Lamp Efficacy, Lumen Maintenance, Lamp Life and Measurement Uncertainties

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Abstract

- The success of any energy efficient lighting strategy relies on providing evidence of a net benefit to the consumer.
- For countries with minimum energy performance standards for lamps, specific evidence is required for decisions.
- Analysing the cost benefit equation for lamp technologies requires representative data for critical parameters.
- This presentation describes:
  - Lamp energy performance parameters
  - Their influence on cost benefit calculations
  - Relevant laboratory procedures and testing standards

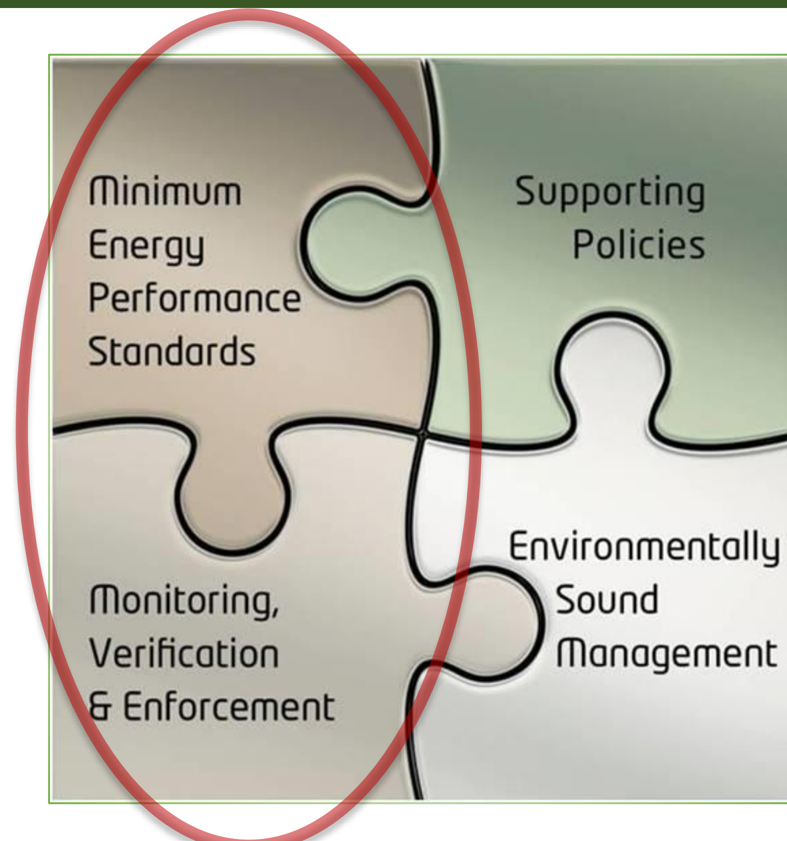
Topics

1. Importance for Regulations
2. Definitions
3. Photometric Laboratory Tests and Uncertainties
4. Resources

1. Importance to Regulations

Monitoring, verification and enforcement schemes support the success of minimum energy performance standards.

Governments need to estimate and verify the impact of minimum energy performance standards.



Cost Benefit Analysis

- The basis for the minimum energy performance standards in an energy efficient lighting strategy requires evidence of a net benefit to the purchaser/consumer.
- Net benefits can be of several types (and indicators):
  - Economic (affordability)
  - Health (UV, flicker, blue light, mercury, respiratory)
  - Social (light quality, personal and public safety)
  - Environmental (CO_2, mercury)

- Today's webinar focuses on the economic benefits to the purchaser or consumer.

Economic Cost Benefit Analysis

- Analysing the costs and benefits for various lamp technologies requires representative lamp data for certain critical parameters, including:
  - The energy used by the lamp (watts)
  - The ability of the lamp to produce the amount of light required for the intended service and length of service (lumens; hours)
  - How often the lamp needs to be replaced (number of lamps during required duration of service)
  - The market price of the lamp (local currency)

2. Definitions

2.1 Lamp efficacy

Lamps discussed in this webinar are limited to single-ended, omnidirectional lamps for general service illumination for indoor applications.

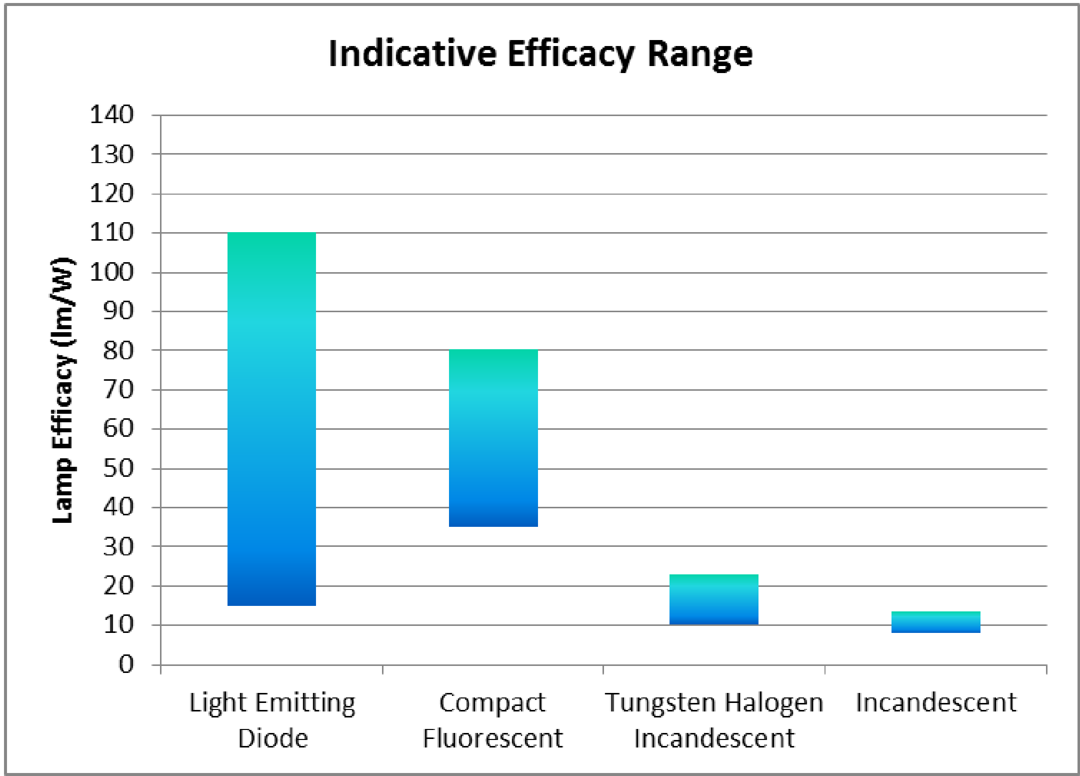
Luminous Efficacy

- An energy efficient lamp is efficient at converting electrical energy into light that is visible to humans.
- The lamp can be of any wattage.
- The term *(luminous) efficacy* defines this parameter.
- The "input" is electricity, measured in watts (W).
- The "output" is visible light, measured and calculated as lumens (lm).
- To determine a lamp's efficacy, the amount of visible light produced (*luminous flux*) and the amount of electrical power required to create this light, must be measured.

Light Sources and Luminous Flux

- Typically a lamp's efficacy is calculated based on the total luminous flux ("output") from a lamp and the electrical power consumed.
- Different lamp technologies ("light sources") have different ranges of efficacies.
- Efficacy is also influenced by the integral ballasts or drivers of lamps.

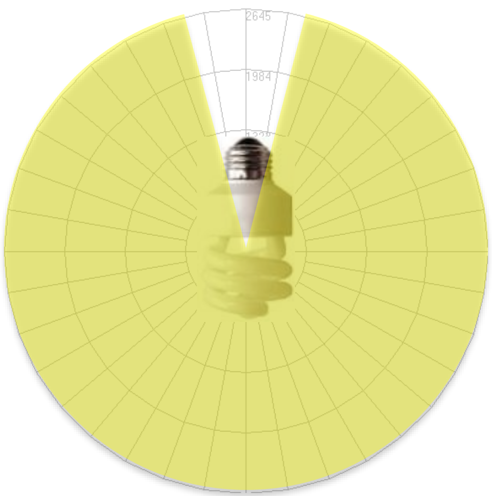
$$Efficacy = \frac{Total\ luminous\ flux}{Power\ consumed} \left(\frac{lm}{W}\right)$$



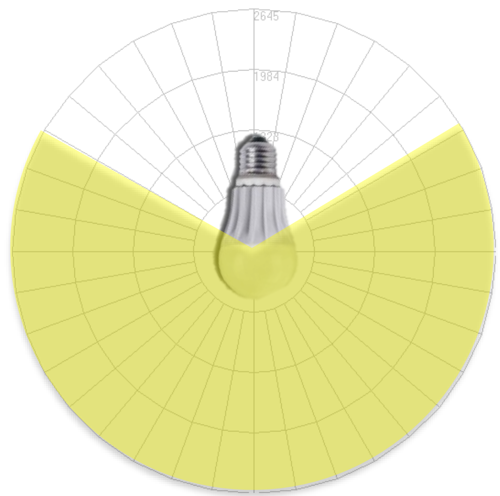
- But there are a number of specific refinements to the definition of efficacy which are called upon for a better appreciation of how efficient a lamp is for their designed service intent.
- In particular situations some of the light output from a lamp may not be useful in providing light for a particular service (excessive distribution). In these situations the *luminous flux* to be measured is geometrically restricted to a "*partial luminous flux*". (defined in CIE DIS 025 – 2014)
- The opposite situation can also occur where a lamp may not provide an adequate distribution of light.

Geometry of Lumens: Lamp distributions

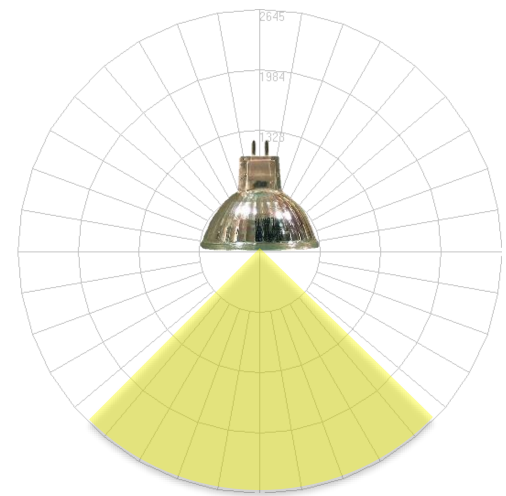
Omnidirectional lamp



Non - directional lamp



Directional lamp



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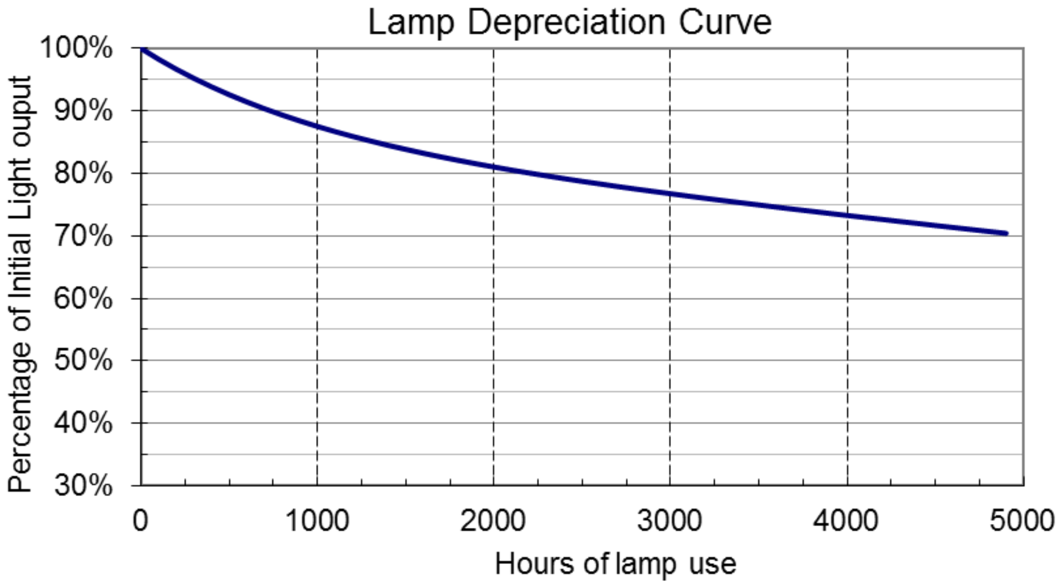
2. Definitions

2.2 Lumen maintenance

Lumen Maintenance

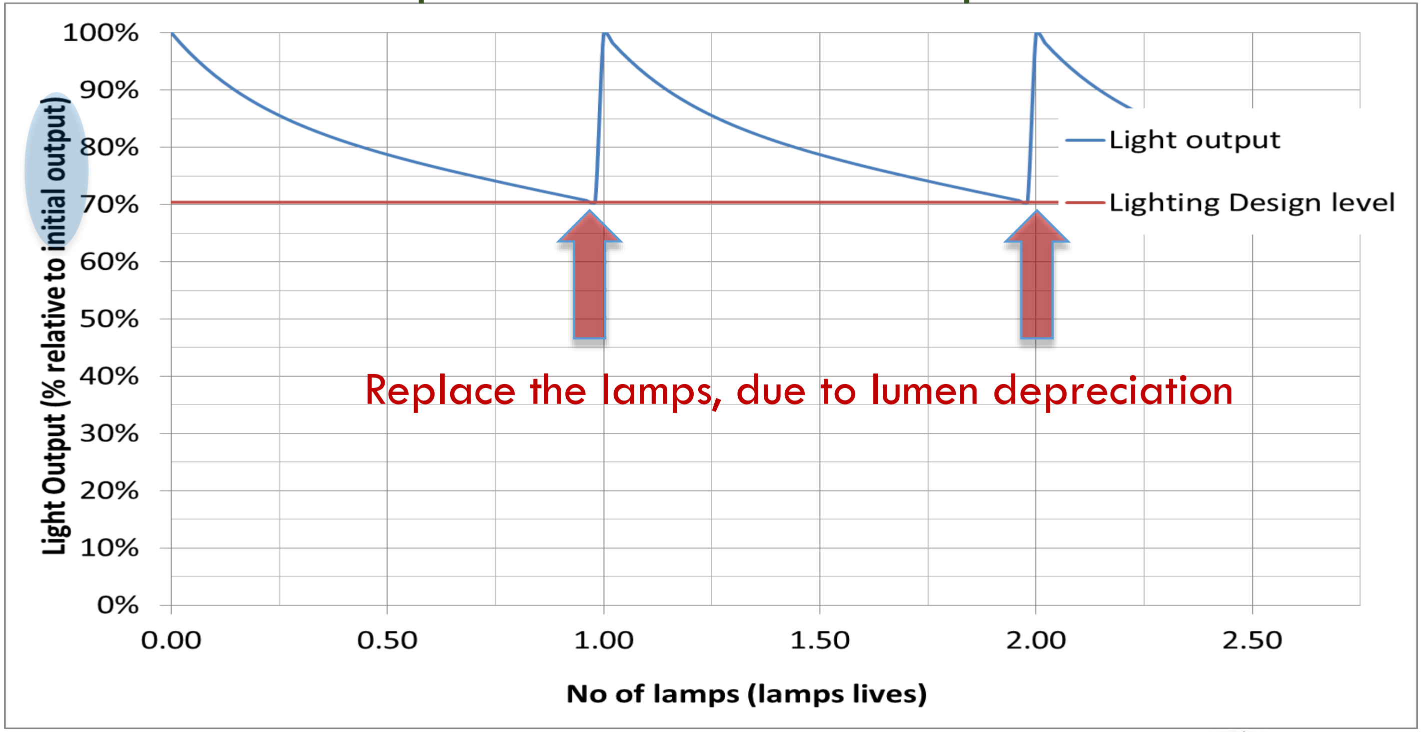
- As a lamp ages, for various reasons, it produces less light, but continues to consume a similar amount of power.
- This reduction is known as *lumen depreciation.*



- *Lumen maintenance* is defined as the ratio of the light output at a particular time relative to the initial output.

Lumen Maintenance – Design Implications

- For lighting designs, the lowest level of light output expected during the life of the specified lamps is used to calculate the type, number and placement of the lamps.



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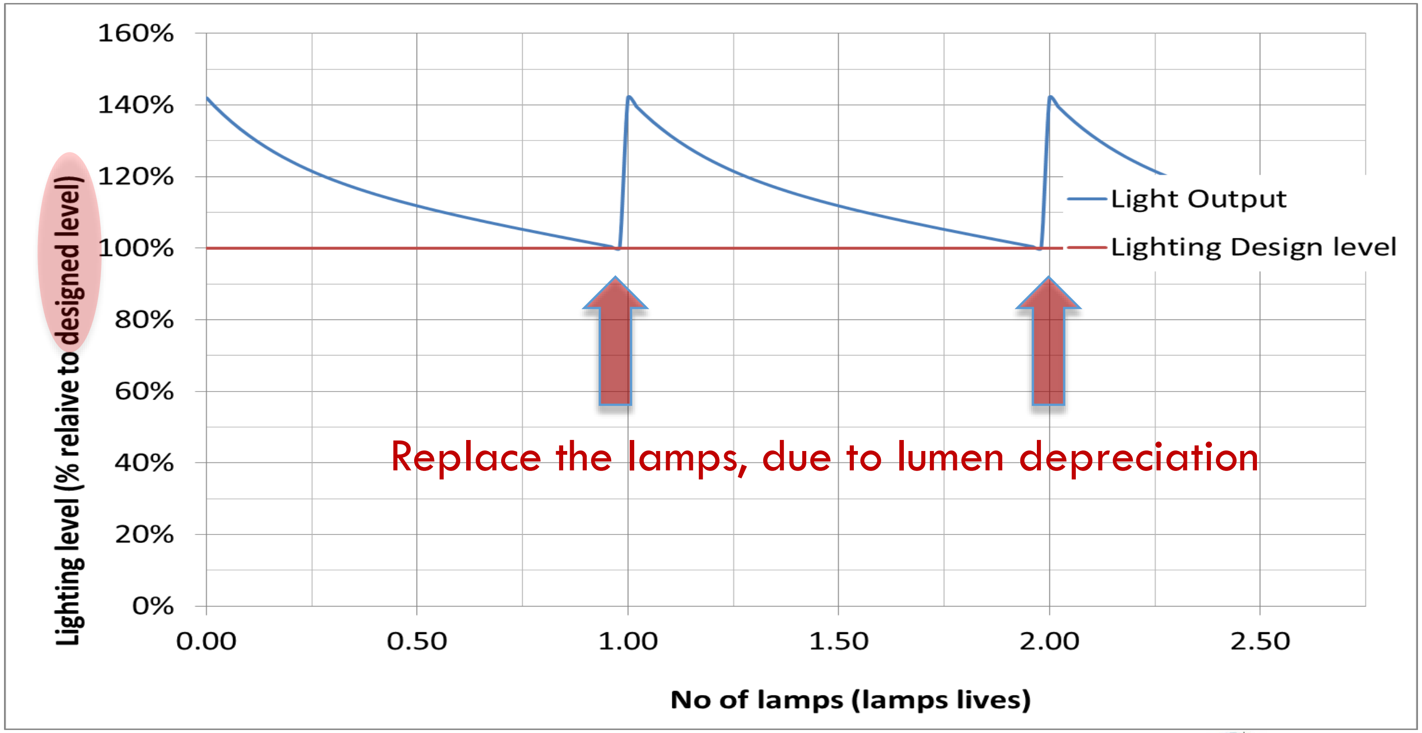
Lumen Maintenance – Design Implications

- The initial light levels in the installation will be significantly greater than required (unless automatic controls are used).



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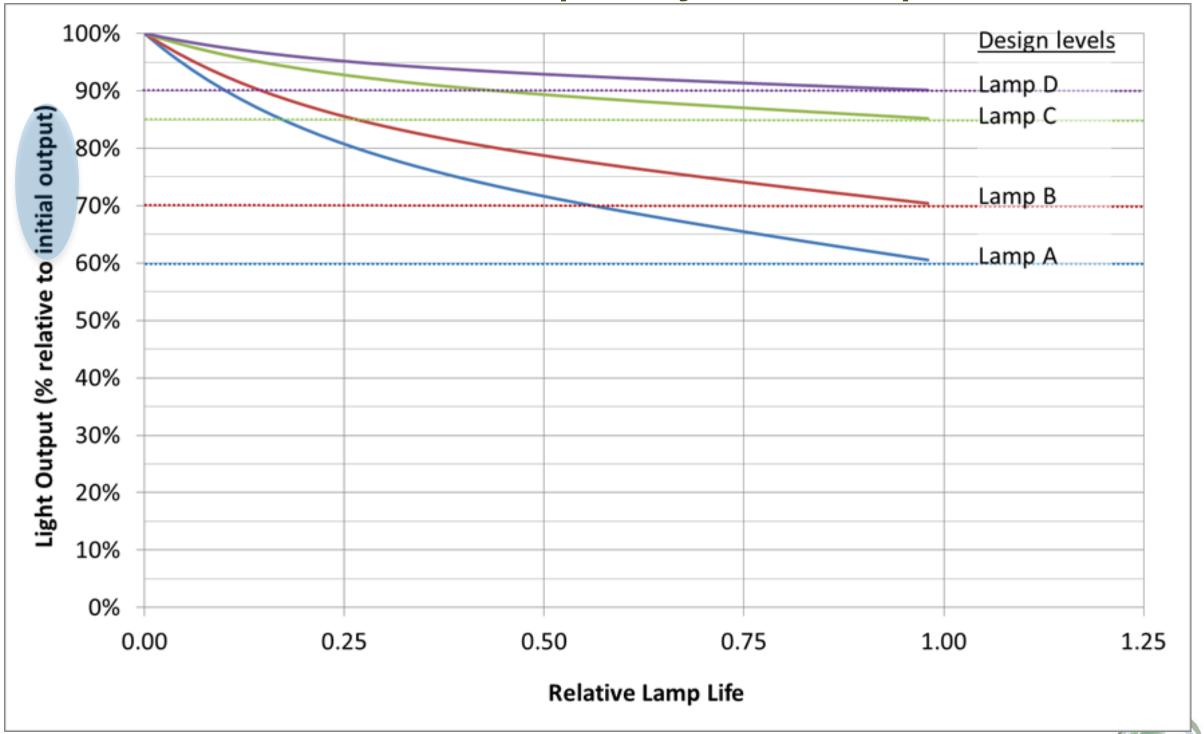
Lumen Maintenance – Energy Implications

- Different lamp technologies depreciate at different rates.
- Among a lamp technology type, there will be a range of depreciation rates due to quality of components and production.



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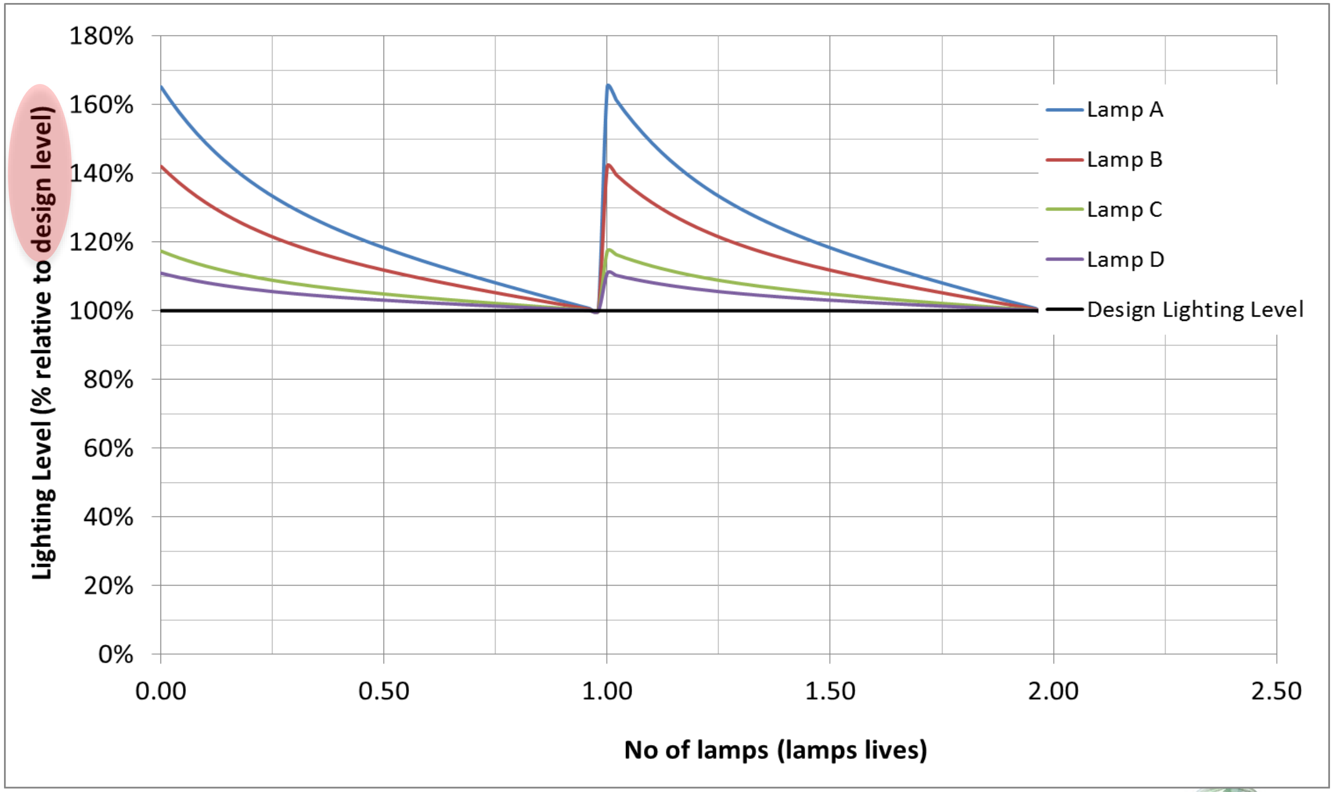
Lumen Maintenance – Energy Implications

- The choice of lamp is an important factor in the overall energy consumption of any lighting installation.



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Lumen Maintenance – Energy implications

- Lamps with high *lumen maintenance* levels can contribute to energy savings.

 Designed level (100%)		
Lumen maintenance	0.9	0.7
Initial lighting level	110%	143%

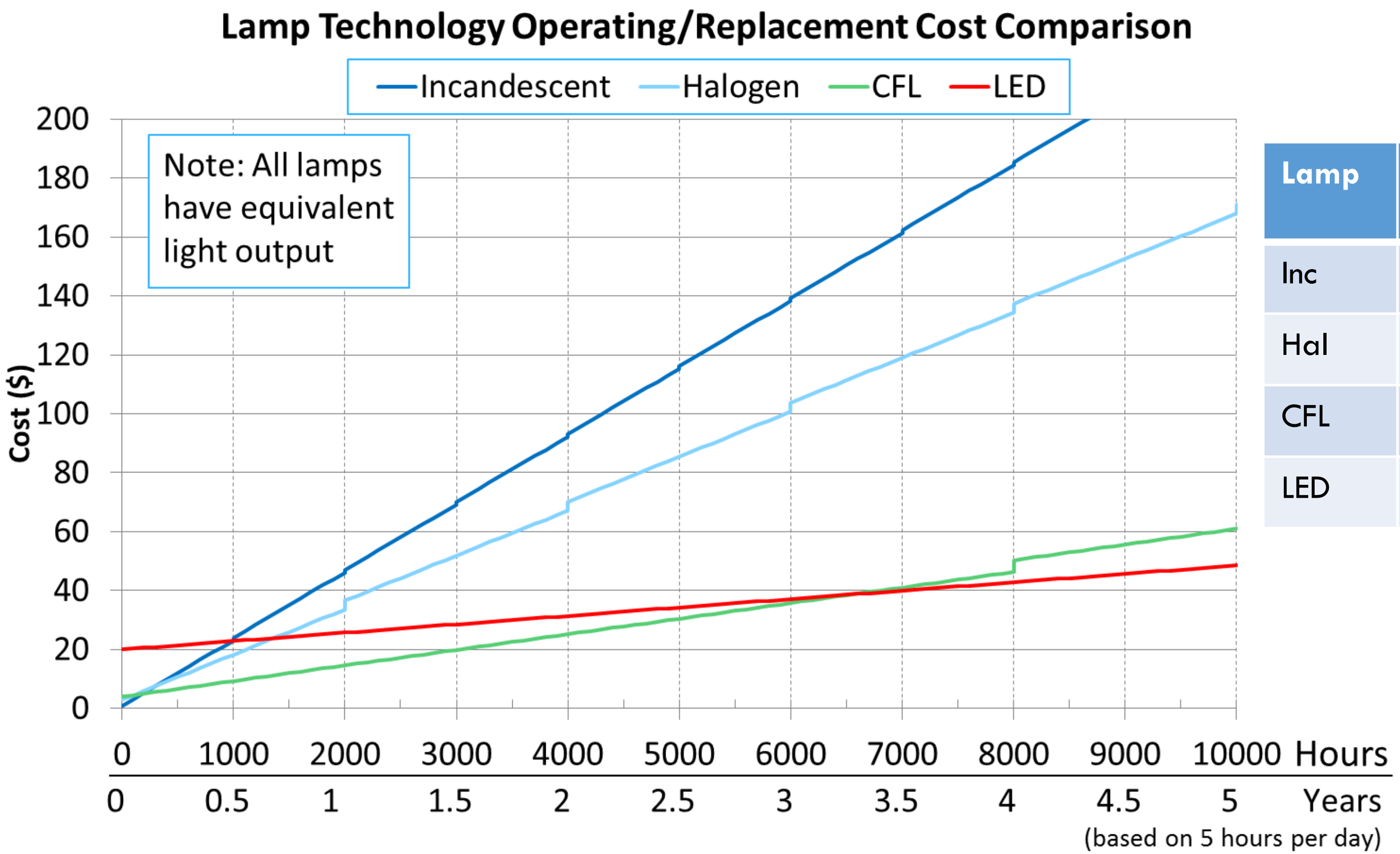
2. Definitions

2.3 Lamp Life

Lamp Life

- The market price of energy efficient lamps contributes to the cost benefit calculation for a consumer.
- Over the life of the lamp, the energy savings firstly contribute to a recovery of any price difference between the efficient lamp and the inefficient alternative.
- Once any initial price difference is recovered, the efficient lamp continues to reward the consumer with ongoing savings.
- Therefore the operational life of the lamp is a key factor in the cost benefit decision for a consumer.

Lamp Life – Consumer Return on Investment
Example of LED lamp (25,000 hrs)



Lamp	Cost	Life (kh)
Inc	$1	1.0
Hal	$2	2.0
CFL	$4	8.0
LED	$20	25.0

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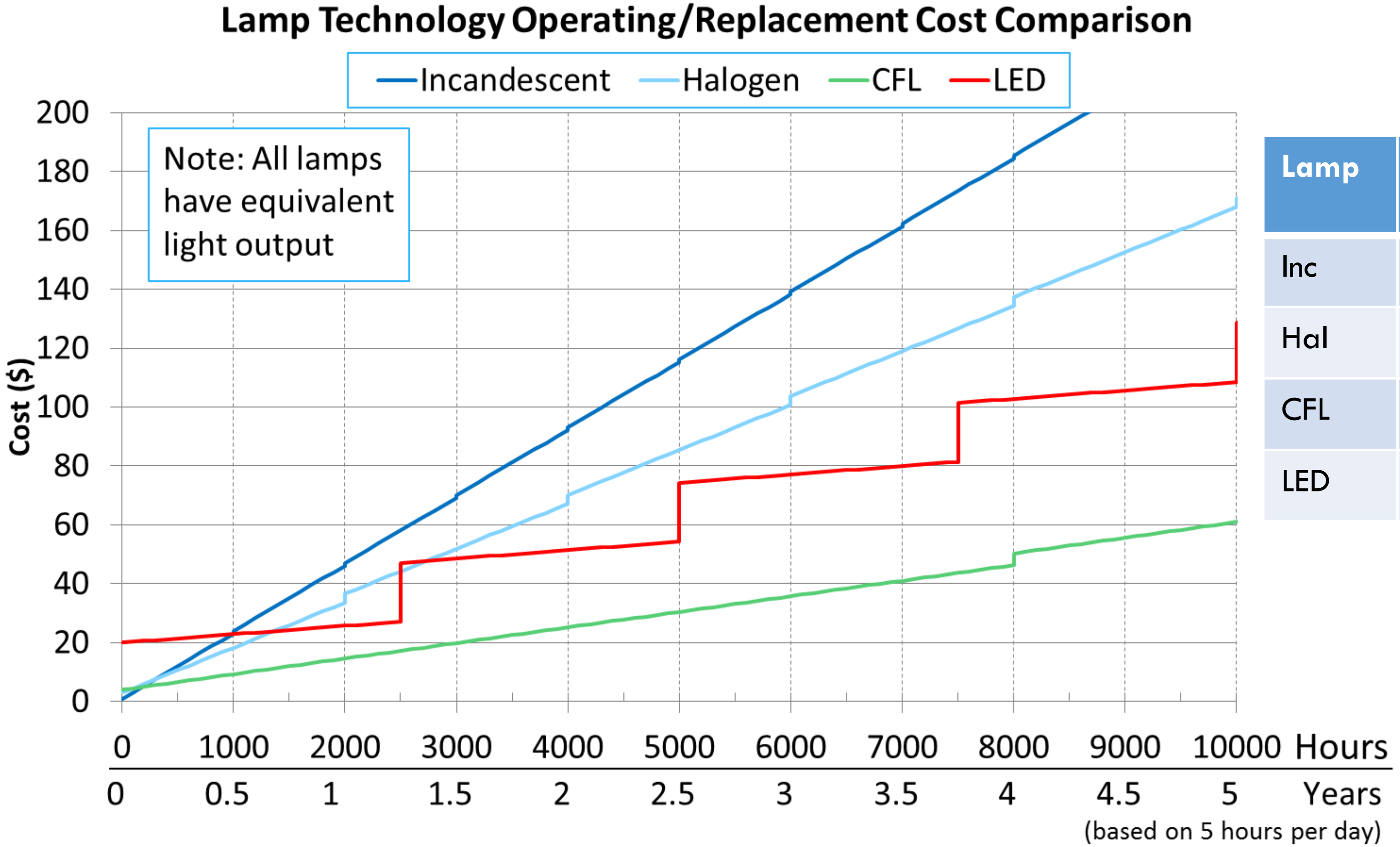
Lamp Life – Consumer Return on Investment
Example of LED lamp (2,500 hrs)



Lamp	Cost	Life (kh)
Inc	$1	1.0
Hal	$2	2.0
CFL	$4	8.0
LED	$20	2.5

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Lamp Life - Definitions

Rated Life

- The lifetime declared by the manufacturer or vendor
- This will be based on the average lamp life

Average lamp life

- Time to 50% failures from testing a sample set under specific switching conditions

Lamp life (of an individual lamp)

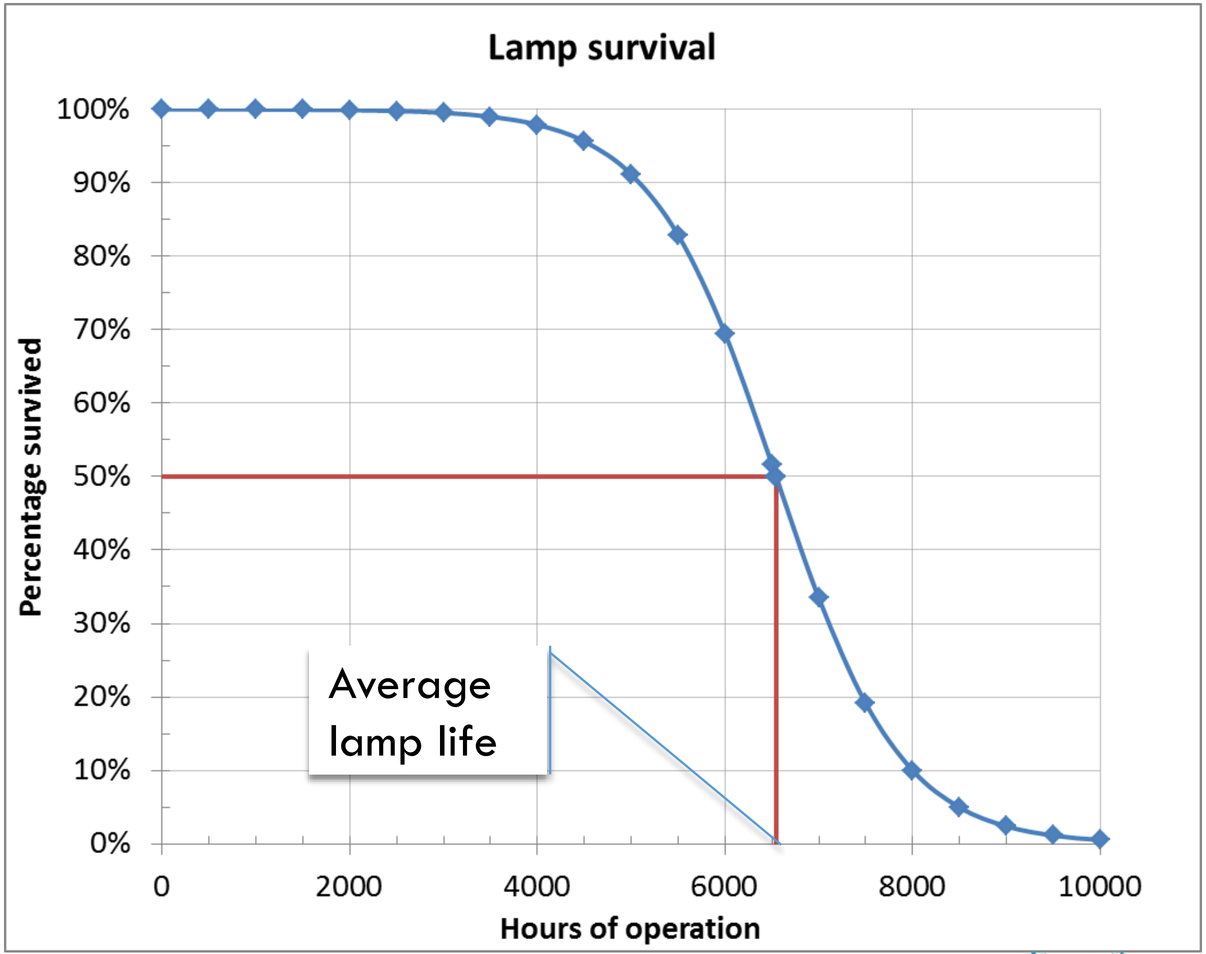
- The number of operating hours to lamp failure.

Lamp failure

- The point at which the lamp fails to light up or to remain alight.

Average Lamp Life – How to Measure
Lamp types with relatively short life

- Directly test a set of lamps till 50% of the set lamp fails
- This method accounts for all types of failure modes under the test conditions.
- Example shows 6500 hours average lamp life



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Average Lamp Life – How to Measure
Lamp types with relatively long life

Since testing to end of life is not commercially feasible (eg 100,000 hours equates to approximately 20 years)

- Need to test for a period less than full life
- Accounts for:
  - Early failures
  - Lumen depreciation
- Predicts:
  - Time to a set lumen depreciation level (typically 0.7)
- Doesn't predict or account for:
  - Likely failures beyond the measurement period on until the time the predicted depreciation level is achieved

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Average Lamp Life – How to Measure
Lamp types with relatively long life

Currently no agreed international method for predicting average lamp life for long life lamp types.

Discussions and research ongoing to determine a cost effective, appropriate and agreed method of predicting average lamp life, incorporating lamp failures and lumen depreciation.

Current defacto for average lamp life is “lumen maintenance life”, the time (hours of operation) it takes for the relative luminous flux to depreciate a given amount. eg 70%.

There are test methods for predicting “lumen maintenance life”.

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Prediction methods for long life products

CFL's - long life

- No current methods

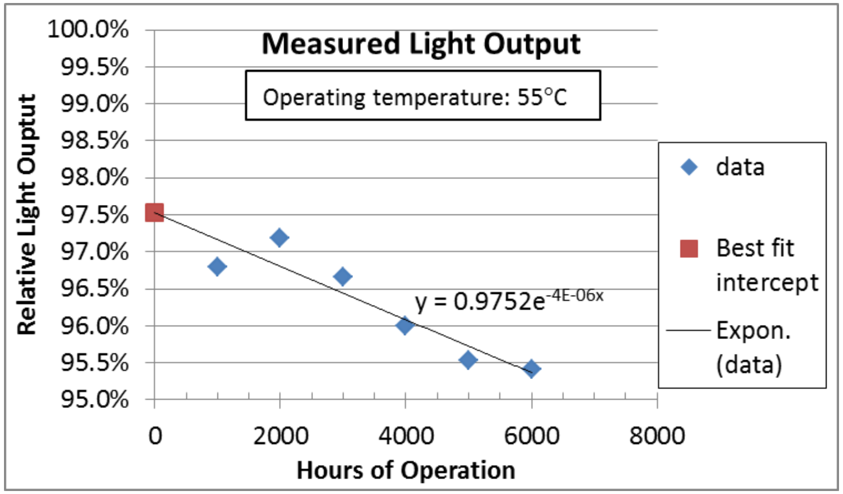
LED modules

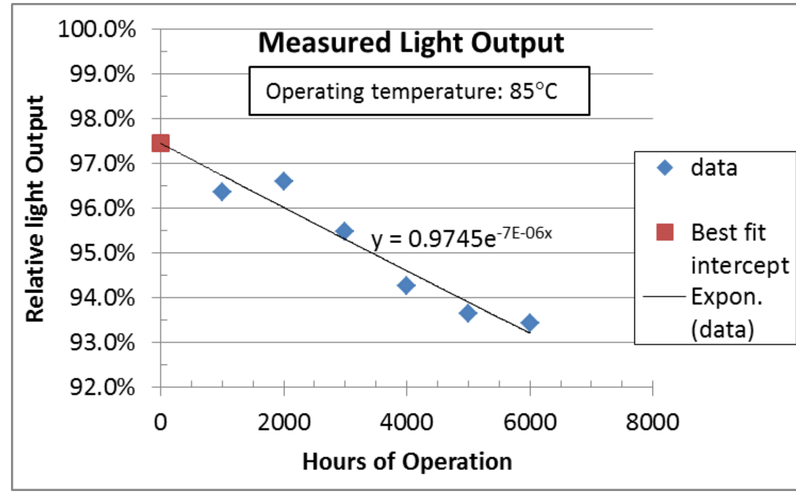
- IESNA LM-80-08 Approved method: Measuring lumen maintenance of LED light sources
- IESNA TM-21-11 Projecting long term lumen maintenance LED packages

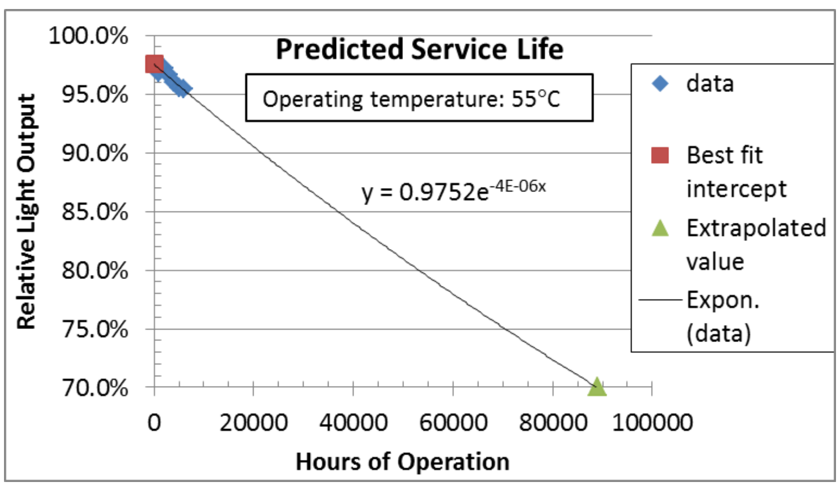
LED lamps and luminaires

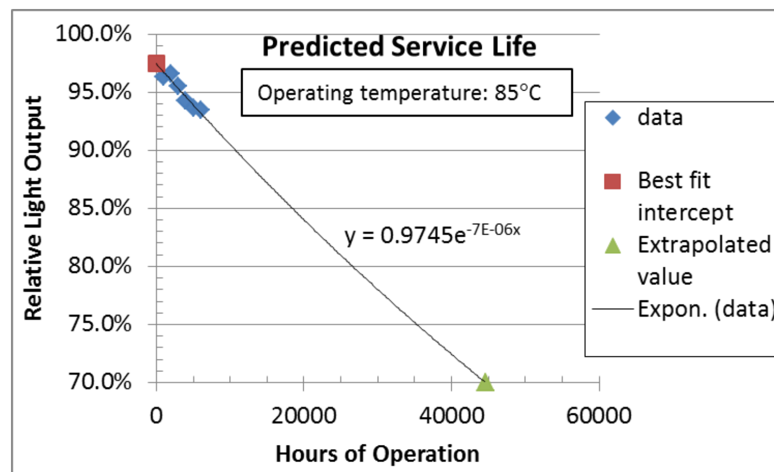
- IESNA LM-84-12 Approved method for measuring lumen maintenance of LED lamps, luminaires and light engines
- IESNA TM-28-13 Projecting Long Term Luminous Flux Maintenance of LED Lamps and Luminaires

Example of Measurement and Prediction (IESNA LM80 & IESNA TM21)









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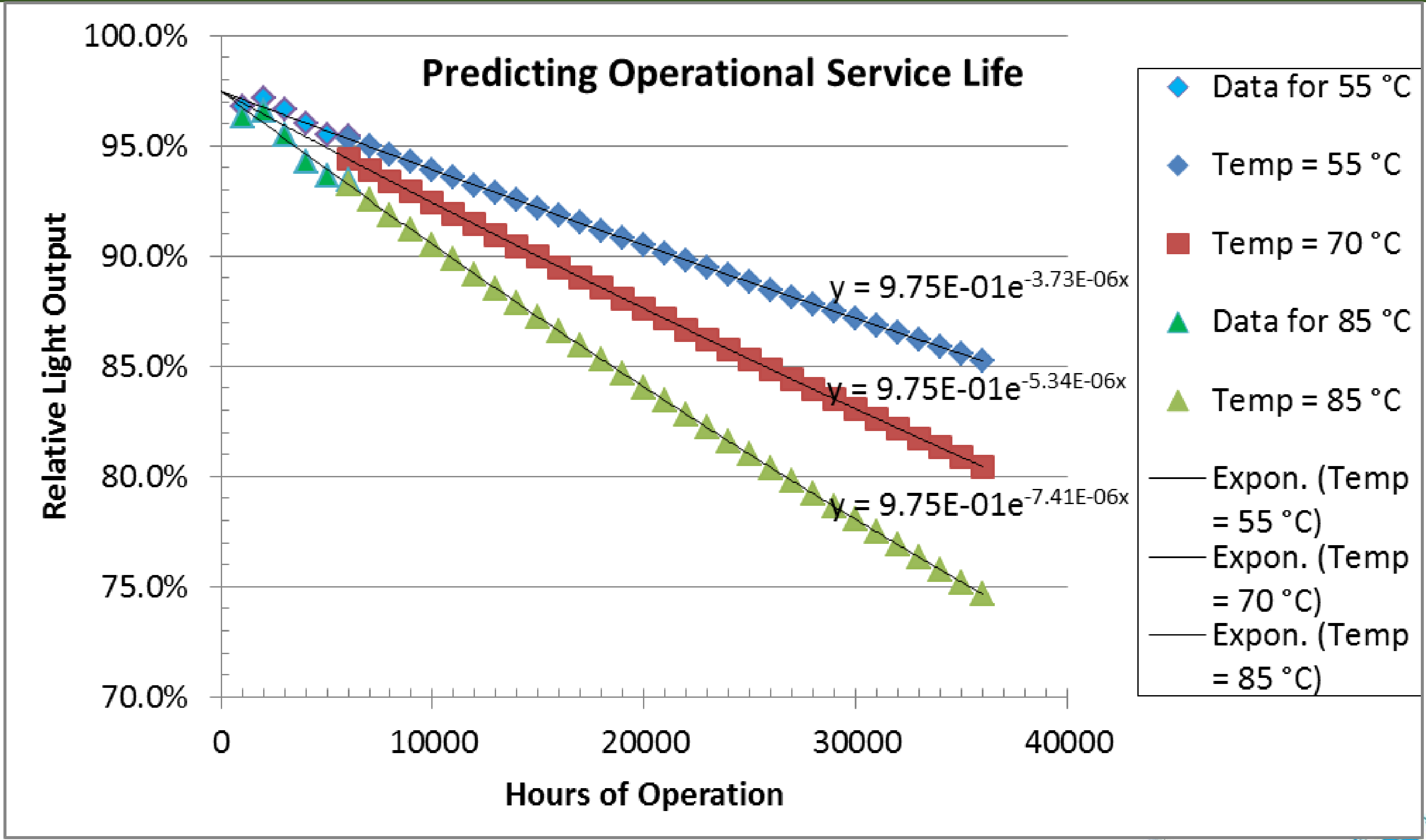
Example of Predicting the Length of Operational Service (IESNA LM80 & IESNA TM21)



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3. Photometric Laboratory Tests and Uncertainties

Measurement for all three parameters discussed requires the measurement of luminous flux.

Luminous Flux Measurement - 2 methods

Goniophotometer

- Expensive
- Slow
- Suitable for directional and non directional lamps

Integrating Sphere

- Inexpensive
- Fast
- Suitable mainly for non directional lamps

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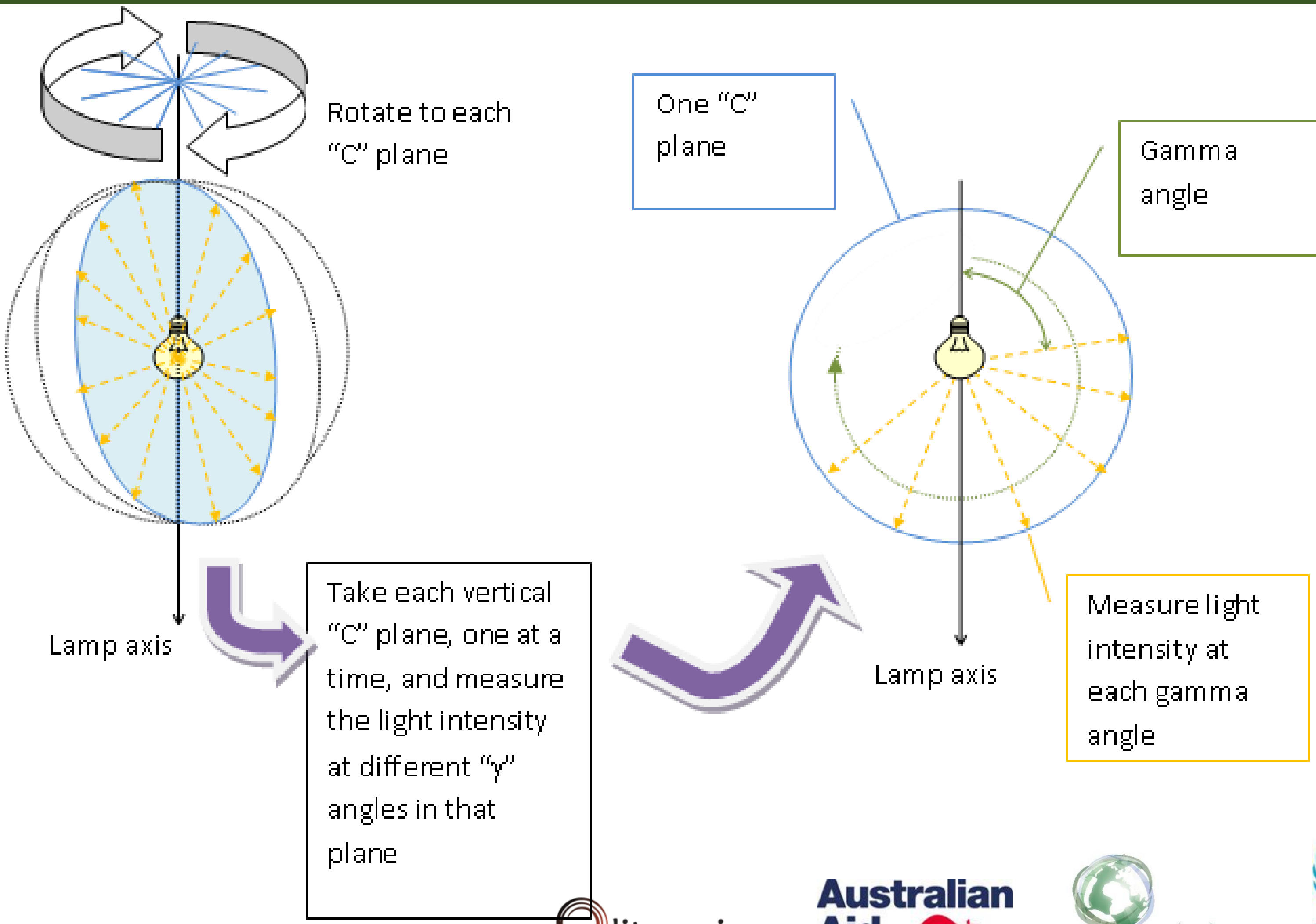
Goniophotometry - explained



Goniophotometry - explained

- Measure light intensity in many directions
- Determine the total amount of light using 3 D geometry integration and interpolation.
- Partial luminous flux can be determined through goniophotometry.
- Accuracy of the result is determined by the number of measurement points taken.

Uncertainties of Measurement

- All measurements have an element of uncertainty to them. This relates to the confidence in the value measured.
- The level of uncertainty is dependent on equipment (calibrated & traceable) and staff (good measurement practices)
- Typically for good measurement systems the uncertainty for luminous flux is approximately 4% to 6%.
- Laboratories participate in proficiency (ie comparison) testing to check/confirm their testing measurement systems.
- Further information on an LED Interlaboratory comparison:

http://ssl.iea-4e.org/task-2-ssl-testing/2013-ic-final-report

- More information on uncertainties and their calculation will be provided in another webinar in this series early next year.

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4. Resources: International Standards

CIE Test Methods

http://www.cie.co.at/

No 84 – 1989: The measurement of luminous flux

DIS 025 – 2014: Test method for LED lamps, LED luminaires and LED modules

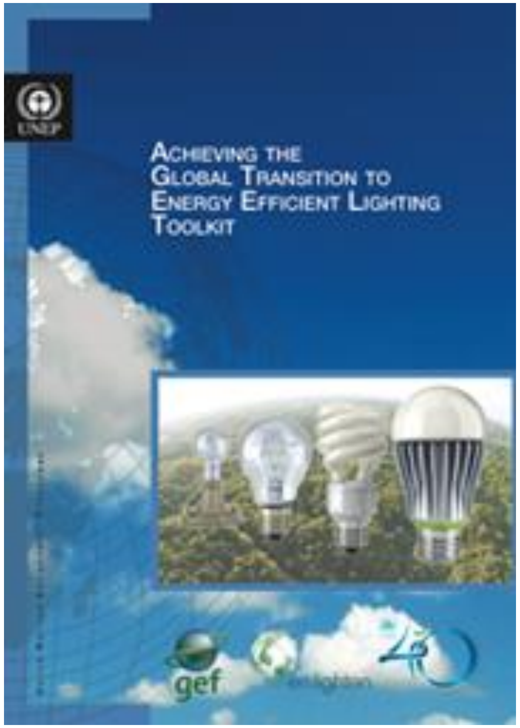
4. Resources: International Standards

IEC Performance Standards (General service lighting lamps)

http://www.iec.ch/

62612 – 2013:	Self-ballasted LED lamps for general lighting services with supply voltages > 50V - Performance requirements
60969 – 2001:	Self-ballasted lamps for general lighting services - Performance requirements
60357 – 2002:	Tungsten halogen lamps (non vehicle) - Performance specifications

5. *Achieving the Global Transition to Energy Efficient Lighting Toolkit*



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Question and Answer Period

Please use the webinar chat feature to send us your questions.

We will answer as many as possible now. We will email responses shortly if we cannot address a topic now.

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Thank you!

Join us for the next webinar on

Development of a Lighting Product Registry

Thursday, 4 December 2014

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