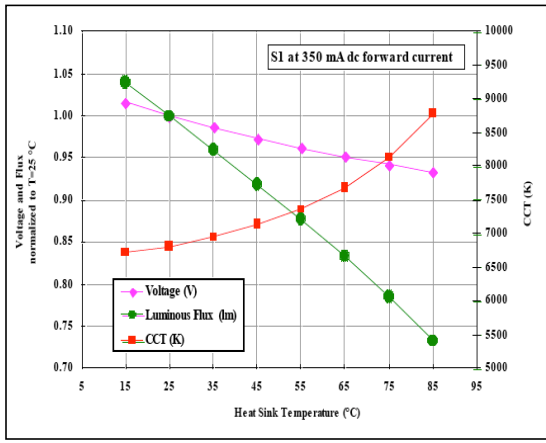
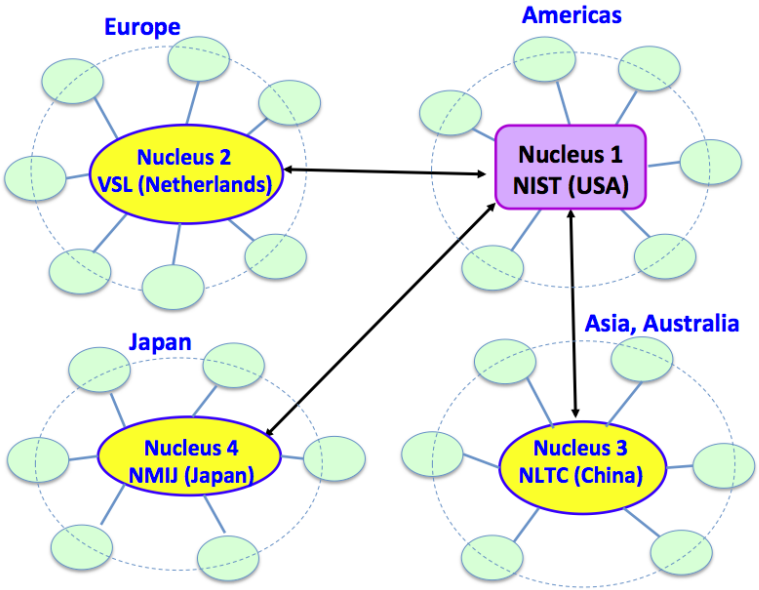


- LEDs operated in lamps and luminaires are very hot (T_j can be >100° C)
- LED performance is a function of T_j but very difficult to measure or reproduce T_j.
- NIST developed a method to measure LEDs at **any given T_j using steady DC current**. It is adopted in IES standard LM-85-14.

Temperature-controlled heatsink

Interlaboratory Comparison (IC 2013)

- **Total 110 laboratories'** measurements of solid state lighting products were compared, including data linked from
  - 35 labs in NVLAP and NIST MAP
  - Data of 19 labs from APLAC SSL PT program



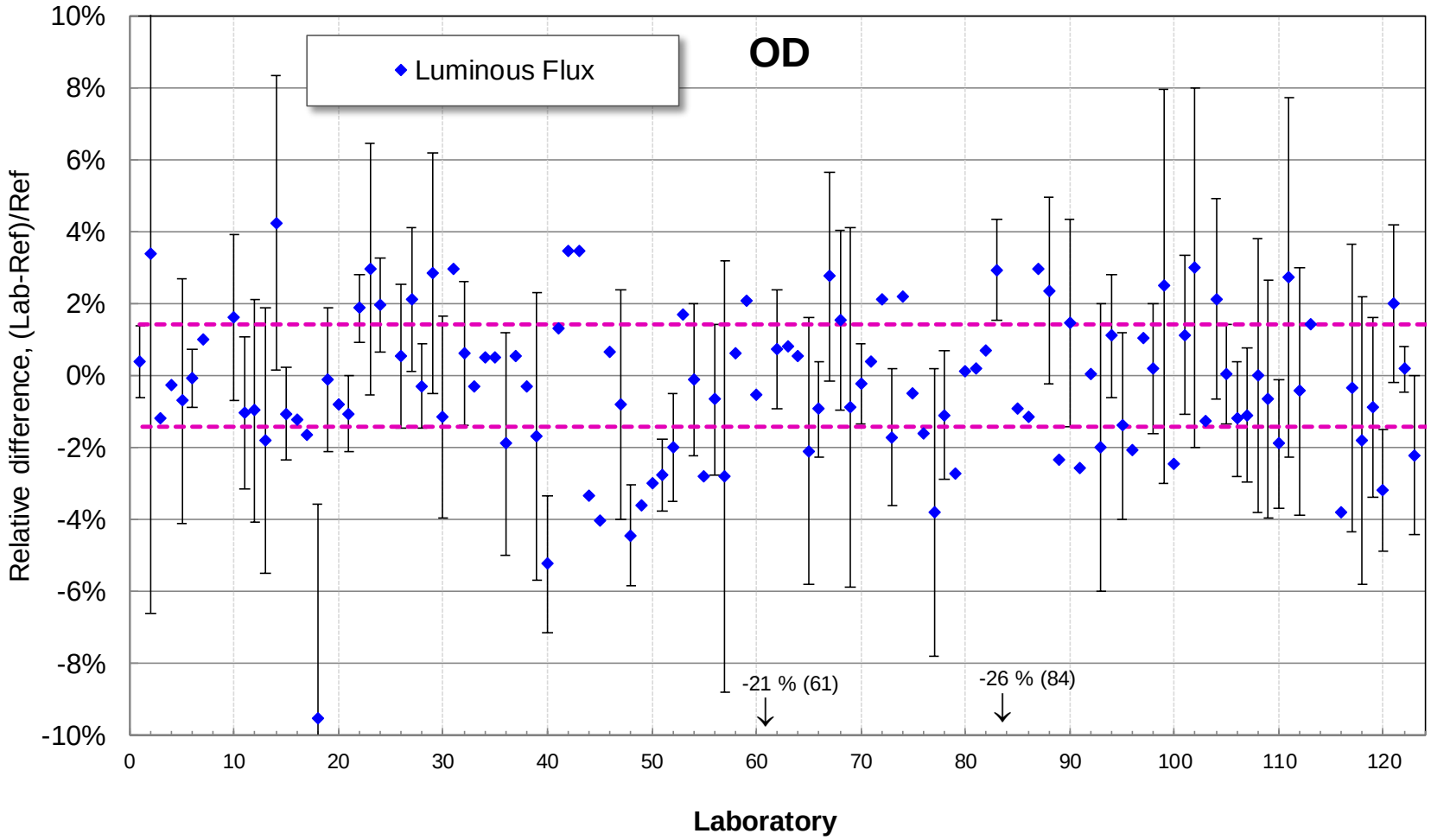
Comparison quantities

- Luminous flux (lm)
- luminous efficacy (lm/W)
- Electrical power, current
- Power factor
- Chromaticity, CCT, CRI

Y. Ohno, et al, http://ssl.iea-4e.org/files/otherfiles/0000/0067/IC2013_Final_Report_final_10.09.2014a.pdf

IC 2013 Final Report to be published in Sep. 2014

An example data (luminous flux of omni-directional LED lamp)



Difficulty in measurement of lifetime

Example

Luminaire V2.0 (EPA) May 4, 2015.

Lifetime L_{70} >25,000 h indoor,
35,000 h outdoor

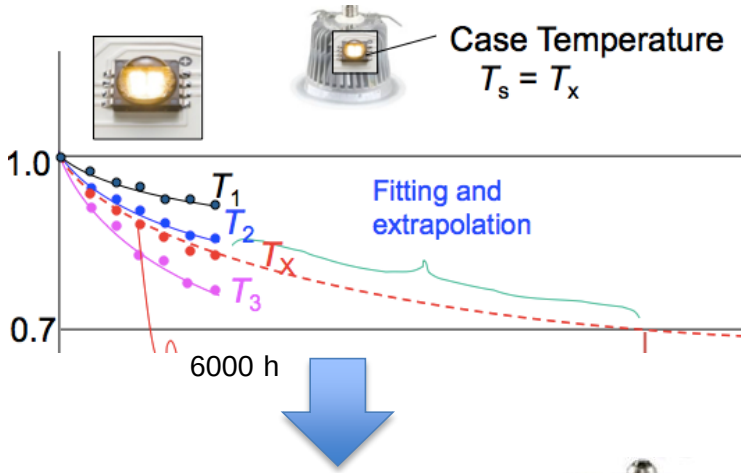
- **Test method** (standard) is needed for regulations.
- Testing products for 35,000 h would take 4 years. Lifetime needs to be **predicted from testing at much shorter time.**
- **Electronics** often fail before LEDs fail. (Lifetime of LEDs is not necessarily the lifetime of LED lamps and luminaires)
- Test procedures should not be too much burden to the industry. (lead to increase of cost, delay of commercialization)

Two approaches to measure (predict) lifetime

Components approach

IES LM-80-08/TM-21-11

Aging test data of components (LEDs, modules)



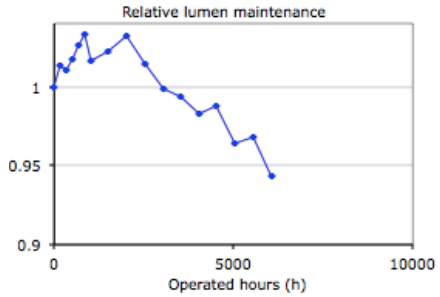
Lifetime L_{70} (h) of LED lamps, LED luminaires

Low cost
Electronics not tested.

Direct approach

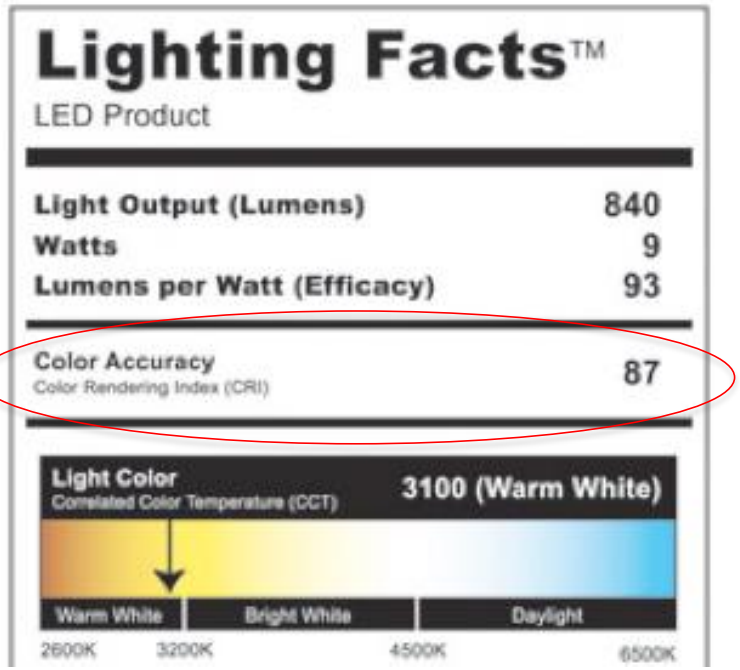
IES LM-84-14/TM-28-14

Aging test directly on LED lamps, LED luminaires for changes of luminous flux, color.



High cost
Test includes electronics

Color Quality Issues



Current standard: **Color Rendering Index** (**CRI**), CIE Pub. 13.3

General Trade-off between color rendering and energy efficiency.

CRI is old (1974 formula) and known to have significant inaccuracies.

→ Accurate color rendering metric is important for best use of energy.

IES published TM-30 Evaluating Light Source Color Rendition

CIE position statement on CRI and color quality metrics
http://www.cie.co.at/index.php?i_ca_id=981

Research on color quality metrics is actively done in many places including NIST.

Thank you for your attention

Contact: ohno@nist.gov