ssl.iea-4e.org

IEA 4E SSL ANNEX

Peter Bennich, Chair, Management Committee

Workshop on Intelligent efficient Solid-state lighting

Basel, 12 December 2016

Contents

Introduction

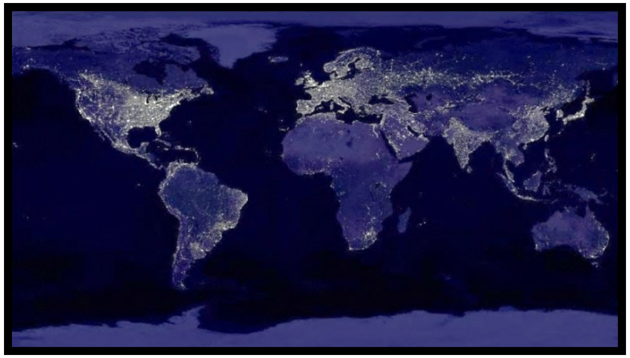
Performance tiers

Interlaboratory comparison 2017

Measurements on smart lamps

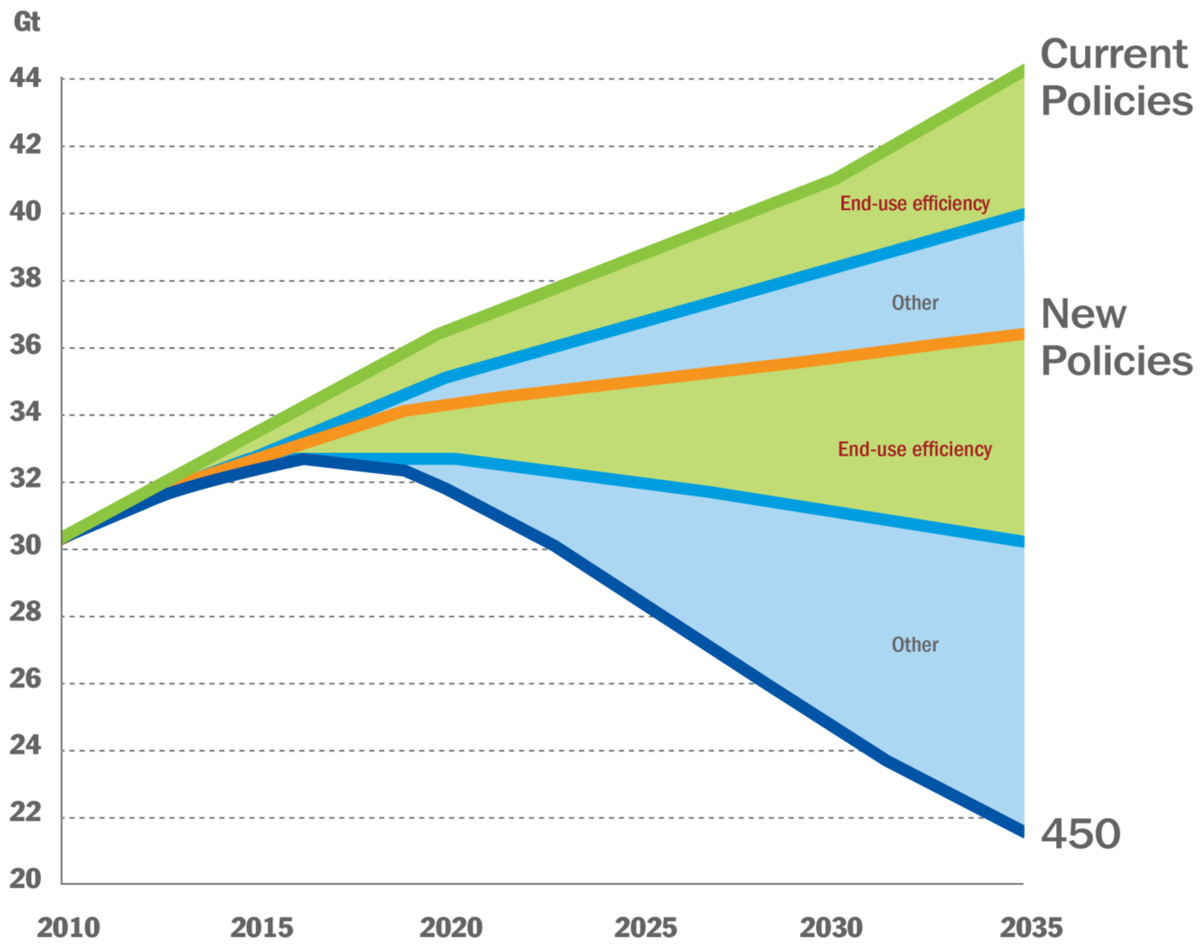
The electricity use for lighting globally

- Lighting used 16 – 19 % of the total electricity use in 2005, or ca 2700 TWh [1,2]
- 1,6 billion people on Earth lack electrical lighting
- *Without policy*, the electricity use for lighting was projected to double to 2030 (5 000 TWh/yr) [1]



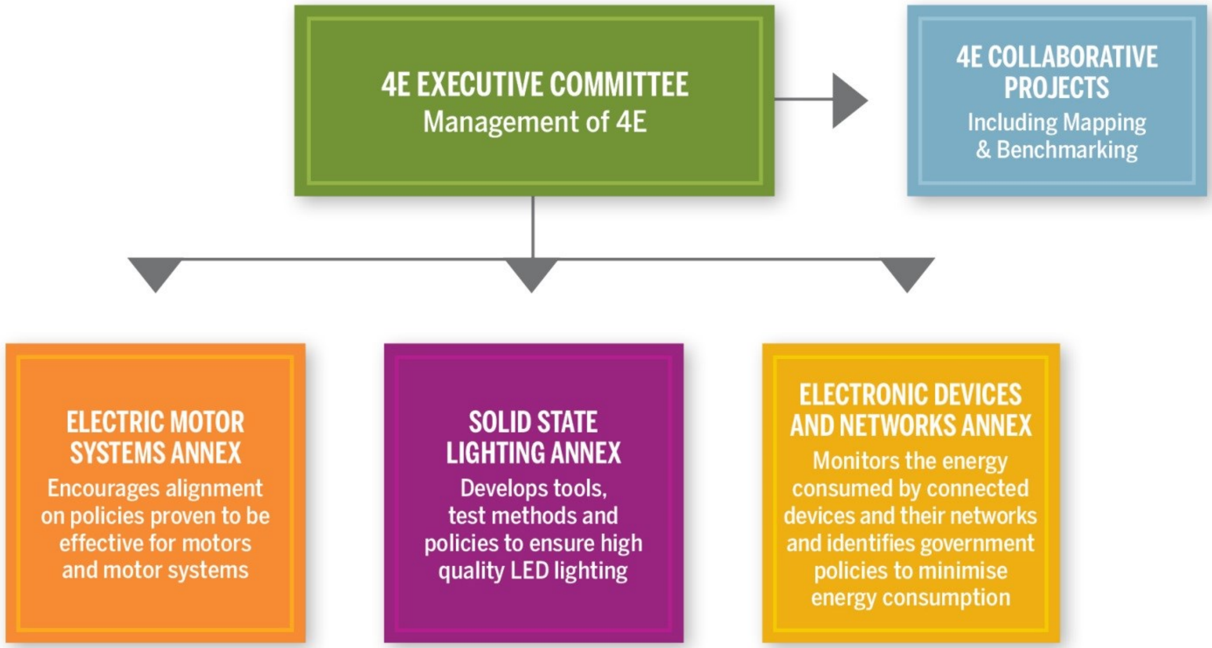
[1] P. Waide, T. Satoshi. Lights Labours Lost, Policies for Energy-efficient Lighting, International Energy Agency (IEA) publication, July 2006.
[2] J. Tsao, P. Waide. The World's Appetite for Light: Empirical Data and Trends Spanning Three Centuries and Six Continents. Leukos, Vol 6 No 4, April 2010, p 259-281

The role of energy efficiency: Estimates by the IEA



Source: IEA World Energy Outlook 2011 and 2012

IEA Implementing Agreement: Energy Efficient End-use Equipment



First term: 2009-2014. Second term: 2014-2019

Here focus on the IEA 4E SSL Annex

Goals of the SSL Annex

In 2009 the LED technology was promising, but governments were not sure about the quality…

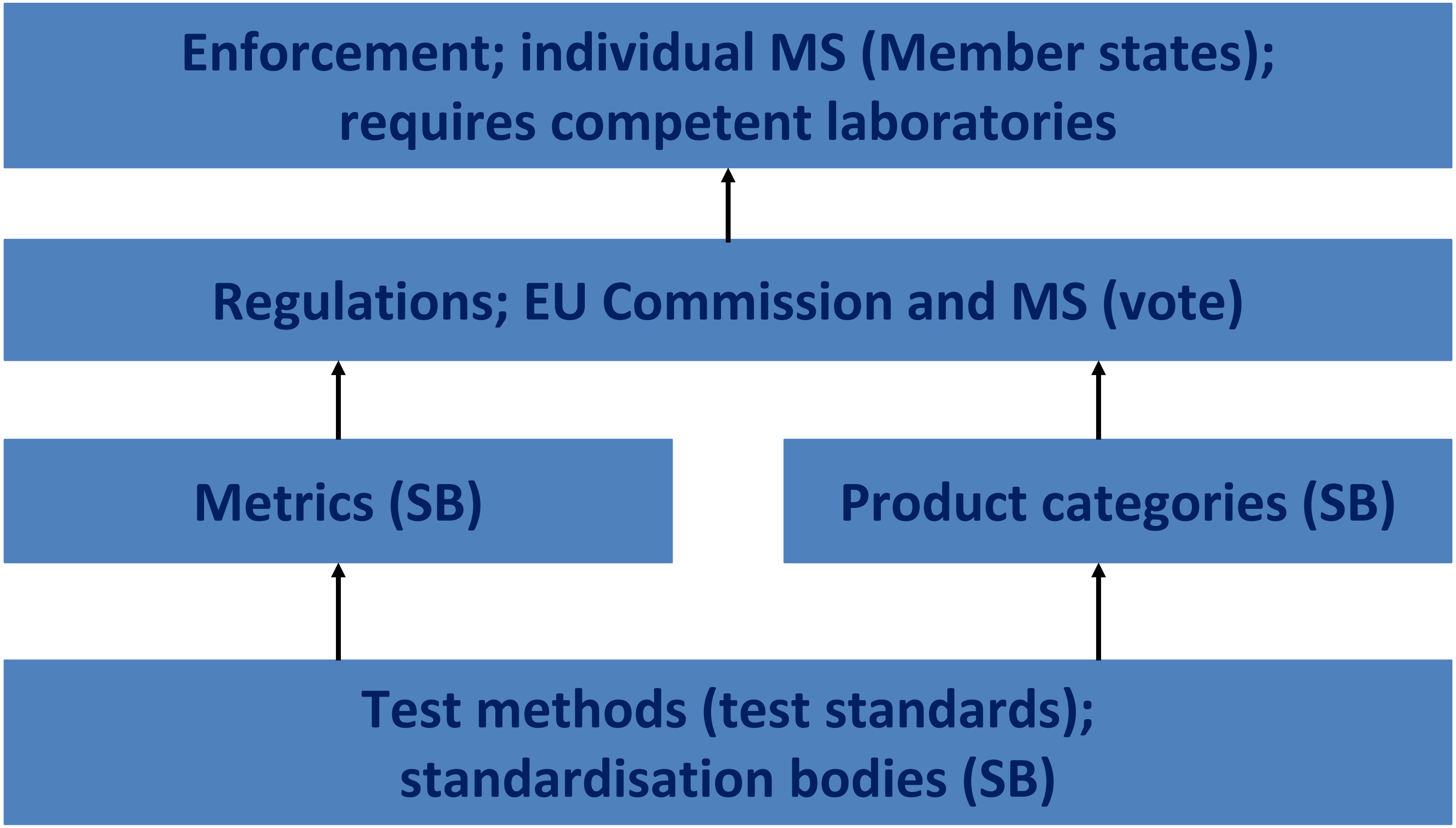
… therefore, the IEA 4E SSL started in 2010, to provide funding governments with:

- Tools to assess the *performance* of SSL,
- Information *assisting* formation of energy-efficient lighting *policies*, and
- Provision for *harmonised* test procedures and laboratory accreditation

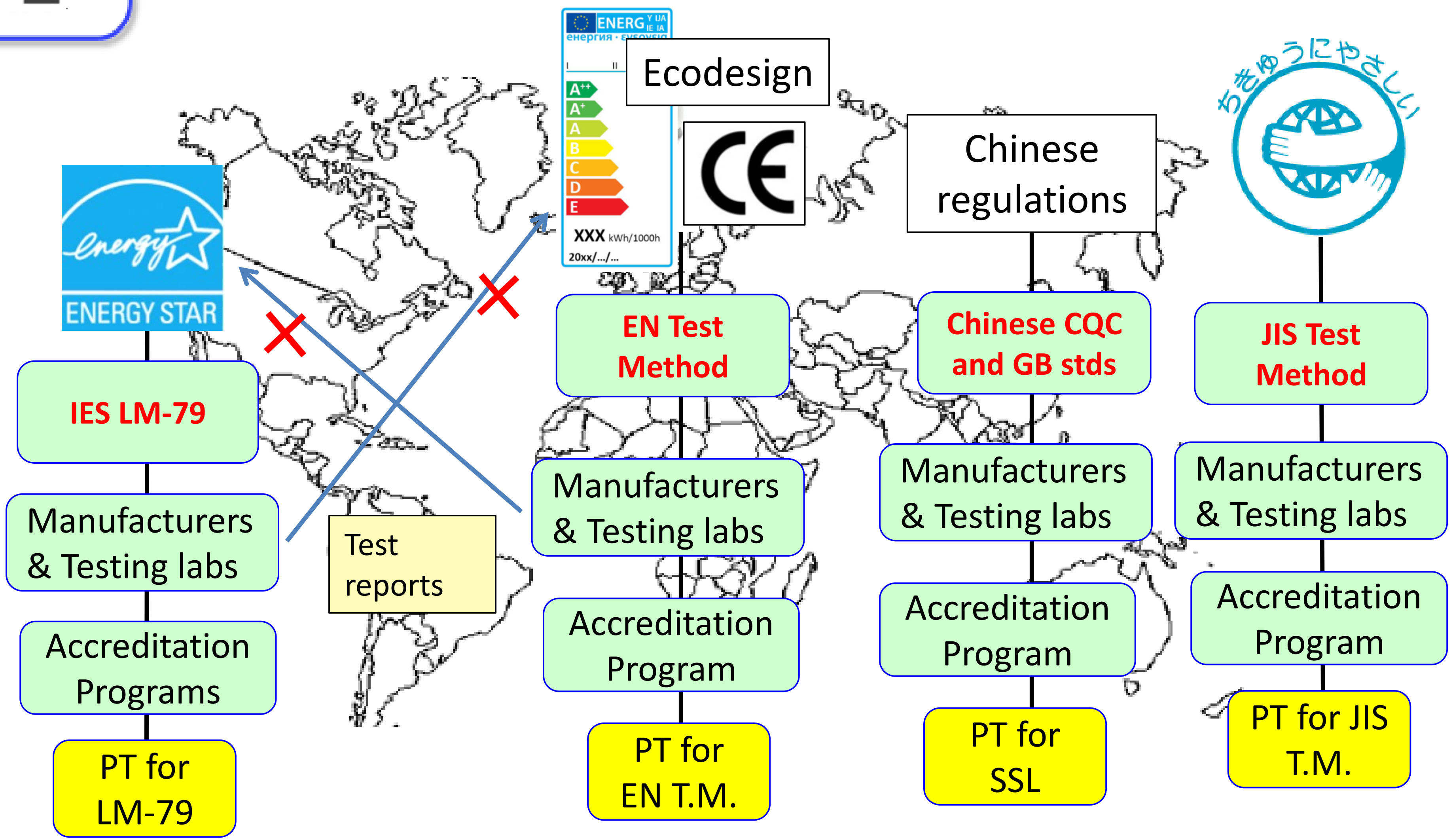
In order to ***increase the confidence of the SSL-technology in the marketplace.***

From Test Methods to Enforcement

(using the EU as an example)

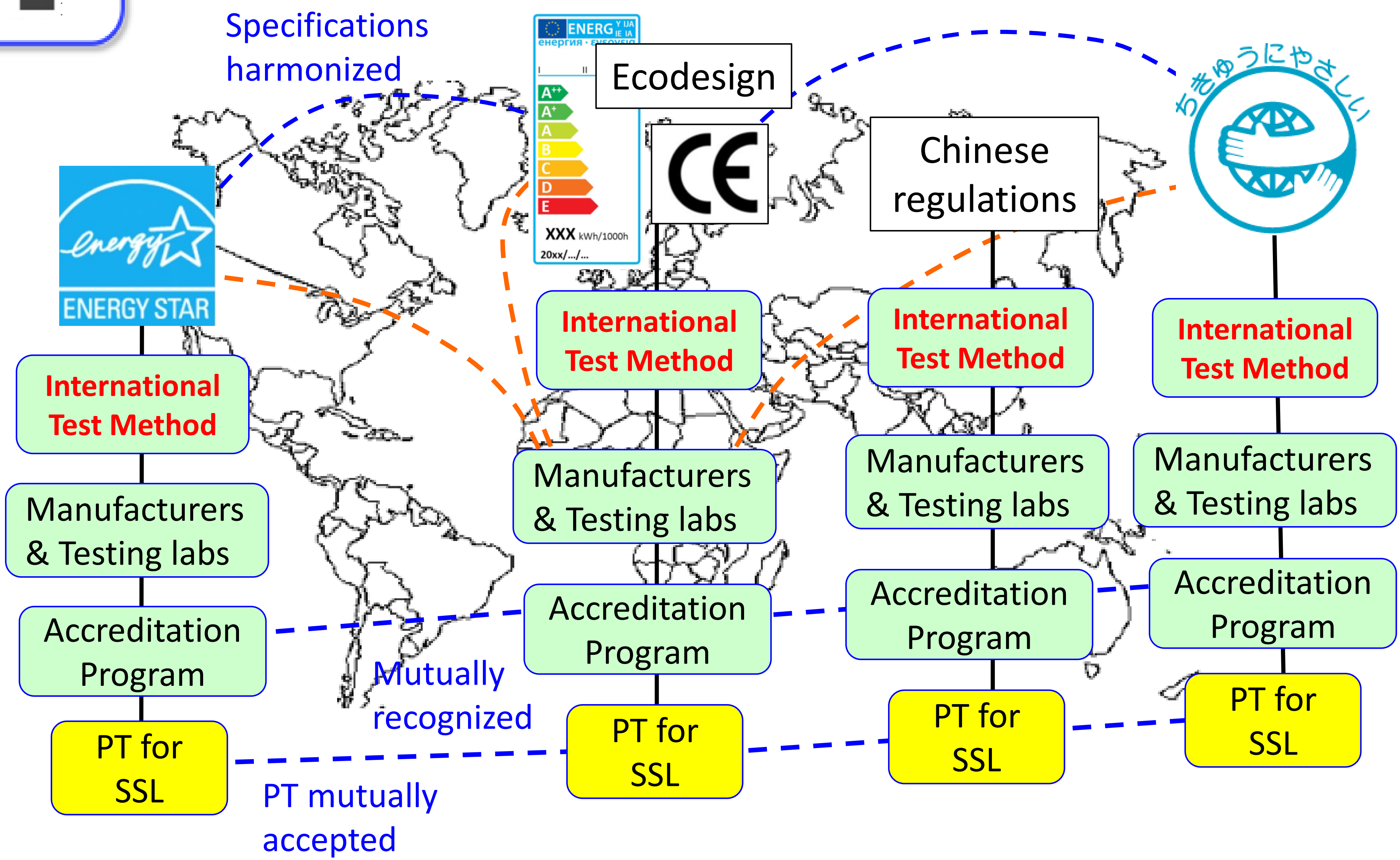


Need for International Harmonisation



Different Test methods, different APs, different PTs

Ideal Scheme – Global Harmonisation



Organisation of the annex

Thematic group of tasks:

- Test Standards and Laboratory Testing
- Market Support and Performance
- Monitoring, Verification and Enforcement
- Communications and Outreach

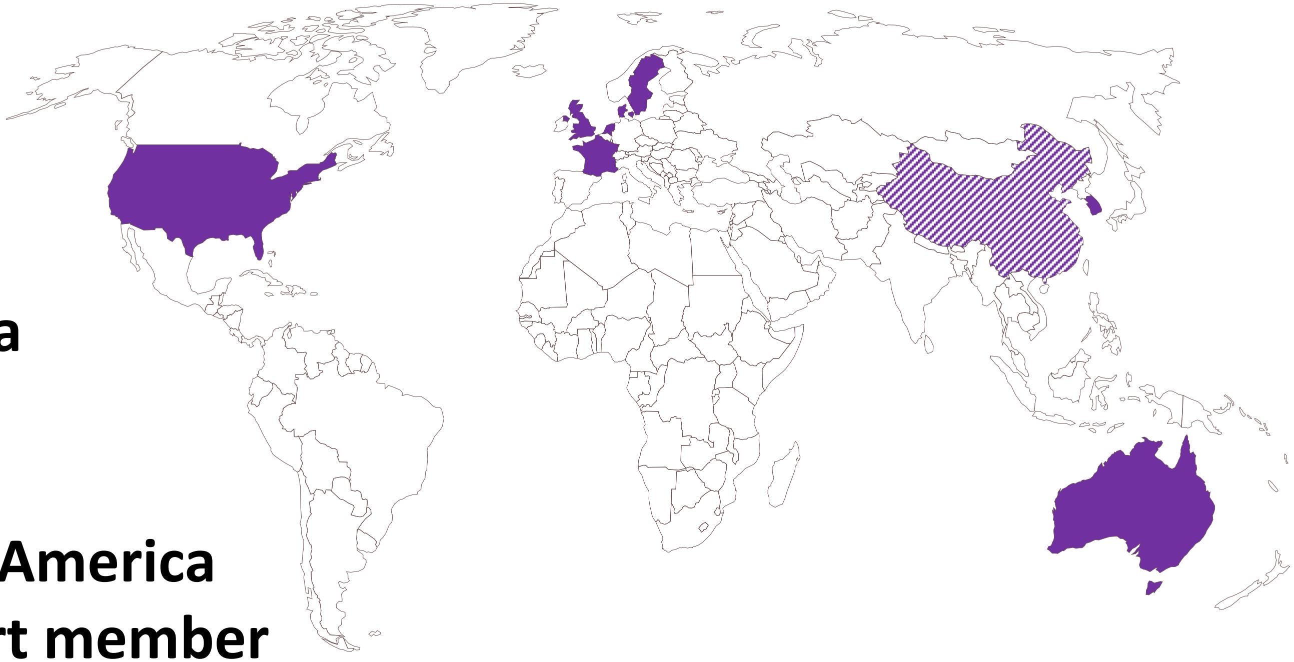
The work is done by *appointed experts and laboratories* steered by the funding governments

***Today´s** presentation focus on:*

- Performance tiers
- Interlaboratory comparison 2017
- Tests of Smart lamps

SSL Annex Member Countries

- Australia
- Denmark
- France
- Republic of Korea
- Sweden
- United Kingdom
- United States of America
- China is an expert member



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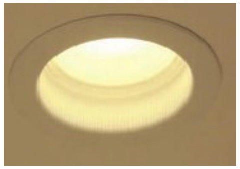
Performance tiers - current products

Promote harmonised SSL *product specifications* by encouraging governments, programme designers and funders to adopt these specifications.

Existing product specifications for:

1. Non-directional Lamps for Indoor Residential Applications
2. Directional Lamps for Indoor Residential Applications
3. Downlight Luminaires
4. Linear Fluorescent LED Lamps and “Retrofit” Lamps
5. Outdoor Lighting (Street Lighting)
6. High- and Low-bay Luminaires
7. Planar Luminaires



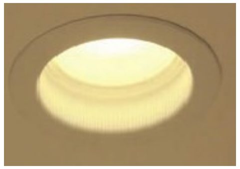




Performance tiers – what they cover


Parameters covers

- Luminous efficacy – lm/W; max standby
- Lighting parameters – min CRI, Duv etc
- Technical parameters – life (Du´v´; L70 etc), min PF etc




The specifications are based on market analyses and are presented in *three tiers*:

Tier 1: Minimum acceptable performance level

Tier 2: Performance required by established quality programs

Tier 3: Current highest commercially available performance



Performance tiers – new products

- **Integrated** non-directional luminaires – up to 2500–5000? lumens ("residential")




- **Integrated** Batons / Troffer luminaires (IEC term) – part of downlight luminaires or planar luminaires


- Outdoor security / area flood lighting.

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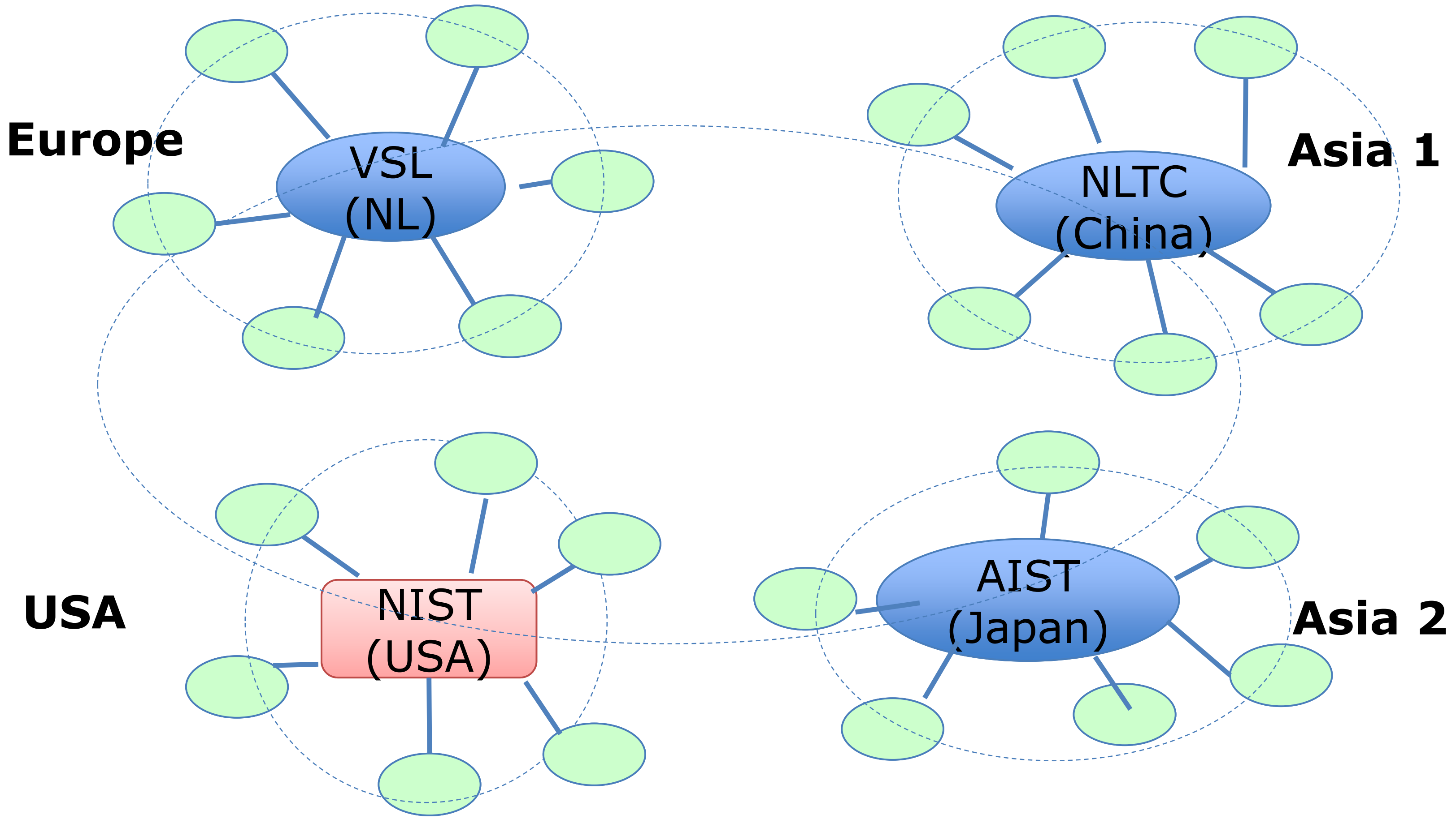
Interlaboratory comparison 2017

Measurements on smart lamps

Back to 2013: the first Interlaboratory comparison, for omni-directional parameters

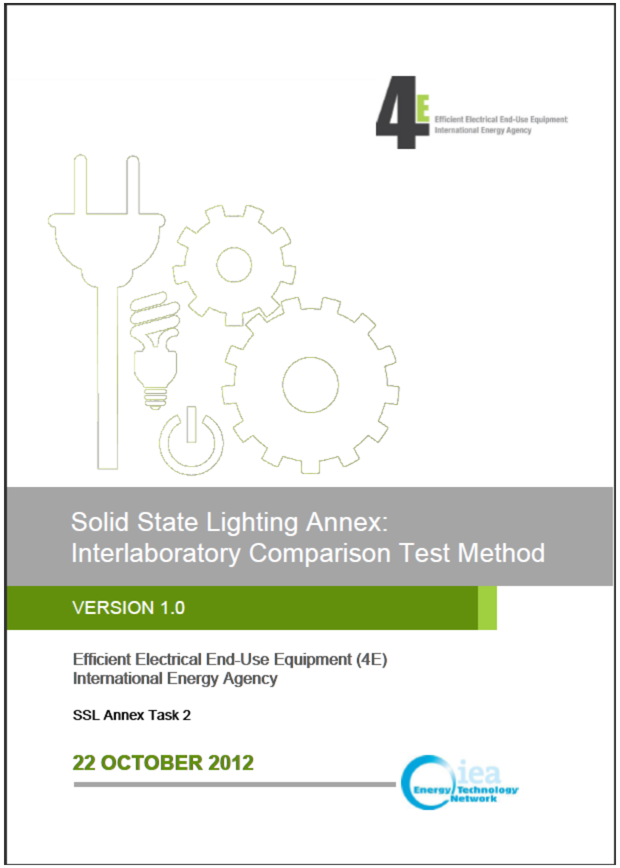
- Looked at test methods and laboratory comparison
- Three-step approach:
  - Collect the *best* test standards from around the world in one document
  - One *interlaboratory comparison* test between the *nucleus labs* (4 labs): 2011-2012
  - Then a larger *interlaboratory comparison, the IC2013,* test between *many labs* with the nucleus labs as core sites: 2012 – 2014

IC 2013 Comparison Testing



IC 2013 Test Method

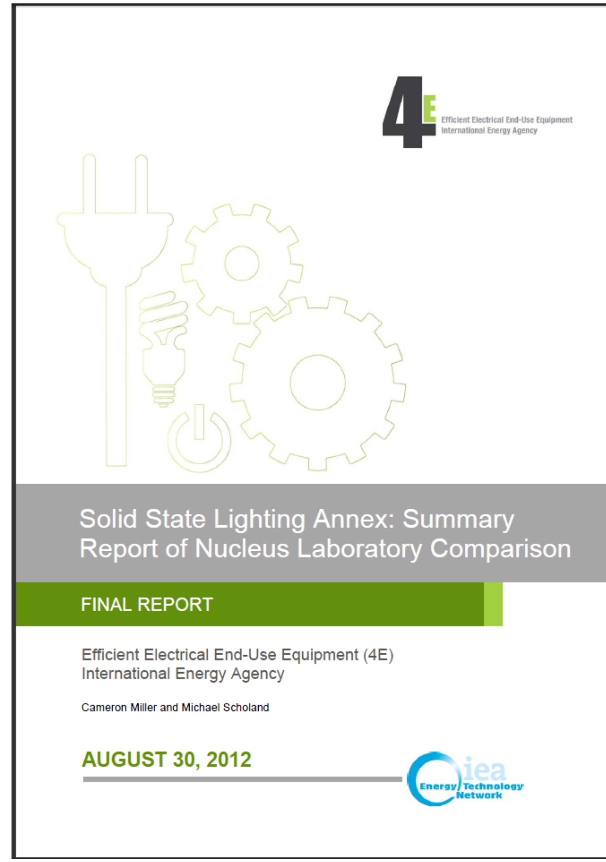
- The Annex developed a test method for the 2013 Interlaboratory Comparison
- *Photometric, colorimetric and electrical properties*
- Incorporates **strictest requirements** from Chinese, Japanese, US and International LED test standards (draft and current)
- Published October 2012



http://ssl.iea-4e.org/files/otherfiles/0000/0051/SSL_Annex_2013_IC_Test_Method_v.1.0.pdf

Test Nucleus Laboratories

- The comparison / calibration of four ‘nucleus’ laboratories
  - National Institute of Standards and Technology (NIST, USA),
  - National Lighting Test Centre (NLTC, China)
  - Dutch Metrology Institute (VSL, The Netherlands)
  - National Institute of Advanced Industrial Science and Technology, National Metrology Institute of Japan (AIST, NMIJ, Japan).
- Report published August 30, 2012


Efficient Electrical End-Use Equipment
International Energy Agency

Solid State Lighting Annex: Summary Report of Nucleus Laboratory Comparison

FINAL REPORT

Efficient Electrical End-Use Equipment (4E)
International Energy Agency

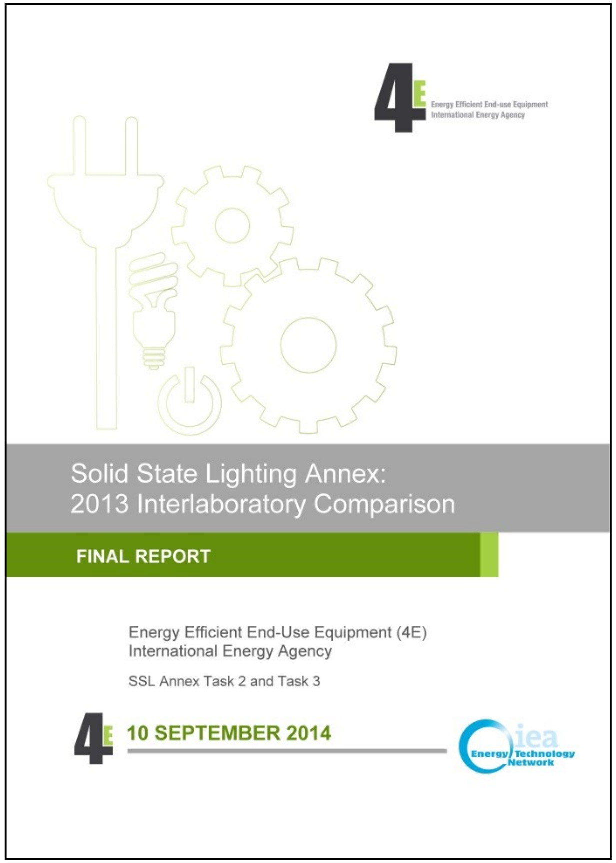
Cameron Miller and Michael Scholand

AUGUST 30, 2012

http://ssl.iea-4e.org/files/otherfiles/0000/0057/4E_SSL_Annex_Nucleus_Laboratory_Comparison_Report_final.pdf

2013 Interlaboratory Comparison Final Report

- Title: 2013 Interlaboratory Comparison Final Report
- Authors: Yoshi Ohno (Task 2 leader and primary author); Koichi Nara, Task 3 Leader; Elena Revtova, VSL; Wei Zhang, NLTC; Tatsuya Zama, AIST, NMIJ; Cameron Miller, NIST
- Published: 10 September 2014
- *Purpose: Present the final results of the 2013 IC, conducted between October 2012 and August 2013. With all the linked laboratory programmes, a total of 123 laboratory results are compared.*
- http://ssl.iea-4e.org/task-2-ssl-testing/2013-ic-final-report



2013 IC Participation and Measurement Quantities

- 123 data sets from 110 laboratories in the comparison, 54 direct participant labs and 56 other labs linked through other comparison schemes: NIST NVLAP/MAP and CNAS/APLAC

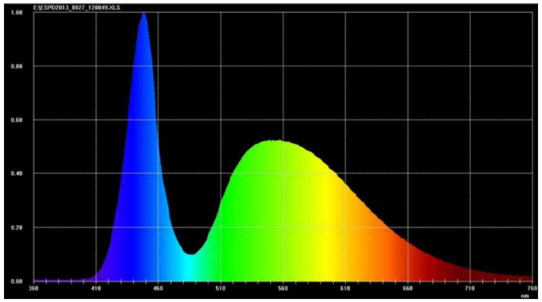
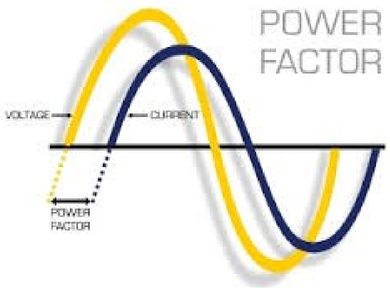
- The following measurement quantities were measured and compared:

1) Total luminous flux (lm)
2) RMS Voltage (V) and Current (A)
3) Electrical active power (W)
4) Luminous efficacy (lm/W)
5) Chromaticity coordinates x, y
6) Correlated Colour Temperature (K)
7) Colour Rendering Index (CRI) Ra
8) Power factor (optional)

IC 2013 Protocol
Artefact Set

- Five lamps selected by each Nucleus Lab based on needs in the region.
  - Incandescent lamp (AC operation)
  - Omnidirectional LED lamp
  - Directional LED lamp
  - High CCT LED lamp or luminaire (>5000 K)
  - Low power factor LED lamp (PF <0.6)
- Each Nucleus Lab could use optional artefacts
  - Incandescent-DC
  - Tubular type LED lamp
  - Remote-phosphor type LED lamp



Performance Evaluation

- An “assigned value” is a value attributed to a particular property of a proficiency test item.

- In IC 2013, assigned values were given by the Nucleus Laboratories, and were calculated as the *mean* of the measurements taken by the Nucleus Laboratory taken for each quantity before sending and after return of artefacts from each participating laboratory.

- Results presented as
  - *Relative differences between participant and nucleus lab for photometric and electrical properties*
  - *Absolute difference between participant and nucleus lab for colorimetric properties*

- The criteria used to analyse and evaluate participant performance are:
  - E_n *number (defined in ISO 13528 and ISO/IEC 17043).*
  - *z’ score (defined in ISO 13528)*

Performance Evaluation
Difference between En and z´

- The concept of the *E_n number* is to test whether the *claimed uncertainty* of a laboratory for a measurement quantity is valid or not, and is suitable for *calibration accreditation*, where the laboratory's uncertainty is certified.

- The *z' scores*, on the other hand, is to test whether the laboratory's results are within an *acceptable range from the reference value*, and is considered suitable for the purpose of *testing accreditation*, as the labs are accredited for compliance to a referenced test method.

- However, the purpose of *a test method is to limit the overall uncertainty of measurement,* not for the labs to report accurate uncertainties whatever they are.

- Both z' and E_n numbers were used in this IC test as requested by some of Nucleus laboratories, but the use of *z' scores, for the reasons above, is recommended for testing accreditations*.

Performance Evaluation: E_n Number

$$E_{\mathrm{n}} = \frac{x - X}{\sqrt{U_{\mathrm{lab}}^2 + U_{\mathrm{ref}}^2}}$$

Where:

- x is the value measured by the participant
- X is the assigned value (average of reference laboratory measurements, before and after)
- U_{lab} is the expanded uncertainty (k=2) of a participant's result
- U_{ref} is the expanded uncertainty (k=2) of the assigned value, calculated by:

$$u_{\mathrm{ref}} = \sqrt{\left(\frac{u_1 + u_2}{2}\right)^2 + \left(\frac{X_1 - X_2}{2\sqrt{3}}\right)^2} \quad \textbf{and} \quad U_{\mathrm{ref}} = 2\, u_{\mathrm{ref}}$$

  - where X_1 and X_2 are measured values by the reference lab, before and after the participant's measurement, and u_1 and u_2 are standard uncertainties of the two measurements.

Performance Evaluation: z' Score

$$z' = \frac{x - X}{\sqrt{\hat{\sigma}^2 + u_X^2 + u_{\text{drift}}^2}}$$

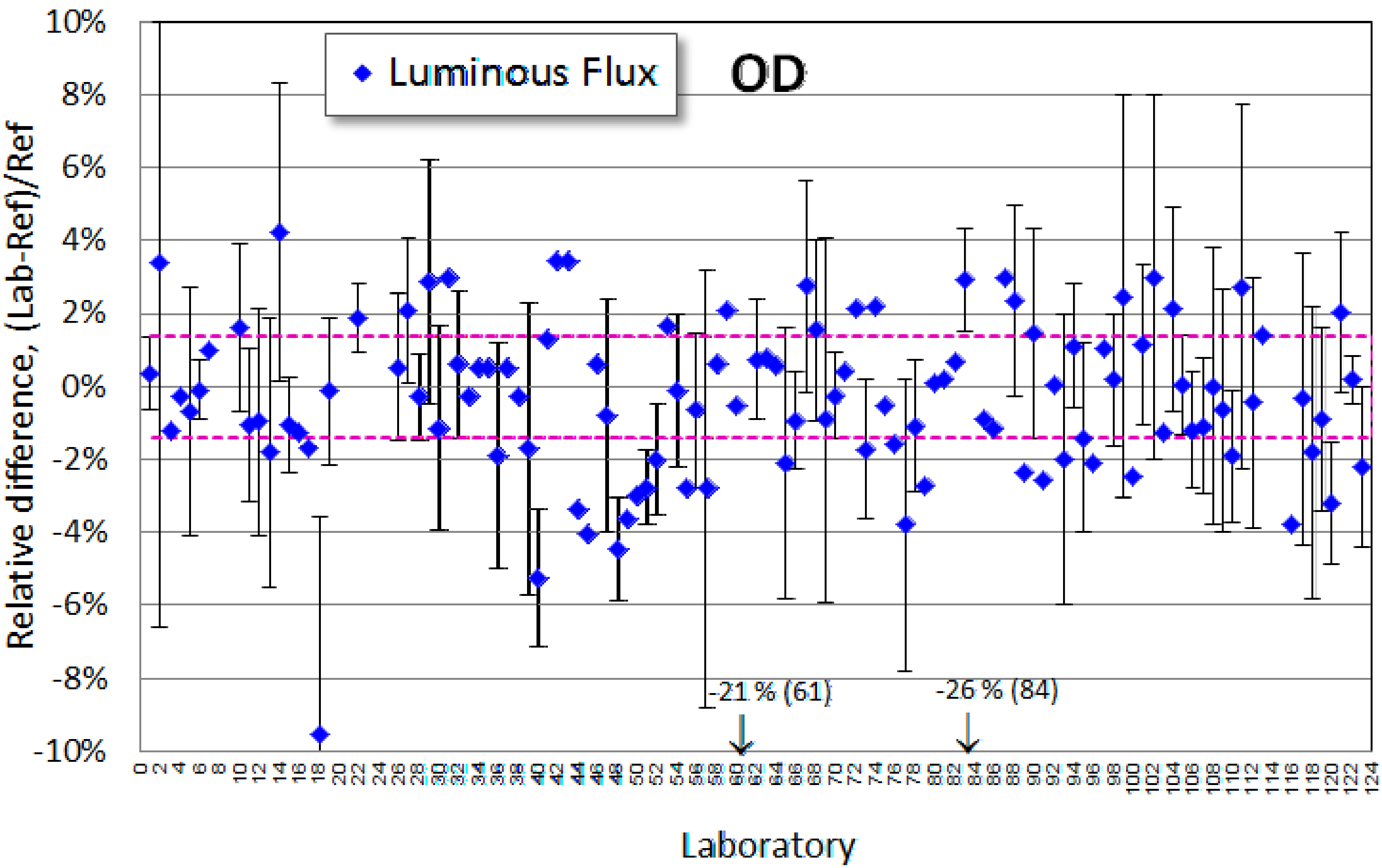
Where:

- $\hat{\sigma}$ is the SDPA value (Standard Deviation for Proficiency Assessment) and, in this IC test, is the generic standard uncertainty of a participant's measurement;
- u_x is the standard uncertainty of the reference value (average of uncertainties of measurement of the comparison artefacts by four Nucleus laboratories reported in the Nucleus Laboratory Comparison Report)
- u_{drift} is the uncertainty from the expected artefact drifts (controlled to within 0.8 x SDPA) calculated by:

$$u_{\text{drift}} = \frac{0.8 \cdot \hat{\sigma}}{2\sqrt{3}}$$

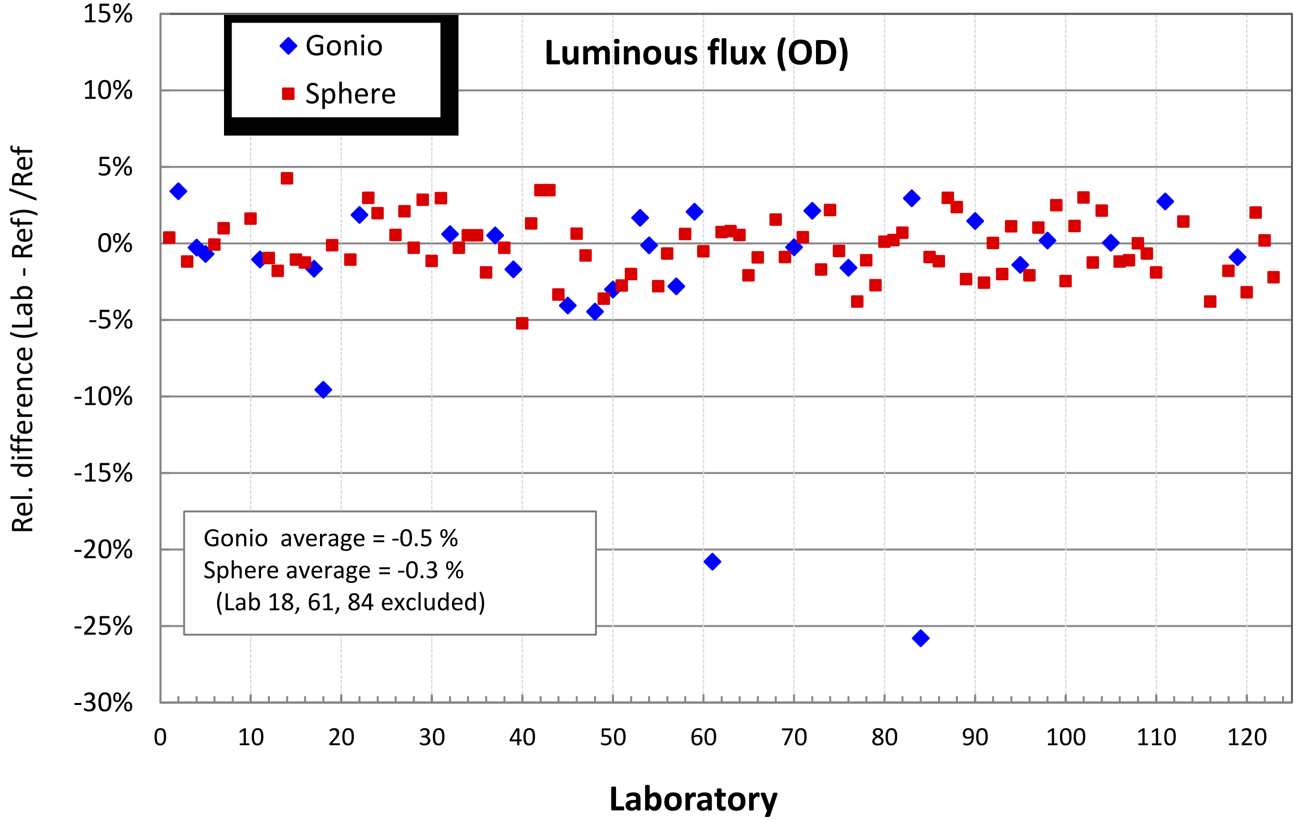
Sample of Final Report Results: Luminous flux, Omni-directional LED

Luminous flux – Omni-directional LED lamp. Most results are within ± 4 %, apart from some extreme *outliers*.

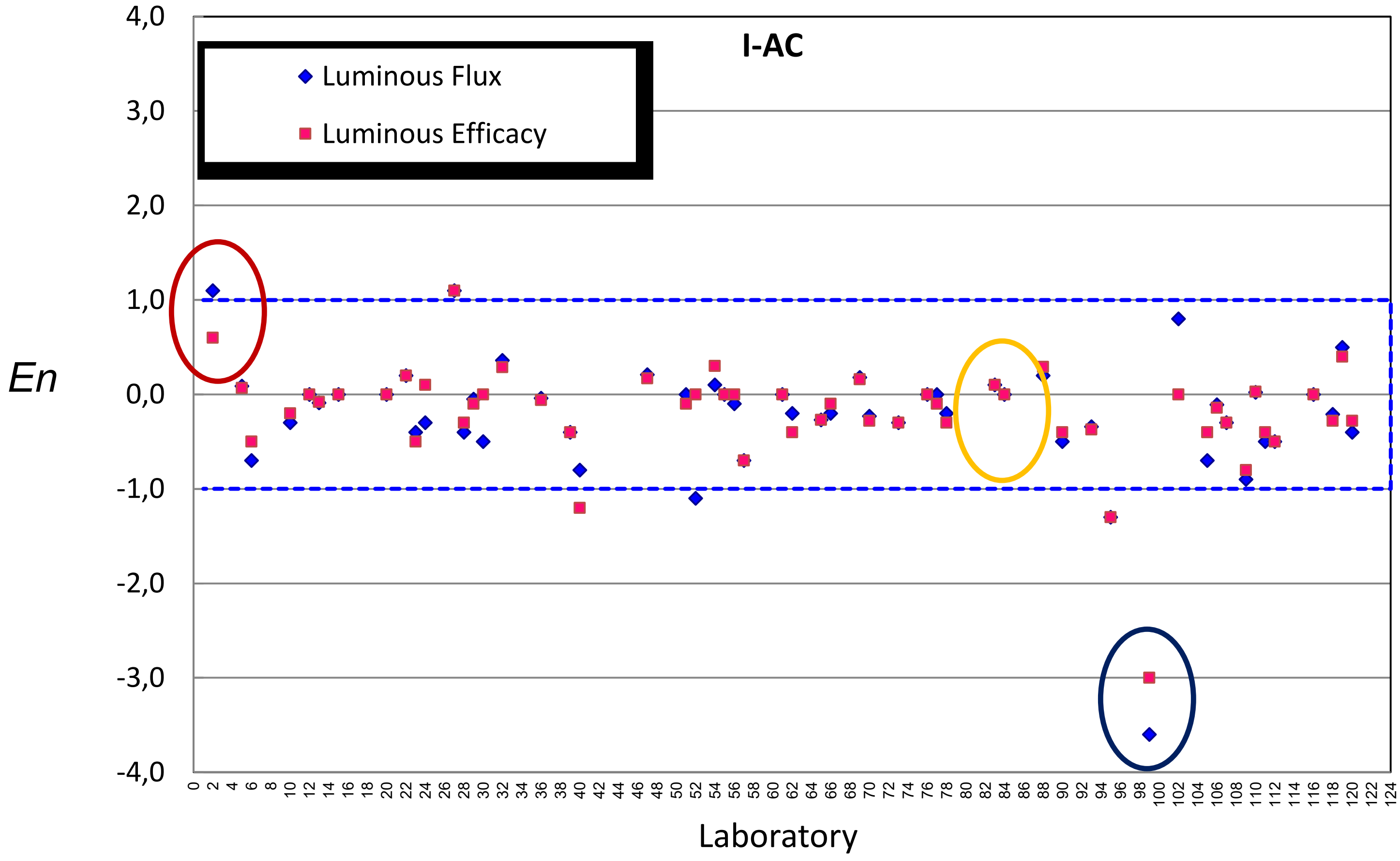


Sample of Final Report Results: Comparing Sphere and Gonio

Luminous flux – Omni-directional LED lamp. No systematic differences between the two instrument types, but all the outliers were goniophotometers

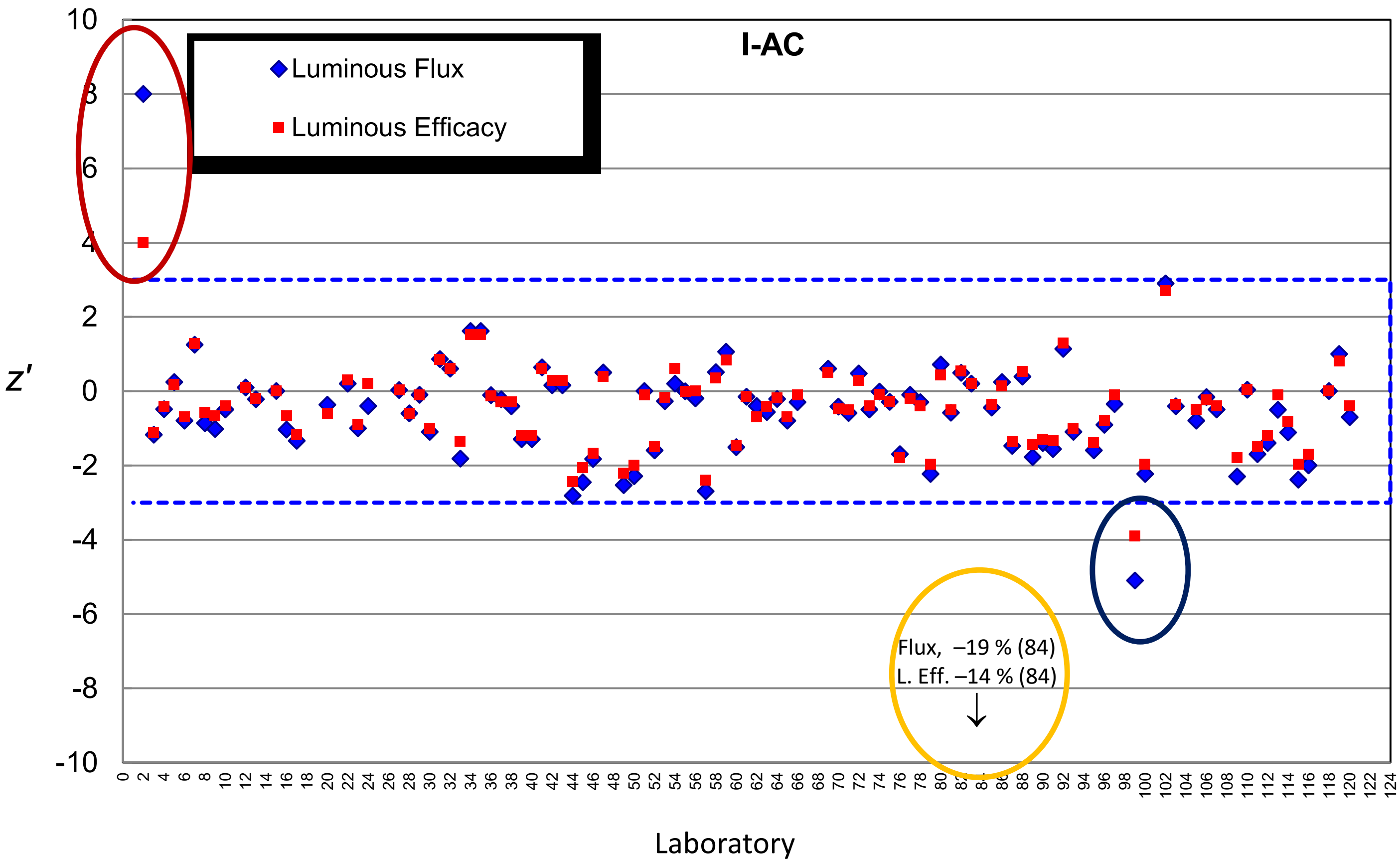


Sample of Final Report Results:
E_n for Incandescent , flux & efficacy



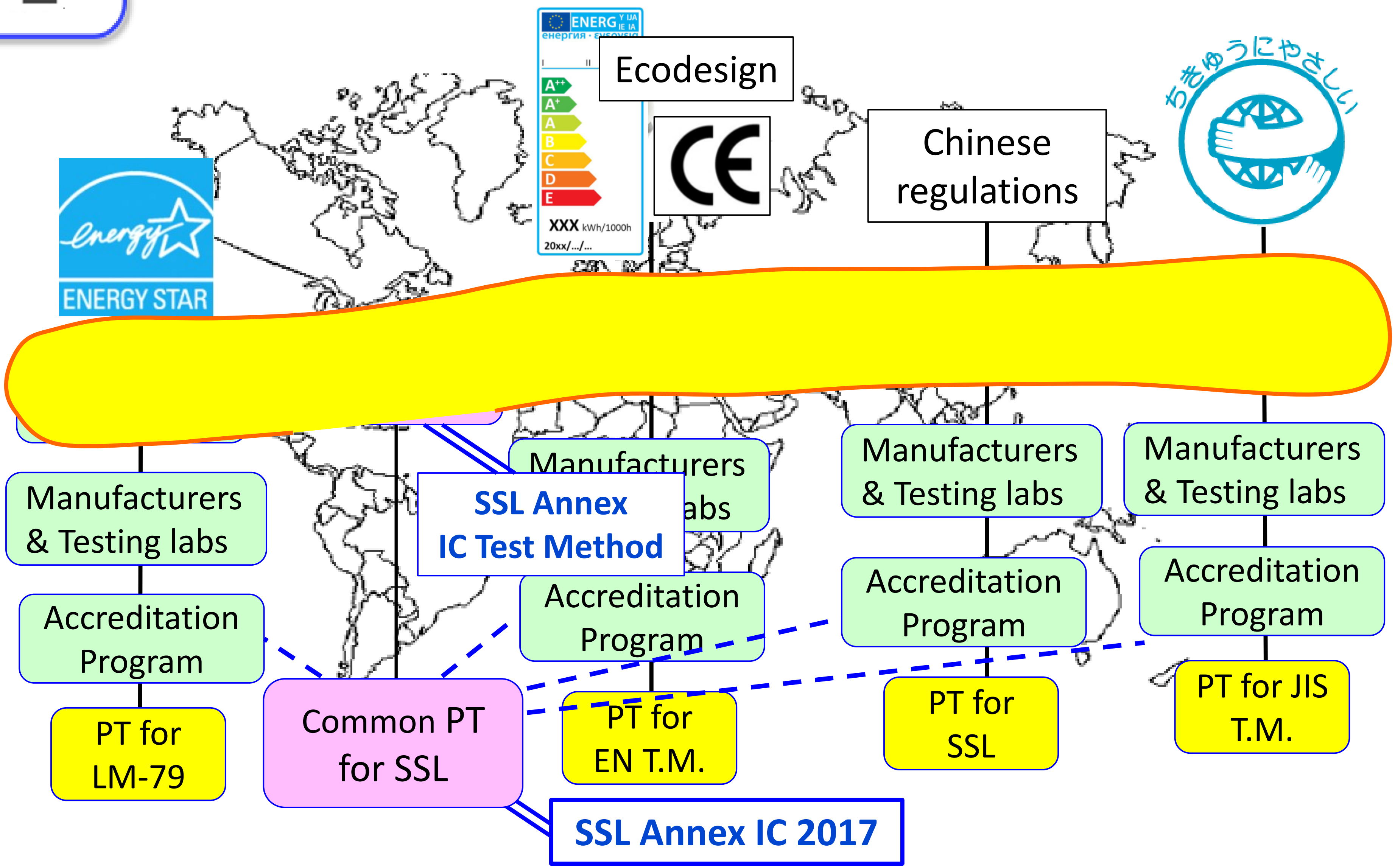
Luminous flux and and efficacy

Sample of Final Report Results:
z´ for Incandescent , flux & efficacy

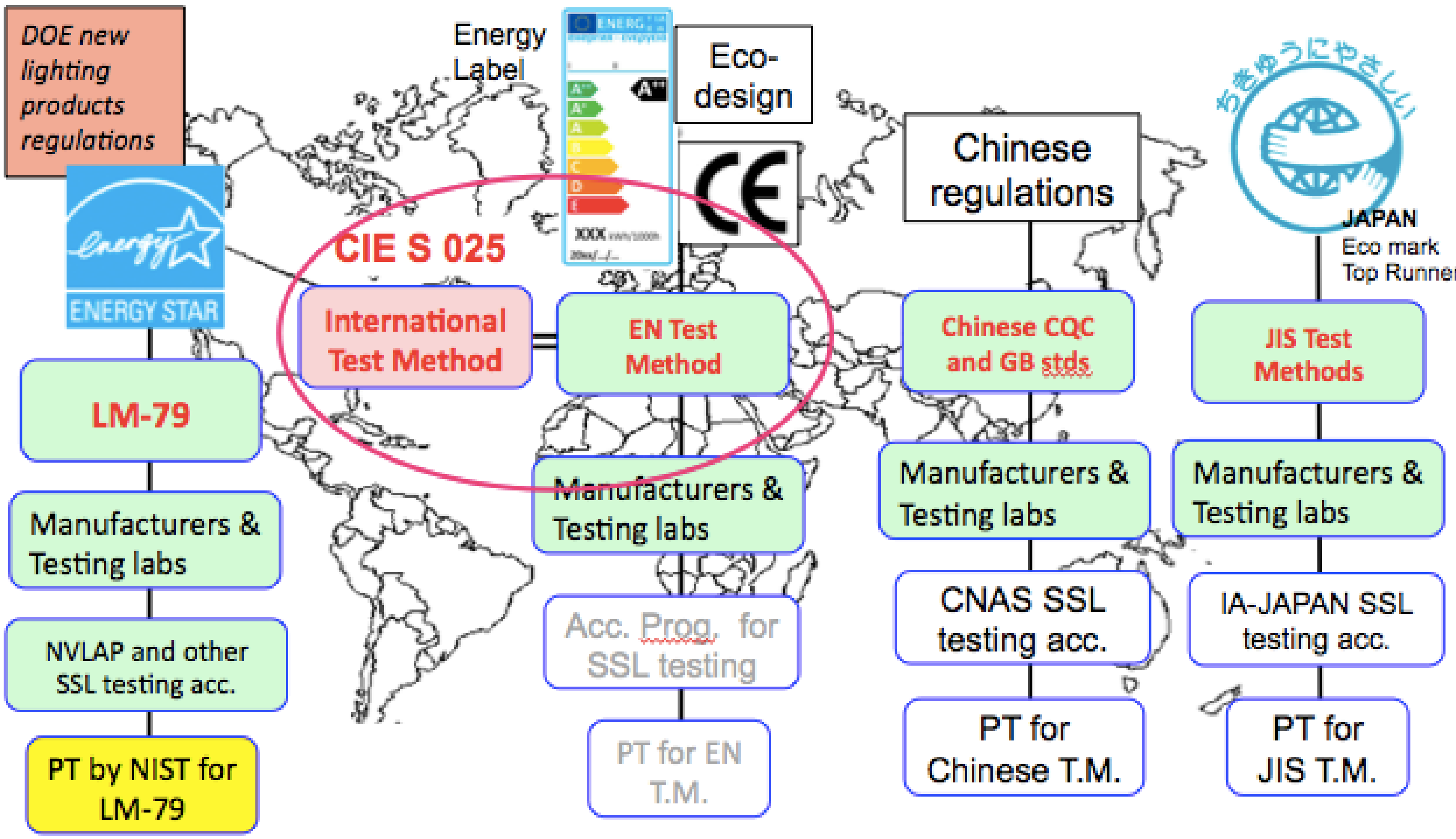


Luminous flux and and efficacy

Short-Term Solution
Common PT (SSL Annex IC 2013) using IC Test Method



… which became the foundation for the CIE S 025 test method, now recognized in US and EU



CIE S 025 – Scope

	Products	Measurement Quantities
Covered	• LED lamps (integrated, non-integrated) • LED luminaires • LED modules (including light engines) • AC/DC power inputs	• electrical quantities (AC/DC current, voltage, power, power factor) • luminous flux; efficacy • luminous intensity distribution • center beam intensity • luminance • colour (chromaticity, CCT, CRI) • angular color uniformity • and more….
Not Covered	• LED packages • OLED products	• long-term maintenance test (life test) of luminous flux, etc. • beam angle • waveform (flicker) • start-up time

2nd Interlaboratory Comparison on SSL products Testing

Objectives

- Focus on parameters and artefacts not covered in IC 2013
- Provide demonstration data for near-field goniophotometers (for accreditation)
- Provide data for level of agreements in measurements of gonio quantities – useful for future PT for LED luminaires
- Serves as **limited PT** for SSL testing accreditation
- **Participants:** open to non-member countries as well as member countries. (member countries will have priority)
- **Fee:** Member countries will have reduced fee, whereas others will pay full fee (400 Euro or so)
- Named **IC 2017**

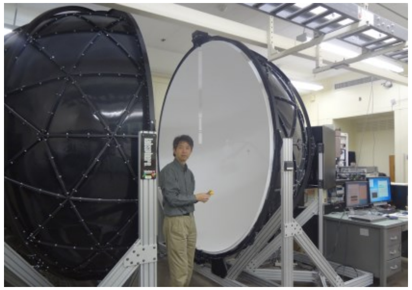
Measurement quantities in IC 2013

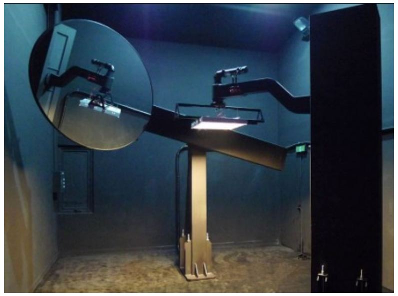
Measurement quantities

- luminous flux (lm)
- luminous efficacy (lm/W)
- active power (W)
- RMS current (A)
- power factor
- chromaticity coordinates x, y
- CCT (K)
- CRI

Instruments used

- Integrating spheres
- Goniophotometers
  (gonio-spectroradiometer)

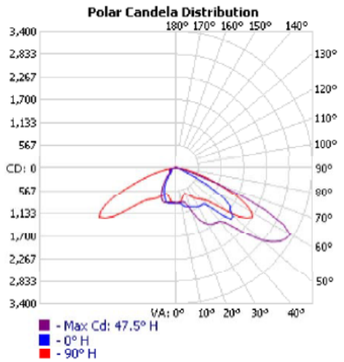


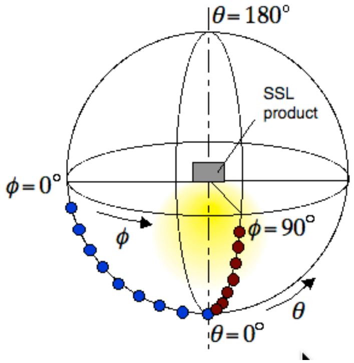


Not covered in IC 2013 – but can be covered in IC 2017

Measurement quantities:

- Luminous intensity distribution
- Center beam intensity
- Beam angle (specified planes)
- Spatial color uniformity Δu'v'
- Partial (useful) luminous flux
- Uplight, back light, forward light for road lighting luminaires (IES LM-31, TM-15)

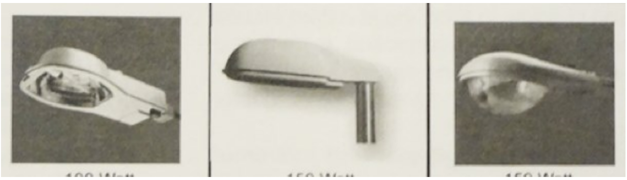




Artefacts:

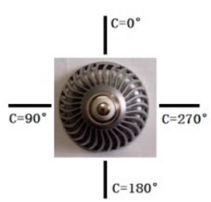
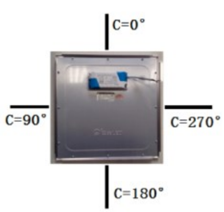
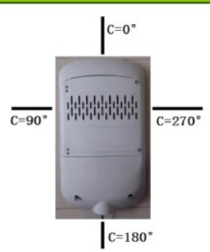
– Large luminaires

- road/street lighting luminaires
- panel type (troffer)
- and more.

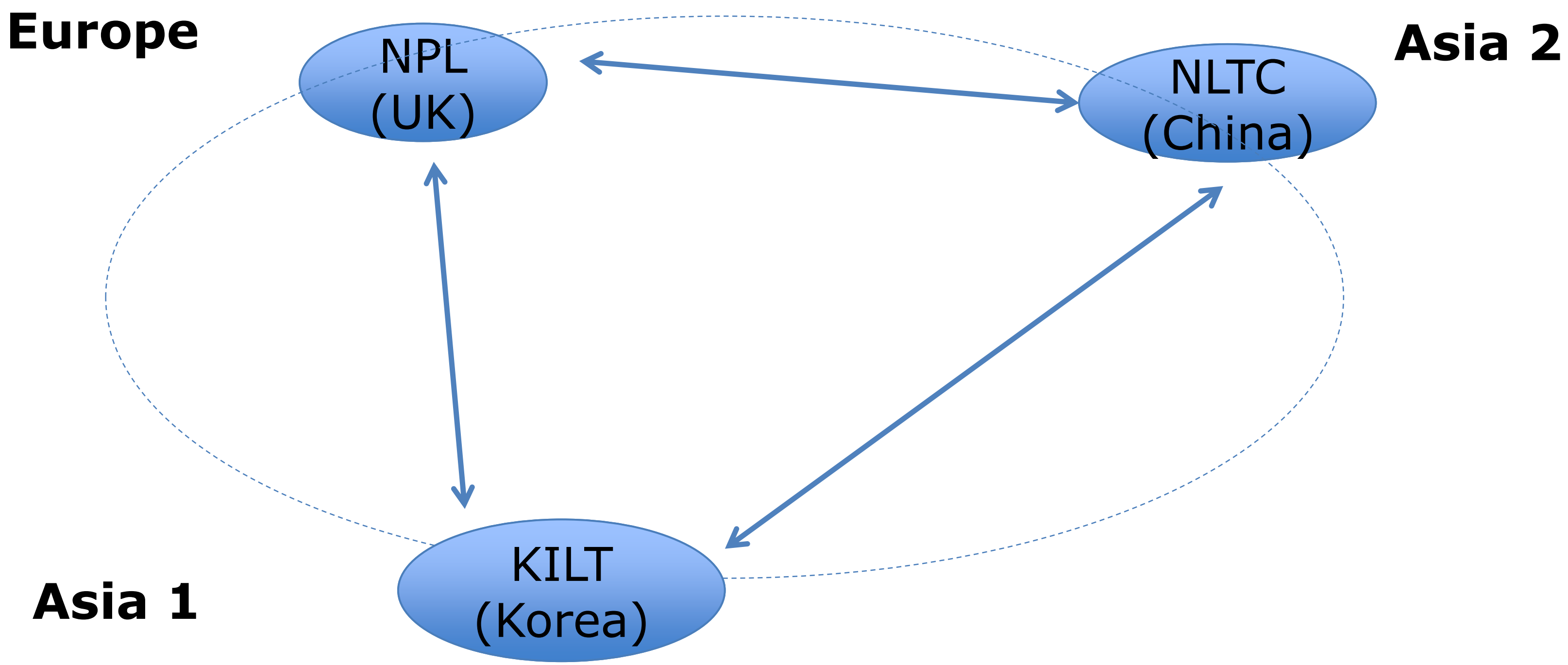


Comparison artifacts

Identifier	Lamp Type	Rated Voltage	Rated Power	Rated Total luminous flux	Rated CCT	Dimension
ANNEX-D	Directional LED lamp	220 V AC	7W	600lm	5000 K	10 cm *(in diameter)*
ANNEX-P	LED Panel lighting	220 V AC	12W	800lm	5700 K	30 cm * 30 cm *(square shape)*
ANNEX-S	LED Street lighting	220 V AC	40W	4200lm	4000 K	(20 cm + 40 cm) * 33 cm *(rectangle shape)*

Artefact idenfifier	Annex-D	Annex-P	Annex-S
Picture			

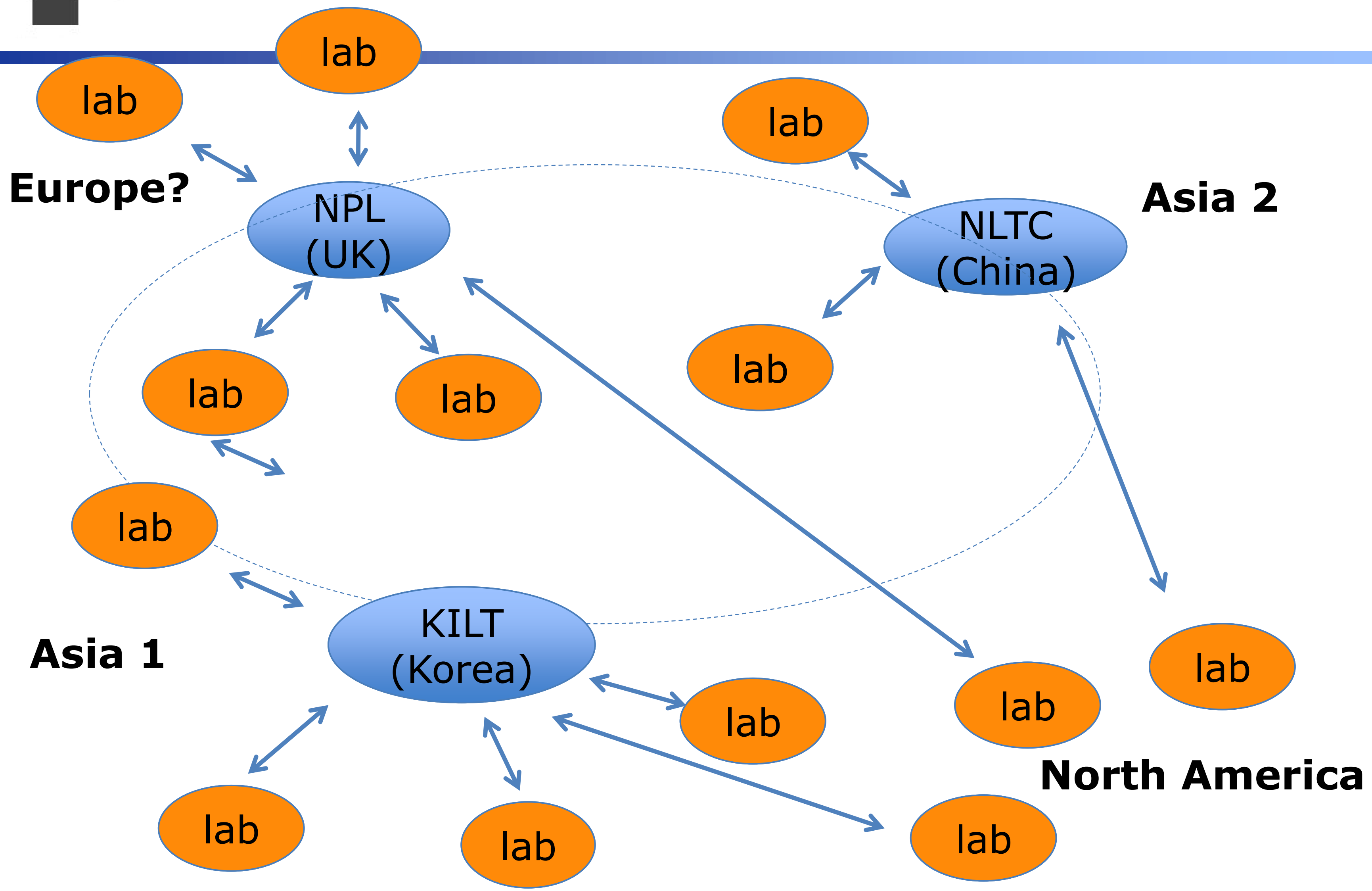
IC 2017: Nucleus Laboratories: Interlaboratory Comparison Testing



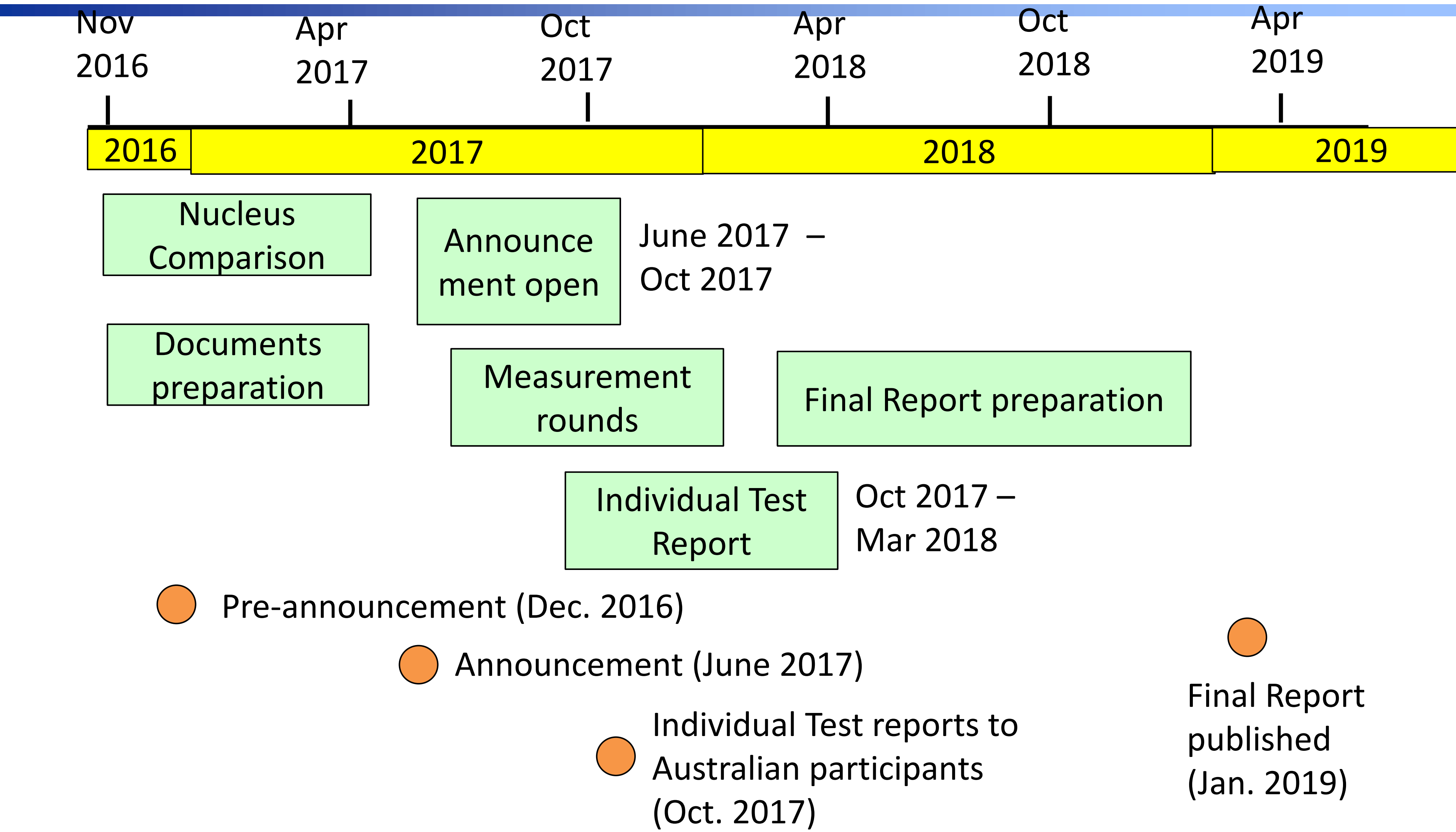
Purpose:

- To determine tolerances through average values
- Make sure all Nucleus lab are close to each other

IC 2017 Interlaboratory Comparison
star-type of comparison



Time Table


Nov 2016
Apr 2017
Oct 2017
Apr 2018
Oct 2018
Apr 2019
2016
2017
2018
2019
Nucleus Comparison
Documents preparation
Announce ment open
June 2017 – Oct 2017
Measurement rounds
Final Report preparation
Individual Test Report
Oct 2017 – Mar 2018
Pre-announcement (Dec. 2016)
Announcement (June 2017)
Individual Test reports to Australian participants (Oct. 2017)
Final Report published (Jan. 2019)

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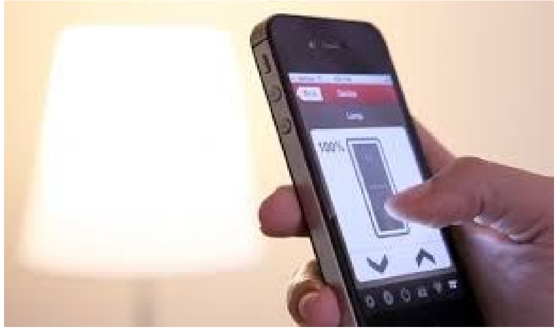
Smart lamps: New Features impact the energy use – *more than just stand-by*!

Energy-related impact of some new features including:

1. User welfare
   - Wireless control (on/off, dimming, colour)
   - Colour tunability
2. Product functions
   - Prolonging life
   - Active thermal control
   - Maintain flux by driver current regulation
3. Environment and economy
   - Energy savings by sensors and others



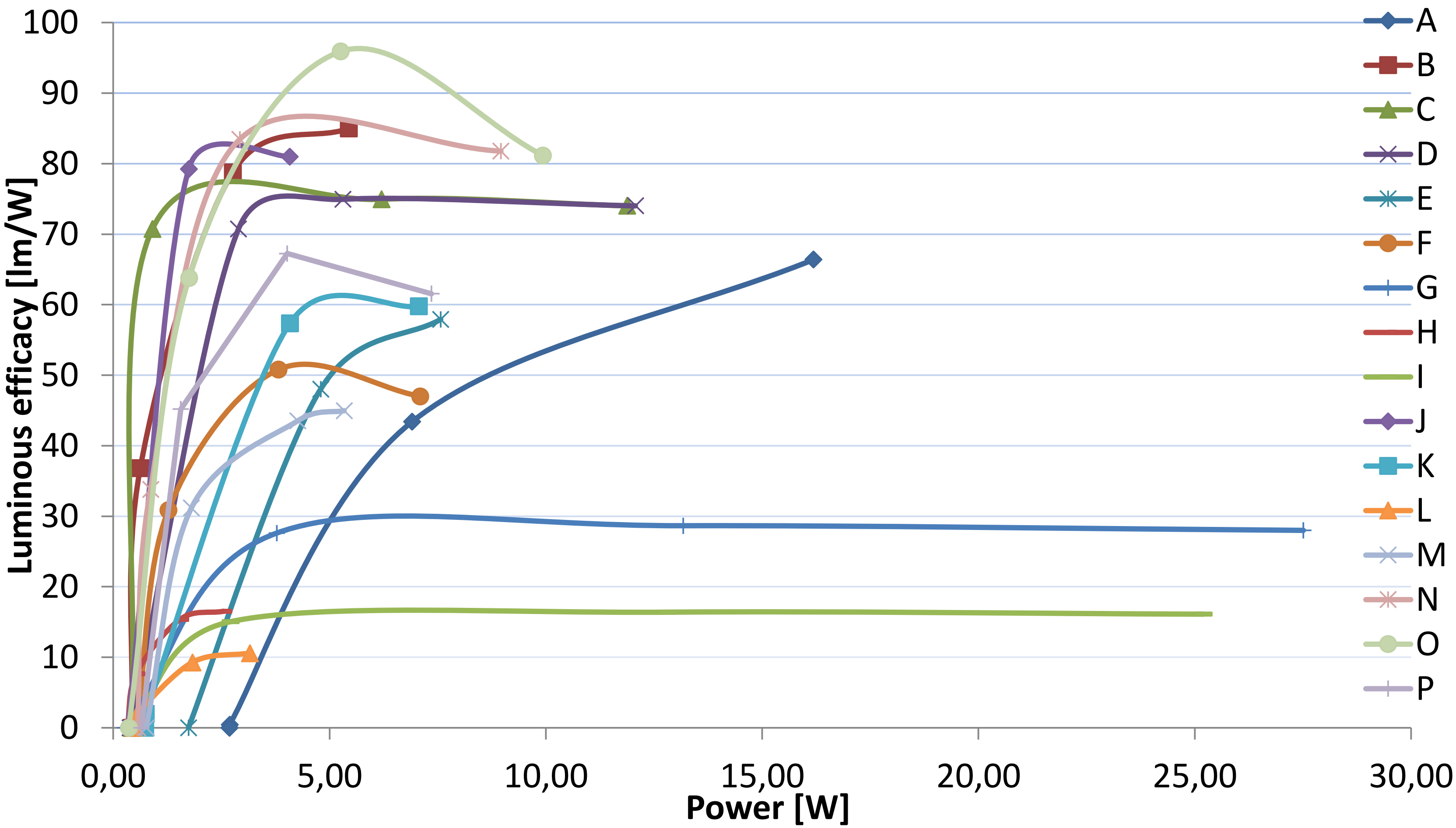
Measurements

Products tested with integrating spheres and a near-field gonio: E27 lamps and LED-strips

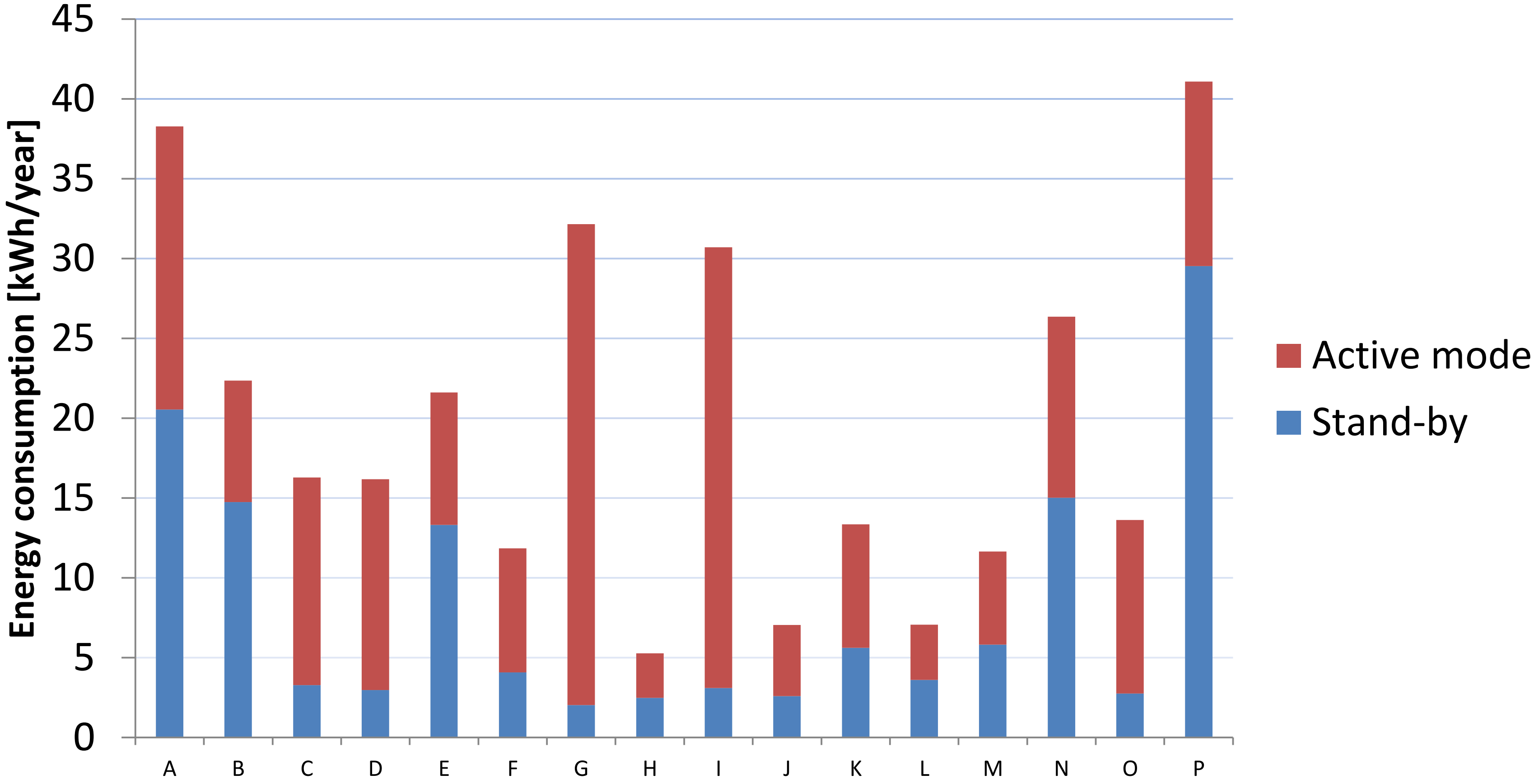
Colorometric and luminous efficacy measurements:

- White light:
  - 100 %
  - 50 %
  - Lowest possible dimmed setting with light
  - Standby
- Blue, green and red light:
  - 100 %
  - Lowest possible dimmed setting with light

Luminous efficacy

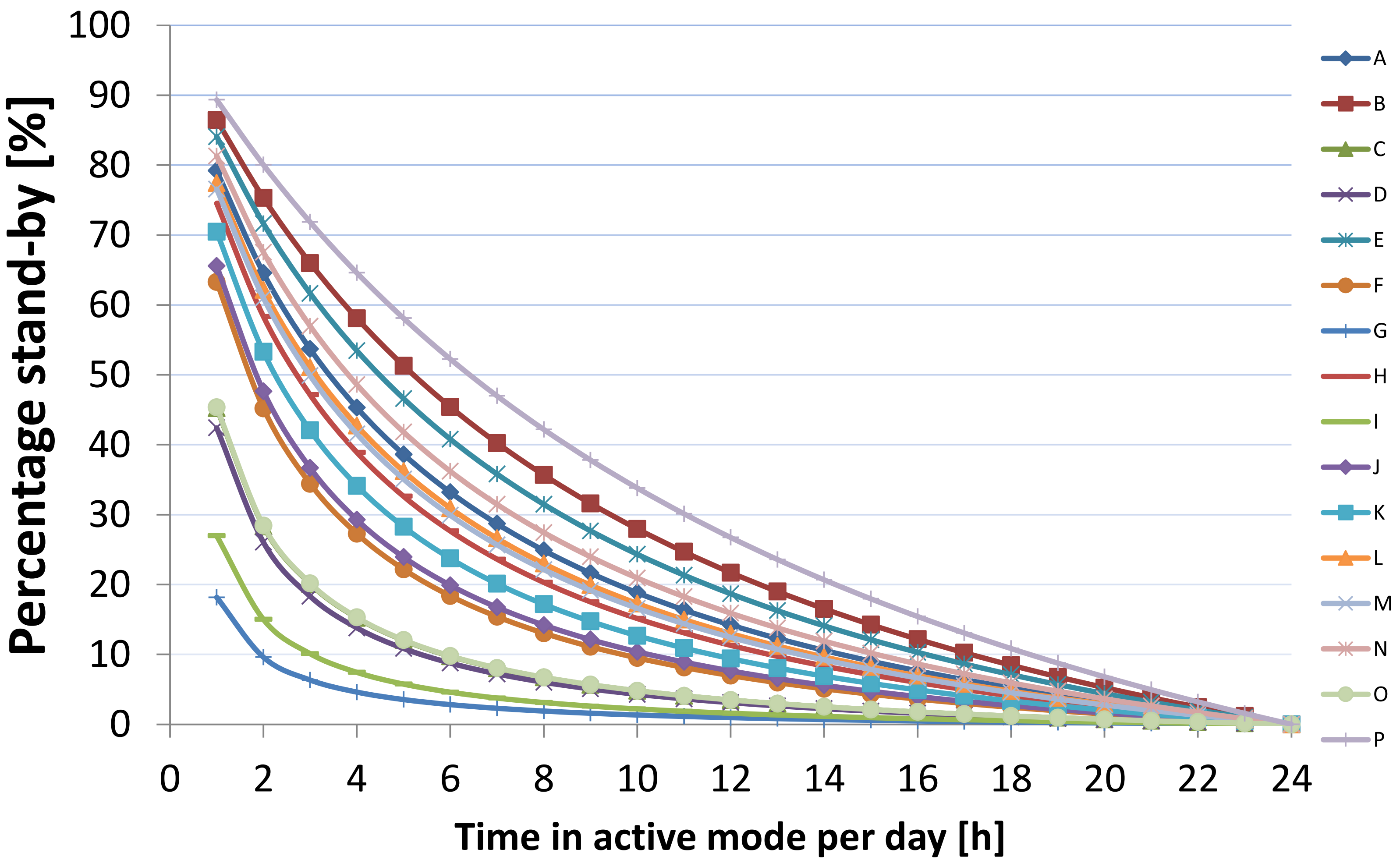


Calculated energy use per lamp and year: assuming 3 h active mode and 21 h standby mode per day

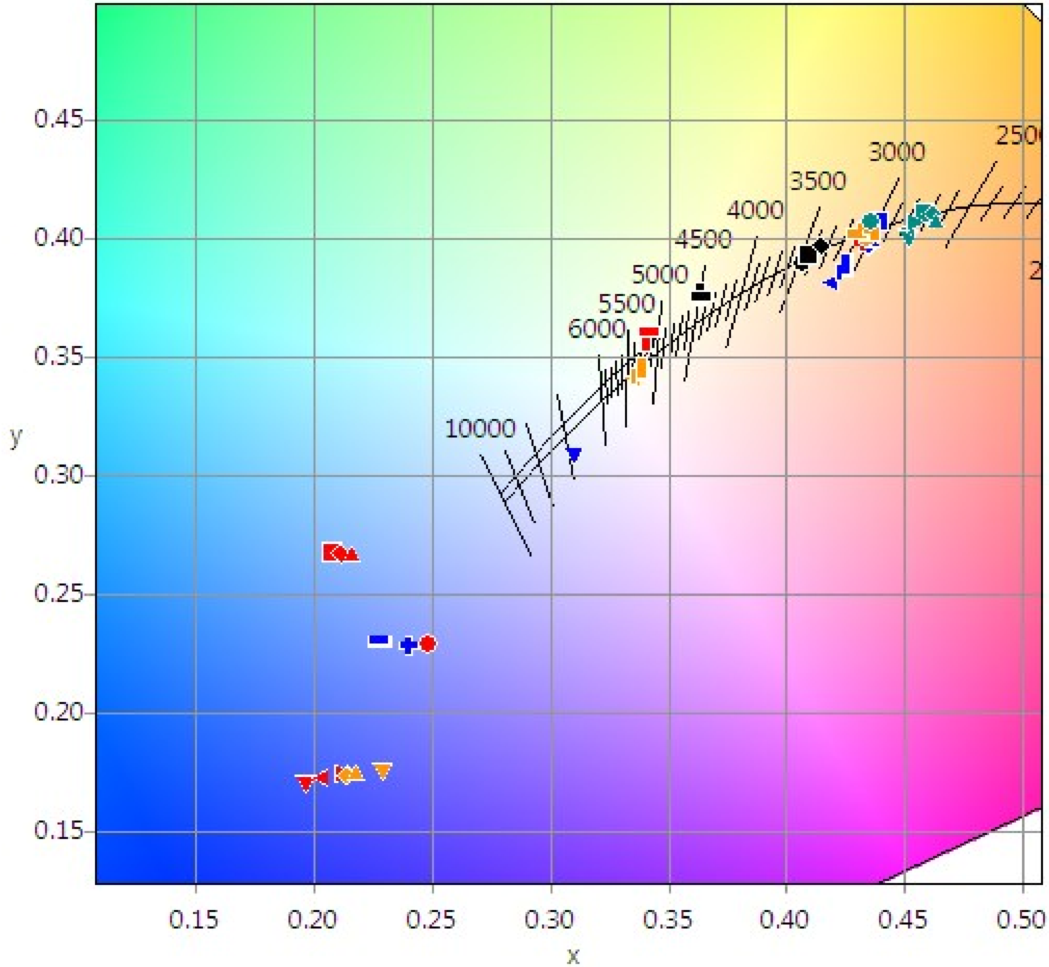


Gateway consumption included; for B, N and P

Relative standby for one lamp, assuming different active/standby ratios



Colour coordinates for different dimmings of the white setting



Stand-by of "smart lamps" can be larger than their energy use for lighting

By SSL Annex · Solid State Lighting · September 6th, 2016

"Smart" lamps combine technology breakthroughs in wireless communications with light emitting diodes (LEDs) to provide many exciting consumer benefits. However, the standby energy use of "smart lamps" can be larger than the energy used for providing lighting, according to a new report from the IEA 4E Solid State Lighting Annex.

Smart lamps are an exciting new family of products which provide an opportunity for the consumer to benefit from smart services, better product quality and energy savings. Combining wireless communication, intelligent controls and light emitting diodes (LEDs), these lamps offer end-users features like colour tuning, dimming, changing lighting scenes, remote control, motion sensing control, daylight control and other features. But these features require energy even when the lamps are not providing light, but are instead waiting for a wireless instruction from a smartphone or remote control unit. A new SSL Annex report (*click box to the right to download a PDF*) explores this topic of smart lighting and new features that impact energy consumption.

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SMART LAMPS STANDBY

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TASK 7: SMART LIGHTING – IMPACTING ENERGY CONSU

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Thank you!

More information on today´s topic and LCA, Health effects, Lifetime issues, market surveillance etc can be found in reports and as ongoing work on

http://ssl.iea-4e.org/

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