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PERFORMANCE TESTING OF LIGHTING PRODUCTS

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FOREWORD

Lighting accounts for approximately 15% of global electricity consumption. The United Nations Secretary-General's Sustainable Energy for All initiative identified energy efficient lighting as a "high impact opportunity", with the potential to reduce countries' greenhouse gas emissions, generate significant economic benefits and improve people's wellbeing.

High efficiency lighting technologies, such as light emitting diode lamps and smart control systems, offer up to an 85% improvement in efficacy, compared with conventional lighting technologies, while providing a better quality service.

Minimum energy performance standard programmes are a crucial policy tool for improving the energy efficiency of lighting, by contributing to the elimination of the least efficient products from the market, and accelerating the phase-in of energy saving technology replacements. However, while an increasing number of countries are adopting minimum energy performance standards, the continued availability of non-compliant, inefficient products jeopardises the achievement of countries' energy efficiency goals.

Robust monitoring, verification and enforcement schemes are crucial to safeguarding the energy efficiency benefits of performance standards and regulations. These activities protect markets from products that fail to perform as declared, or required; guarantee that products meet consumers' expectations; and ensure that policymakers, government regulators and programme administrators attain their energy saving objectives. Monitoring, verification and enforcement activities also protect suppliers' competitiveness by ensuring that they are all subject to the same market entry conditions.

Successful monitoring, verification and enforcement implementation requires long-term policy commitment and planning. The Government of Australia has long been committed to the development and implementation of monitoring, verification and enforcement policy and activities on its own territory, as part of its Equipment Energy Efficiency Program. Since 2009, Australia has been assisting other developed and developing countries to follow the same path, by sharing its expertise and best practices, and making its resources available to other countries[1].

Most recently, the Government of Australia has provided its financial and technical support to the United Nations Environment Programme-Global Environment Facility en.lighten initiative to strengthen capacities for monitoring, verification and enforcement in Southeast Asia and the Pacific. As part of this project, and drawing on the experience and knowledge of international experts and practitioners, the United Nations Environment Programme developed a series of six guidance notes on specific aspects of monitoring, verification and enforcement.

This guidance note and its associated publications are designed as manuals for government officials, technical experts and others around the world responsible for developing, implementing and refining structured and effective monitoring, verification and enforcement programmes. They describe the technical, methodological and institutional resources required, and provide easy-to-use, generic tools and templates that readers can adapt to their particular country situations.

We hope that these guidance notes will convince governments of the importance and benefits of monitoring, verification and enforcement and assist with implementation. We strongly encourage policymakers and those involved in implementing monitoring, verification and enforcement policies to take advantage of the practical advice presented.

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1 Including: International Electrotechnical Commission (IEC), International Energy Agency 's Energy Efficient End-use Equipment Solid State Lighting Annex (IEA 4E SSL Annex), lites.asia, Pacific Appliance and Labelling Programme (PALS), Vietnam Energy Efficiency Standards and Labels (VEESL), and others

ABOUT THE UNEP-GEF EN.LIGHTEN INITIATIVE

The United Nations Environment Programme (UNEP)-Global Environment Facility (GEF) en.lighten initiative was established in 2010 to accelerate a global market transformation to environmentally sustainable, energy efficient lighting technologies, as well as to develop strategies to phase out inefficient incandescent lamps to reduce CO_2 emissions and the release of mercury from fossil fuel combustion.

The en.lighten initiative serves as a platform to build synergies among international stakeholders; identify global best practices and share this knowledge and information; create policy and regulatory frameworks; address technical and quality issues; and encourage countries to develop National and/or Regional Efficient Lighting Strategies.

The United Nations Secretary General's Sustainable Energy for All (SE4ALL) initiative selected the UNEP en.lighten initiative to lead its lighting 'Energy Efficiency Accelerator'.

The initiative is a public/private partnership between the United Nations Environment Programme, OSRAM and Philips Lighting, with the support of the Global Environment Facility. The National Lighting Test Centre of China became a partner in 2011, establishing the Global Efficient Lighting Centre, and the Australian Government joined in 2013 to support developing countries in Southeast Asia and the Pacific.

In 2015, based on the lessons learned from the en.lighten initiative, UNEP launched the United for Efficiency (U4E) initiative to support countries in their transition to energy efficient appliances and equipment, including room air conditioners, residential refrigerators, electric motors, distribution transformers and information and communication technologies.

ABOUT THE UNEP-GEF EN.LIGHTEN INITIATIVE MONITORING, VERIFICATION AND ENFORCEMENT SERIES

This guidance note is one of a series of six publications on monitoring, verification and enforcement (MVE) commissioned by the UNEP-GEF en.lighten initiative under its Southeast Asia and Pacific Monitoring, Verification and Enforcement Project, funded by the Australian Government:

- *Developing Lighting Product Registration Systems;*
- *Efficient Lighting Market Baselines and Assessment;*
- *Enforcing Efficient Lighting Regulations;*
- *Good Practices for Photometric Laboratories;*
- *Performance Testing of Lighting Products;*
- *Product Selection and Procurement for Lamp Performance Testing.*

The series provides practical tools in support of lighting policy compliance frameworks and to help countries achieve a successful transition to energy efficient lighting. These publications build on the existing guidance given in the UNEP-GEF en.lighten reference manual, *Achieving the Global Transition to Energy Efficient Lighting Toolkit*. They focus on individual aspects of an effective MVE infrastructure and how these contribute to improved product compliance and the success of policies that aim at transforming the market to efficient lighting.

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ABBREVIATIONS AND DEFINITIONS

CCT	correlated colour temperature
CFL	compact fluorescent lamp
CIE	Commission Internationale de l'Eclairage/International Commission on Illumination
CRI	colour rendering index
eceee	European Council for an Energy Efficient Economy
EU	European Union
GEF	Global Environment Facility
GELC	Global Efficient Lighting Centre
IEA	International Energy Agency
IEC	International Electrotechnical Commission
IES	Illuminating Engineering Society of North America
ILAC	International Laboratory Accreditation Cooperation
ISO	International Organization for Standardization
LED	light emitting diode
lm	lumen
MEPS	minimum energy performance standard
MVE	monitoring, verification and enforcement
NIST	National Institute of Standards and Technology
NVLAP	National Voluntary Laboratory Accreditation Program
UNEP	United Nations Environment Programme

GLOSSARY

A

ageing (or seasoning): Preconditioning of lamps by operating them at controlled conditions for a specified period. (IEC)

average life: The average of the individual lives of the lamps subjected to a life test, the lamps being operated under specified conditions and the end of life judged according to specified criteria. (IEC) Average life represents the expected service life of a lamp, usually reported in hours by the manufacturer, and is based on the median of a sample of lamps tested.

B

(light) bulb: Transparent or translucent gas-tight envelope enclosing the luminous element(s). (IEC)

C

calibration: Set of operations which establishes, by reference to standards, the relationship which exists, under specified conditions, between an indication and a result of a measurement. (IEC)

colour rendering index (CRI): Measure of the degree to which the psychophysical colour of an object illuminated by the test illuminant conforms to that of the same object illuminated by the reference illuminant, suitable allowance having been made for the state of chromatic adaptation. (IEC)

compliance: Conforming to a rule, such as a law, policy, specification or standard.

correlated colour temperature (CCT): The temperature of the Planckian radiator whose perceived colour most closely resembles that of a given stimulus at the same brightness and under specified viewing conditions. Unit: K (IEC)

D

discharge lamp: Lamp in which the light is produced, directly or indirectly, by an electric discharge through a gas, a metal vapour or a mixture of several gases and vapours. (IEC)

E

(luminous) efficacy: Quotient of the luminous flux emitted by the power consumed by the source. Unit: lm/W; symbol: ηv or ϕv. (IEC)

F

fluorescent lamp: A discharge lamp of the low pressure mercury type in which most of the light is emitted by one or several layers of phosphors excited by the ultraviolet radiation from the discharge. Note: These lamps are frequently tubular, and in the UK, are then usually called fluorescent tubes. (IEC)

full procedure verification test: A test where all procedures for measurements and records stipulated in the entry conditions for an accreditation scheme have been followed.

I

international standard: Standard recognized by an international agreement to serve internationally as the basis for fixing the values and uncertainties of all other standards for the given quantity. (IEC)

L

light emitting diode: Solid state device embodying a p-n junction, emitting optical radiation when excited by an electric current. (IEC)

lumen (lm): SI unit of luminous flux. The luminous flux emitted in unit solid angle (steradian) by a uniform point source having a luminous intensity of 1 candela. (IEC)

lumen depreciation: Luminous flux lost at any selected, elapsed operating time, expressed as a percentage of the initial output. Converse of lumen maintenance..

lumen maintenance (luminous flux maintenance factor): Ratio of the luminous flux of a lamp at a given time in its life to its initial luminous flux, the lamp being operated under specified conditions. Note: This ratio is generally expressed in per cent. (IEC)

GLOSSARY

luminous flux: quantity derived from radiant flux Φe by evaluating the radiation according to its action upon the CIE standard photometric observer. Unit: lm. (IEC)

luminous intensity (of a source, in a given direction): Quotient of the luminous flux dΦv leaving the source and propagated in the element of solid angle dΩ containing the given direction, by the element of solid angle
Iv = dΦ v /dΩv
Unit: cd = lm/sr. (IEC)

M

model: Manufacturer's particular lamp design.

N

national standard: Standard recognized by an official national decision as the basis for fixing the values and uncertainties, in a country, of all other standards for the given quantity. (IEC)

O

omnidirectional: Emits light in all (or near to all) directions

P

photometer: Instrument for measuring photometric quantities (IEC)

R

reference standard: Standard, generally having the highest metrological quality available at a given location or in a given organization, from which measurements made there are derived. (IEC)

S

screen-testing: A preliminary assessment of products to determine which are likely to fail a full verification test.

spectroradiometer: Instrument for measuring radiometric quantities in narrow wavelength intervals over a given spectral region. (IEC)

EXECUTIVE SUMMARY

This guidance note focuses on the performance testing of lighting products, and the interpretation and application of the results of those tests, as a tool for increasing energy efficiency. It is primarily aimed at countries that wish to implement new, or revised, testing procedures and use test data to support the development of their energy efficient lighting policies and compliance programmes. It serves as a practical resource for governments on recommended processes to follow for testing products, interpreting testing results, and using them to inform policy. It offers both specific and general recommendations that policymakers, laboratory personnel, and other stakeholders can use in developing testing programmes.

Testing is a fundamental step in creating lighting policy and transforming the market to energy efficient products. Broadly, tests help government and other stakeholders verify product performance. Assuring compliance with testing requirements, following a set of standard metrics, and providing proper testing facilities become necessary to launch or maintain a meaningful monitoring, verification and enforcement programme. Together with other collected product information, test data provides a snapshot of market energy performance, can be used to estimate achievable energy savings, and inform a host of decisions. How countries use the results can vary from one to the other, depending on their respective market, energy efficiency programmes and requirements, economics, and national culture.

Following a structured, multi-step approach is recommended when developing a testing programme, as illustrated in the diagram opposite.

Before initiating a testing programme for lighting, testing objectives should be well defined to ensure that the performance testing strategy fulfils the necessary programme requirements. The types of products to be tested should be determined in advance, as well as the energy use and performance characteristics for which the lamps should be tested.

Next, policymakers should consider who will carry out the testing. In-country, national or independent laboratories, and international laboratories offer potential opportunities. Policymakers must assess their needs, objectives, available resources, procurement policies, and other variables when deciding what option to select. As testing programmes demand significant physical and human capacity, it is worth noting that the sharing of resources and laboratory experience across countries can conserve these resources, thereby reducing costs, and lead to collaborative data gathering.

A key step in the testing process is to determine which lighting standards to adopt. Depending on a country's particular market conditions and regional relationships, it can be advantageous to adopt or align standards and harmonise on key parameters regionally or bilaterally. As lighting products are globally traded, harmonising minimum energy performance and test standards can accelerate market transformation and make efficient products more affordable.

This guidance note provides an overview of the key lamp performance and lifetime parameters for lamps[2], as well as key equipment required for testing, explaining why they are important and how they could be used to inform the development of lighting policy and compliance frameworks. Because energy efficiency lighting regulations are designed to give preference to products that demonstrate higher energy performance, it is crucial that energy performance metrics be measured in a consistent manner and that the values are reported accurately.

Where and how to obtain the lamp samples to be tested is another important consideration, which can be guided

2 This guidance covers all residential lamp types, however specific reference is made to omnidirectional lamps in relevant test standards.

by the objectives of the testing process. Generally, the compliance framework, or programme entry conditions, may also define the sampling approach to be used in certain situations. However, most energy efficiency regulations for lighting products tend to incorporate sampling requirements. Requirements for sample size may vary based on regulatory requirements and differ among test standards.

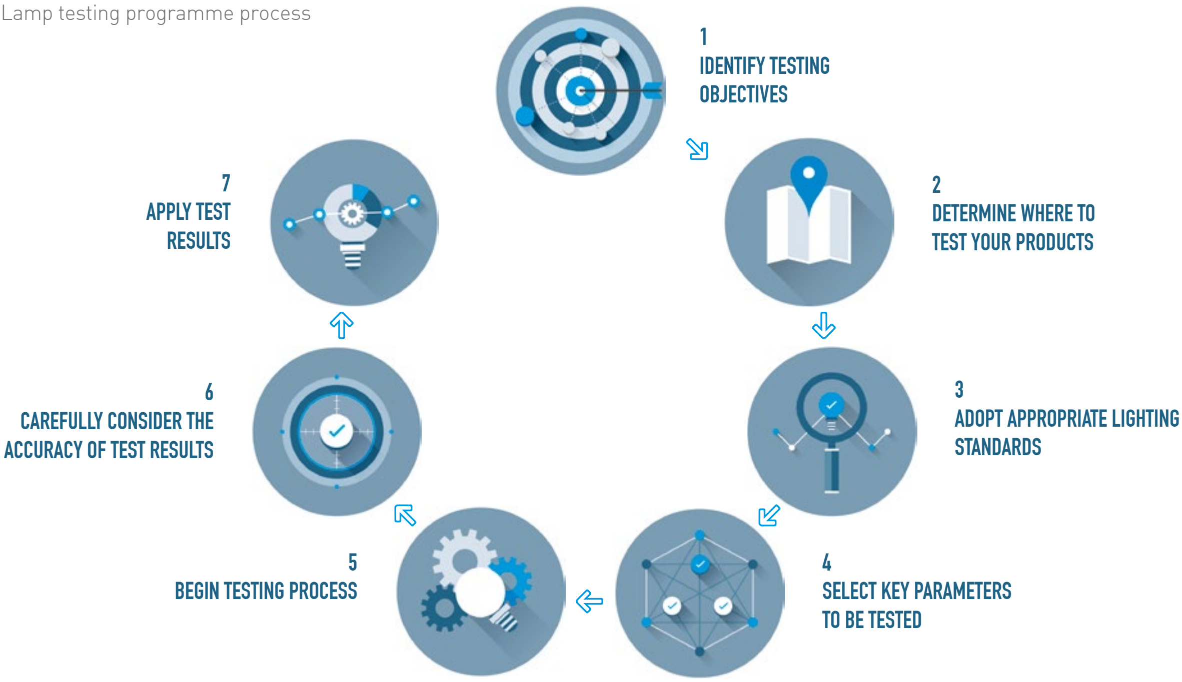
Many factors can affect the final results of a tested lamp. Even if the same lamp is measured several times, in the same way, and in the same conditions, a different value may result each time. For this reason, test standards typically specify a sample size of lamps (such as n=20 lamps) in order to use a mean or median value derived from testing several samples. It is therefore important for policymakers to understand testing results and their limitations, and the concept of uncertainty is addressed herein, as well as how to ensure the traceability of measurements, including the determination of 'pass' or 'fail' conditions in testing.

Accurate and timely product data, some of which can be derived from product testing activities, are essential for designing, evaluating, and revising product performance standard and labelling thresholds. Test reliability may be safeguarded by accrediting the testing laboratories, training personnel, and using specific calibrated equipment. Even countries with constrained resources can develop a programme with streamlined testing and reporting.

The use to which product testing data is put will typically be defined when setting the objectives of a performance-testing programme. For example, in a compliance framework, product testing normally forms the basis for determining whether energy performance claims have been met, thus ensuring compliance and programme integrity. Policymakers can also use product testing data to inform cost-benefit calculations, to estimate the environmental impacts of policies and to support establishing market baselines. Case studies, best practices from various countries, and technical standards issued by internationally accepted programmes also help inform critical decision-making.

This guidance note also discusses the economic benefits of various testing strategies. For example, testing plays a part in enabling fair competition among manufacturers and importers by ensuring that all products meet the same criteria for quality, safety, energy performance, and other factors. In this way, testing can also be said to encourage investment and innovation in energy efficient products.

Lamp testing programme process



1 INTRODUCTION

Lighting accounts for approximately 15% of total electricity use worldwide.[3] Developing regulatory measures that specify efficiency levels and accompanying labels for these products offers the potential to reduce this energy consumption, lessen peak electricity demand, diminish the need to build power plants and save money for governments and consumers. In addition, efficient lighting policies cut air pollution, abate greenhouse gas emissions and are among the most cost effective forms of energy policy. This guidance note discusses the use of performance testing to ensure that all products comply with lighting efficiency regulations so that these policies achieve their predicted benefits. It highlights the key considerations when establishing a performance testing programme and provides guidance on the interpretation and use of the results.

This guidance note is designed as a manual for policymakers, programme administrators, and others responsible for developing, implementing, and maintaining lighting policy compliance frameworks and testing programmes. It focuses primarily on general service lighting products, specifically, single-ended, omnidirectional lamps that are used for ambient or general illumination, such as those with incandescent, tungsten halogen incandescent, compact fluorescent and light emitting diode (LED) light sources. It does not address directional lamps or special-purpose lamps. Many of the steps outlined can also be applied to verification testing for reflector lamps; however, these lamps require additional testing relative to their directional aspects.

Testing serves a number of functions when making the transition to energy efficient products:

- Use of standardised test methodologies facilitates the accurate and reliable assessment of product performance and quality;
- Testing for initial compliance with mandated standards prevents non-compliant (less efficient) products from entering the market;
- Compliance testing informs monitoring verification, and enforcement (MVE) activities;
- Testing activities can also support manufacturing and provide market protection by ensuring that all manufacturers' products comply with the same set of regulations. This is especially important for eliminating or phasing out the least energy efficient lighting products.

Following a structured, multi-step approach is recommended when developing a testing programme, as illustrated in Figure 1.

CHAPTER 2 discusses the testing process for lamp performance. Points include choosing and securing adequate laboratory capacity, selecting the appropriate test standards to use, using appropriate test samples and outlining the various stages of testing. Laboratory accreditation is also discussed as a means to ensure that testing is accurate and more widely accepted. The chapter also presents some of the key performance parameters that are typically measured and provides a table of international standards applicable to different lighting types. In addition, some of the necessary equipment and resources are described.

CHAPTER 3 provides guidance on interpreting the results of testing. The testing must be accurate to withstand legal scrutiny, yet policymakers must understand that there are limits to test results and some inherent uncertainties. Reducing uncertainties in testing is discussed in this chapter, as is using the results to make pass or fail determinations.

3 UNEP 2015

CHAPTER 4 discusses how the test results may be used. Test data can support compliance activities, both before and after products are placed on the market. Both technical and economic data are outputs of product testing and can help track energy performance to evaluate energy policy.

CHAPTER 5 summarises the recommendations of the guidance note from a practical perspective.

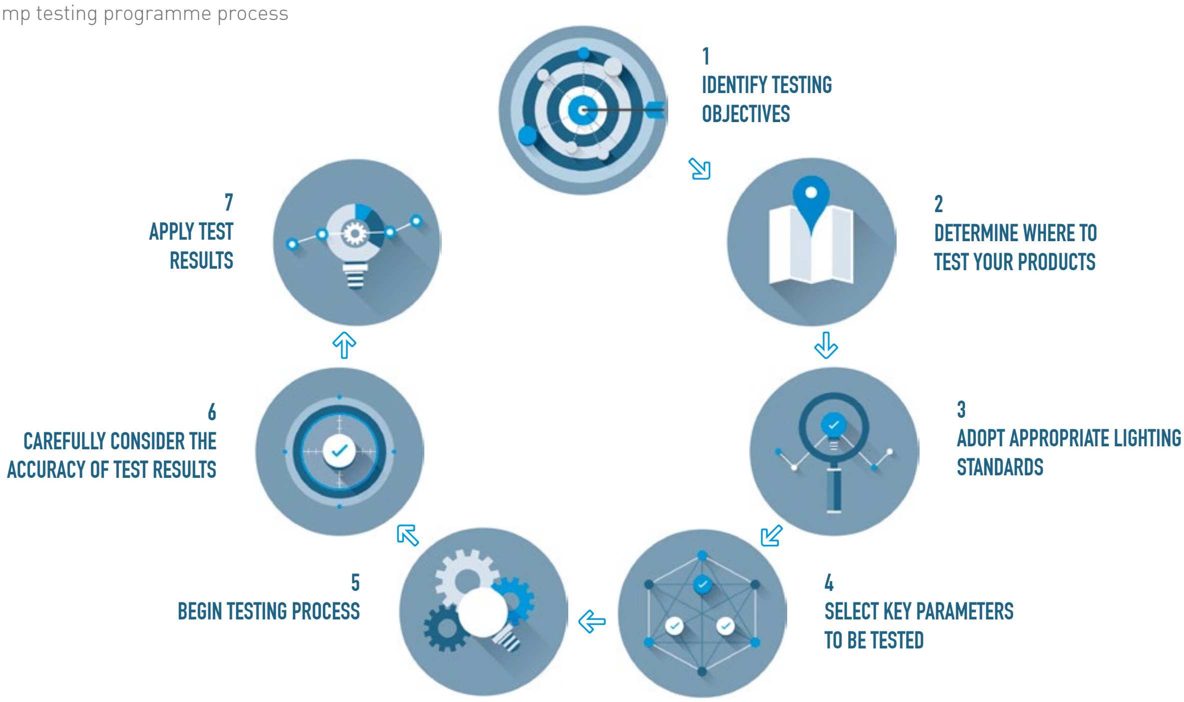
CHAPTER 6 signposts resources that provide additional information for policymakers, laboratory personnel, and other practitioners and stakeholders. Some of these resources are the source of the case studies presented in the guidance note.

Detailed information on laboratory accreditation, key lighting parameters, the international standards discussed in the guidance note and an Australian case study are included in the Annexes.

The authors acknowledge that governments operate under constrained resources, and therefore examples of activities and policies that have been implemented successfully with efficient use of resources and minimal costs are presented throughout

Figure 1

Lamp testing programme process



2 PERFORMANCE TESTING OF LAMPS

Uniform testing procedures and processes for lighting products are important elements in the development of performance standards or labels for efficient lighting products, as equivalent products must be evaluated in the same way. A process for assuring compliance with testing requirements, a set of standard metrics, a standard test and a standard testing facility for every category of lighting product are all required to ensure the accuracy and applicability of test results. This chapter discusses the testing process for lamp performance: from assessing and securing adequate laboratory capacity and selecting the appropriate test standards; through the lamp testing process and the selection of samples for the testing process; to the stages of testing.

2.1 IDENTIFY TESTING OBJECTIVES

The transition to energy efficient lighting requires an integrated policy approach[4] supported by the accurate assessment of product performance and quality, and the monitoring and verification of product compliance with mandated standards. Each of these activities demands careful consideration, as they can require different types of testing offering varying levels of evidence to support their different goals. Therefore, before initiating any testing programme, the policymaker should set their objectives for the programme. How test results may be used will be discussed in Chapter 4.

2.2 DETERMINE WHERE TO TEST YOUR PRODUCTS

Once the testing objectives have been identified, the second step in the testing process is to determine where lighting products should be tested. A suitably equipped testing laboratory that offers a high level of testing competence is a prerequisite for an effective compliance framework.[5]

Authorities seeking to establish an energy efficiency programme for lighting, along with a complementary MVE programme, typically have three options to consider when deciding where to test lighting products:

1. Using a national (government-funded) testing facility (existing or newly built);

2. Using for-profit testing laboratories (in-country or internationally-based); and

3. Seeking opportunities to share testing laboratory capabilities within a region.

Choosing among these three alternatives should be based on: the availability of existing local testing services (private or national); the amount of funding available to support the various testing needs; the level of opportunity for regional collaboration; and the in-country testing requirements of the MVE programme (including demand for both testing of products before they enter the market and ongoing compliance verification by regulators, industry, and consumers).

The specific testing requirements will vary by market size and type (e.g. importer versus producer). Establishing a national testing laboratory is an easier investment to justify when a large domestic lighting market and significant manufacturing base exists. In China, for example, the scale of the local market creates a high demand for in-country testing capacity. Alternatively, some countries with a large domestic manufacturing base will already have for-profit testing laboratories that can supplement or even replace new national facilities (i.e. the government may contract

4 For an explanation on the four elements of an integrated policy approach, see the UNEP-GEF en.lighten initiative publication, *Achieving the Global Transition to Energy Efficient Lighting Toolkit.*

5 CLASP 2010

with these laboratories to conduct the required testing on its behalf).

Conversely, in countries where there is a small, or no, domestic manufacturing base and most, or all, units of particular products are imported, it is often more cost effective to rely on foreign testing facilities.

However, the decision to establish a domestic testing facility is not solely based on economics. Some countries may legally require MVE testing to be carried out by nationally supported or domestically located laboratories. Some countries may want to build their own testing capacity if the government determines it is easier for manufacturers to access testing services in their home country.

Some countries use a combination of both national and in-country, for-profit laboratories; perhaps using different laboratories for carrying out particular tests or for testing particular products. This approach, as well as any other that relies on an in-country, for-profit laboratory, requires that testing can be run as a successful business within the particular country under consideration.

It is important to carefully estimate the testing capacity necessary to support national or regional energy efficient lighting policies. Policymakers should estimate needs at programme start-up and forecast future needs as the programme matures.

⇨ **IF THE NATIONAL MARKET VOLUME IS SMALL,** e.g. half a million to less than 5 million units per year, and the quality control target is to test one or two samples per 100,000 units, then the total testing volume would range from 5 to 200 units per year. This testing volume alone might not be enough to justify a dedicated national testing facility.

⇨ **IF THE NATIONAL LIGHTING MARKET VOLUME IS SIGNIFICANT,** e.g. 50 million to 100 million units per year, and the quality control target is the same one to two samples per 100,000 units as above, then the testing volume would range from 500 to 2,000 units a year. This could be a reasonable annual volume for a small national testing laboratory. However, the cost of operating a testing laboratory over time should also be considered.

When considering a regional approach, market similarities among countries are an important consideration. For example, two neighbouring countries with different lamp voltages or consumer preferences (e.g. lamp colour, shape, etc.) may have difficulty collaborating on product testing. However, countries with harmonised lighting markets are well placed to expand the number of test facilities and/or utilise mutual recognition agreements to share test results (See Box 1).

Box 1 **Policymaker resource: Sharing test capacity**

Mutual Recognition Agreements enable participating countries to recognise some, or all, aspects of each other's testing results and supporting documentation, thereby simplifying the inspection process for commonly traded products. Accepting test results already generated by neighbouring countries or major trading partners can reduce testing costs for energy efficient lighting programmes and provide policymakers with additional market intelligence.

* For examples of European mutual recognition agreements, see: http://ec.europa.eu/growth/single-market/goods/international-aspects/mutual-recognition-agreements/index_en.htm

2.2.1 ESTABLISHING A NATIONAL TESTING FACILITY

Developing testing capacity for lighting requires significant initial investments in construction, equipment, and human resources, especially where no testing capability has existed previously. Policymakers must also be willing/able to make long-term financial commitments to the operation and maintenance of testing laboratories, bearing in mind that the budget required may fluctuate, especially with the introduction of new products and test methods. Policymakers must have sufficient funding for ongoing operations, management, accreditation and training.

If a national testing facility has been justified and sufficient resources are secured, a significant time investment is still required to establish a new testing facility and to acquire familiarity with testing equipment and methods. Trial runs often take six months or more. Accreditation begins after that and can itself be a lengthy process (See Box 2). All of this must be complete before a laboratory can begin official product testing.

Furthermore, intermittent or part-time operation of a testing laboratory is impractical. On-going building and equipment maintenance and instrument calibration, as well as the certification, training and retention of technical staff, require regular investment.

In summary, establishing a national testing laboratory is logistically, administratively and financially challenging from start-up through ongoing operation. Annex E includes further points of consideration for establishing a national testing laboratory for lighting.

Box 2 Policymaker resource: Example of accredited testing laboratories

The National Voluntary Laboratory Accreditation Program (NVLAP)[*1], which is administered by the National Institute of Standards and Technology (NIST) in the United States, provides third-party accreditation to testing and calibration laboratories in response to legislative actions or requests from government agencies or private-sector organisations.

NVLAP-accredited laboratories are assessed against the management and technical requirements published in the International Standard, ISO/IEC 17025:2005 (for calibration laboratories), and test method standards (e.g. IES LM-79 and LM-80)[*2] for laboratories testing LED lighting products§. Note that other accreditation schemes are also available, for example, APLAC (Asia Pacific Laboratory Accreditation Cooperation).

Further information on accreditation is given in Section 2.5.3. and Annex A.

*1 www.nist.gov/nvlap
*2 See Annex D for full references to each standard listed, including where they can be located online for access or purchase.

2.2.2 USING FOR-PROFIT TESTING FACILITIES

A lack of in-country testing facilities and equipment, or resources for their establishment, can pose a serious barrier to nascent and developing energy efficient lighting policies. Independent and accredited private-sector laboratories can provide, or supplement, the testing needs for compliance monitoring and verification. Some benefits from using independent testing facilities include:

- **Saving time:** Existing laboratories often can implement testing tasks immediately upon request. This enables compliance testing to start sooner and be conducted in a timely manner.

- **Increasing competition:** Instead of spending resources to establish new testing capabilities, policymakers can allow different laboratories — independent or regional —to bid on national testing projects. Competitive bidding among laboratory providers incentivises them to provide lower prices for testing services, which in turn reduces costs for the national government. Additionally, specifying requirements for testing laboratory accreditation in the tender document may improve testing quality.

2.2.3 SHARING NATIONAL TESTING FACILITIES AT A REGIONAL LEVEL

Alternatively, or in addition to independent laboratories, it may be possible to access regionally funded and managed test facilities, or collaborate with other countries to establish one. This tactic is especially useful for countries that have not allocated funding for testing or that lack qualified local personnel.

Soliciting testing services from regional partners offers the following advantages:

- **Alignment of standards:** Inter-country testing can increase regional alignment of test standards and minimum energy performance standards (MEPS), which facilitates trade and reduces the burden on manufacturers to produce different goods for different countries.

- **Collaboration on compliance activities:** By collaborating on testing, partnering countries may learn from each other's programme experiences and develop best practices. They may also opt to collaborate on additional efforts, further reducing programme costs throughout the lifetime of the lighting policies and their compliance frameworks.

- **Developing mutual laboratory recognition:** If the country seeking testing services eventually establishes its own testing facility, collaboration experience can help to establish mutual recognition conditions. (See Box 1).

- **Sharing resources:** This allows for more efficiently used resources, with the caveat that policymakers must determine if their national legal framework enables enforcement based on the results obtained from a foreign facility. Since verification testing forms the basis of enforcement actions that remove inefficient products from the market, policymakers must understand legal considerations such as the:

  - National requirements around the handling and selection of test products or other evidence[6];
  - Ability of the laboratory to provide an accepted expert witness in court; and
  - Ability to maintain nationally-mandated legal timeframes.

Policymakers working on developing energy efficiency policies for lighting products may therefore wish to include stipulations for using out-of-country testing laboratory results in their regulations.

Box 3 **Case study: Toward a regional lamp testing laboratory in Central America**

In December 2013, Energy Ministers of eight countries in Central America (Costa Rica, Dominican Republic, El Salvador, Guatemala, Honduras, Mexico, Nicaragua and Panama) endorsed a regional efficient lighting strategy, developed collectively with the support of the UNEP en.lighten initiative. Among the priority objectives identified in the strategy document is the identification and endorsement of a laboratory to provide standardised testing services for lighting services across the region. The Costa Rica national lamp testing laboratory, which has an international accreditation, is being considered for servicing the region. Feasibility and cost-effectiveness studies are being conducted to ensure that the laboratory will be able to meet the regional demand. Participating countries will also need to review their legislation for monitoring, verification and enforcement to ensure that they can accept test results from other countries.

For further information see: http://www.proyectomesoamerica.org/joomla/index.php?option=com_content&view=article&id=652&Itemid=269

2.2.4 'LIGHT-TOUCH' TESTING FOR RESOURCE-CONSTRAINED COUNTRIES

Where policymakers wish to build national testing capacity but lack sufficient resources or justification to establish a comprehensive national testing facility, other options can supplement outsourcing testing to independent or foreign laboratories. These are referred to as 'light-touch' testing methods, and consist of the following.

⇨ ESTABLISHING SCREEN-TESTING CAPABILITIES

This involves a two-step approach where products can be initially investigated using lower cost, simpler equipment or procedures, and a minimised set of parameters to identify possible non-compliant products. Full verification testing, in an accredited facility, can then be performed on these products. Note that results derived from screen-testing may not withstand legal challenges and they should not be used to develop MEPS or performance baselines. Furthermore, measuring some key lighting parameters, such as luminous flux, still requires specialised equipment. An integrating sphere, for example, is still required for most light sources.

⇨ DOCUMENT-BASED 'TESTING'

This method is applicable for countries that do not include an up-front registration process as part of their energy efficient lighting regulation requirements (an up-front registration process that requires submission of test results effectively completes this exercise for 100% of products registered). It involves using the careful review of documents requested from manufacturers to identify products that may have non-compliant results. This approach requires no investment in testing facilities, and only entails actual testing if non-compliant products are found and subsequently submitted for full verification

6 For detailed guidance on selecting products for performance testing see UNEP-GEF en.lighten initiative guidance note, *Product Selection and Procurement for Lamp Performance Testing.*

testing. However, it does necessitate having technicians, or testing experts, with significant experience in reviewing and interpreting test results, particularly to avoid the 'golden sample' issue, where test results may come from a specially built product sample instead of a production unit. Document-based testing also places the burden of testing on manufacturers, because results must come from certified or accredited laboratories.

Policymakers also must be attentive to the possibility that some suppliers may purposefully alter documentation to meet requirements, showing product compliance on paper where it does not exist in practice. For this reason, requiring accredited third party testing for certification can alleviate the verification burden on programmes, as the reported values are more likely to be results from laboratory testing.

Box 4 | **Case study: Denmark drives effective compliance through review of technical documents**

In 2010, to reduce testing costs, the Danish Energy Agency refocused its compliance checking efforts from product testing to include evaluation of technical documentation supplied by product suppliers. As a result, it was able to increase the number of products inspected without increasing its total costs. Products that failed the document inspections were then targeted for laboratory testing. This approach has the following advantages:

- Quick and effective insight into supplier awareness of legal requirements. Documentation is generally present and of high quality where the supplier is aware of the regulations; when they are unaware, documentation is often absent or of a low quality;
- Document inspections reveal the need and possibility for improved information, dialogue, and cooperation with suppliers;
- Expensive laboratory testing can be carried out at a lower frequency.

For more information, visit the Danish Energy Agency website at: http://www.ens.dk/en/consumption-savings/energy-labelling-eco-design-appliances-products. (eceee 2013).

COMMON TEST REPORT TEMPLATES

Common test report templates are a useful tool for regions that are looking to align, or coordinate, activities. They can facilitate documentation review, even where the materials are in a foreign language. For additional information, see the case study on Ecopliant, Box 8.

2.3 ADOPT APPROPRIATE LIGHTING STANDARDS

The third step in the testing process is to determine which lighting standards to adopt. Policymakers around the world have been working to increase lighting efficiency through the implementation of performance standards and labelling programmes, therefore numerous examples of good policy and standards exist.

Depending on a country's particular market conditions and regional relationships, it can be advantageous to adopt an international, regional, bilateral, or multilateral approach where lighting policies in different countries can share aligned standards and harmonise on key parameters. Because lighting products are globally traded, harmonising MEPS and test standards can accelerate market transformation and reduce manufacturers' testing costs. This also makes efficient products more affordable.

This section lists some existing lighting standards used globally, including MEPS, other performance standards, and test standards. Table 1 presents select international efficient lighting programme standards and the international or national standards that they reference. Annex D contains full references to each standard listed, including where they can be located online for access or purchase.

In selecting the regulatory standards most appropriate for their country, the objective of policymakers is to have accurate and comprehensive data to inform such parameters as MEPS, cost-benefit scenarios, and compliance checking activities. These data can only be obtained by applying prescribed test standards to the products under laboratory conditions. MEPS typically establish the requirements and reference the appropriate test standard by which those requirements shall be measured.

Complex methods of photometric measurements and specialised equipment are needed within the lighting industry to measure lighting products. (See Box 5. Further information also can be found in the UNEP-GEF en.lighten initiative guidance note, *Good Practices for Photometric Laboratories*.)

Box 5 Technology focus: Relative and absolute photometry for testing LEDs

Prior to the advent of solid state lighting, traditional light sources were assumed to have omnidirectional, uniform, and scalable light outputs. When characterising and reporting a luminaire's performance, a manufacturer could conduct a comprehensive set of tests on a single luminaire, which could be fitted with different wattage lamps. When a different lamp or light source is used in the same luminaire, the manufacturer simply alters the magnitude of the luminaire's light output based on the increase or decrease in the light source's total light output (linked to the lamp wattage). This is possible because the light distribution pattern of the luminaire either remained the same or was sufficiently close for the various wattage lamps for industry needs and reporting. This testing and reporting method is referred to as relative photometry because all the data contained in the luminaire's files are relative to the lumen output of the lamp.

While relative photometry is an appropriate measure for luminaires that have interchangeable lamps, this method is limited in its usefulness for measuring LED luminaires. Most LED luminaires are integrated units and cannot be easily separated and tested like traditional luminaire/lamp combinations.

The manner in which LEDs are integrated into the luminaire also has an impact on their performance. Depending on the parameter under consideration, the resulting efficacies can therefore vary. In addition, most LED lighting systems are composed of many discrete components. The losses in these components also need to be measured accurately in order to calculate overall efficacy, not just that of the LED chips.

Because it is not appropriate to apply relative photometry to test LED-based devices, even for omnidirectional devices, the lighting industry needs a new approach. The new test standard, CIE S 025/E:2015, uses absolute photometry, and requires the reporting of actual intensity values measured during the test, not those relative to any particular light source.

Table 1

Select international efficient lighting programme standards and performance, photometric, and colorimetric standards for lamps

Reference Standard for Lamp Performance		Reference Standards for Electrical and Photometric Tests	Reference Standards for Colorimetry
Performance standards set requirements for a variety of parameters that require testing. They can also refer to or include test methods	***Product Scope[7]***	***These standards define how certain tests and measurements should be carried out. They can also include requirements for test equipment, e.g. accuracy requirements. These standards can either stand alone, or be included within performance standards.***	
IEC 60969-2001 Edition 1.2	CFLs	IEC 60081-1984	
IEC 60969 Ed.2 Draft	CFLs	IEC 60081-1984	CIE 13.3, 15, 63, 84, 121
Australia/New Zealand, AS/NZS 4847	CFLs	IEC 60969-2001	CIE 13.3, 15, 63, 84, 121
China GB/T 17263.2002	CFLs	IEC 60969-2001	CIE 13.3, 15, 18.2, 63, 84, 97
ELI voluntary standard, March 2011	CFLs	IEC 60969-2001	CIE 13.3
EU, EC No 244/2009	CFLs and LEDs	IEC 60969-2001	CIE 13.3, 15, 18.2, 63, 84, 97
Indian Standard (IS) 15111 (Part 2) 2002	CFLs	IS 15111 (Part 2) 2002 (referred to IEC 60969-2001)	CIE 15
United Kingdom Energy Saving Trust Lamp Spec, V7.0-2010	CFLs	IEC 60969-2001, EU regulation No 244/2009	
United States voluntary ENERGY STAR Lamps V1.1	CFLs and LEDs	ANSI C78.5, IES LM54, LM65, LM66, LM79, LM80, TM21, EU EC No 244/2009	CIE 13.3, 15

Source: Updated from UNEP 2012.

7 These standards may apply only to CFLs or LEDs, or to more lighting products. However, 'product scope' here only tends to show if CFLs and/or LEDs are covered. These standards may also have specific criteria on power, shape, with or without cover, etc. Please refer to these standards for detailed product scope. Some of them may also have updated versions.

The International Energy Agency (IEA) Energy Efficient End-use Equipment Solid State Lighting Annex[8], commonly known as the IEA 4E SSL Annex, also has developed a range of performance specifications for LED products.[9] These are not lighting standards but rather guidance for when there is an absence of international standards.

Generally, these international testing standards underpin many lamp MEPS and energy labelling programmes because they provide the means by which lamp energy performance is measured and compared. However, there are different regional approaches to the application of these standards.

The standards in Table 2 represent some best practice international performance standards or test standards for incandescent lamps, CFLs, and LED lamps. These could be well suited to countries where no standards are in place. MEPS should be developed with reference to the market baseline status of each country.[10]

For these categories of lamps, the reference standards for the main technologies are:

- IEC 60969, Self-ballasted Lamps for General Services – Performance Requirements;
- CIE S 025/E: 2015, Test Method for LED Lamps, LED Luminaires and LED Modules.

Until the publication of the international standard CIE S 025/E:2015 in early 2015, the Illuminating Engineering Society of North America (IES) LM-79 was frequently referenced around the world as an international LED test standard, even though it had been developed for the North American market. CIE S 025 was designed so that product testing would also satisfy the requirements of IES LM-79.

Table 2

Applicable international and regional standards for different light source types

Product	Standards[11]	
	International Electrotechnical Commission (IEC)	International Commission on Illumination (CIE)
Incandescent/Halogen	IEC 60064, IEC 60357	No 84 – 1989 (luminous flux in general)
Fluorescent	IEC 60969, 60081	
LED	IEC 62612:2013	CIE S 025/E:2015

2.4 SELECT KEY PARAMETERS TO TEST

Because energy efficiency lighting regulations are designed to give preference to products that demonstrate higher energy performance, it is crucial that energy performance metrics be measured in a consistent manner and that the values are reported accurately. This section provides an overview of the key performance parameters of omnidirectional lamps, explaining why they are important and how they could be used to inform the development of lighting policy and compliance frameworks.

Table 3 shows key lamp performance parameters with brief explanations of how each test parameter is used. A more comprehensive version of this table is available in Annex B.

8 See the website at www.ssl.iea-4e.org
9 See Annex D for full details of the performance specifications, including where they can be located online
10 Further guidance on the development and application of market baselines can be found in the UNEP-GEF en.lighten initiative guidance note, *Efficient Lighting Market Baselines and Assessment*
11 See Annex D for full references to each standard listed, including where they can be located online for access or purchase.

Table 3

Key Lamp Performance Parameters

Parameter	Definition	Special Considerations[12]
Light Output (Total Luminous Flux)	Light output describes the total amount of light radiating from the light source into the surrounding space. Total luminous flux is the measured quantity of visible light to humans from a particular light source or lamp.	This is a measurement of the product's ability to perform its function, namely to produce visible light. It is, therefore, one of the most important parameters that needs to be measured (rated) for lighting products. Compared to a goniophotometer, the use of an integrating sphere is a more time efficient and cost effective method for measuring the light output of most light sources (see Section 2.4.).
Electrical Power (Consumption or Rated Power)	Rated or input power is the total amount of power that is used by a light source, or system, to deliver its light output. It indicates the amount of electrical power required by such a device in an electrical circuit.	Required in order to calculate luminous efficacy (see below).
Luminous Efficacy	Luminous efficacy (lumens per watt) represents the ability of a lamp source to convert electrical energy into visible light for a particular application.	Many MEPS and labelling programmes establish energy efficiency requirements based on initial luminous efficacy (measured when products are new).[13] This is usually the key measurement of the efficiency of the product used to determine compliance with minimum efficiency levels in regulation.
Lifetime	The total time for which a lamp has been operated before it becomes useless, or is considered to be so according to specified criteria. Note: Lamp life is usually expressed in hours. (IEC). Lifetime, as reported by manufacturers, reflects the calculation of the product lifetime which is usually based on the median of a sample, and can be the point at which light output falls below a certain level.	A characterisation of 'lifetime' is needed so that various light sources and their operational cost over time can be compared. Lifetime testing can take a long time. Currently, there is no globally recognised acceleration method for lifetime testing for fluorescents or LEDs. IES has LM-80 and TM-21 for testing and projecting luminous flux maintenance life of LED packages and modules and LM-84 and TM-28 for testing LED lamps and luminaires.
Lumen Maintenance (luminous flux maintenance factor)	Lumen maintenance determines how much of a lamp's light output remains after a period of controlled operation, compared to when it was new.	For all lighting products, as operational hours increase, light output decreases. Regulating this parameter helps to ensure lamps degrade in light output slowly, and also to improve long-term performance and consumer satisfaction. Lumen maintenance could also be regarded as efficacy maintenance. While some electrical parameters, including power do not change noticeably, light output can change significantly over time.

12 See Annex D for full references to each standard listed, including where they can be located online for access or purchase.

13 Commission Regulation (EC) No 244/2009 asks for lumen and watt, rather than lumen/watt. However, efficacy can be regulated using these two parameters. (European Commission 2009)

2.5 THE TESTING PROCESS

The fifth step in the testing process is learning how to test lighting products in accordance with adopted standards. This section presents the step-by-step process of lamp testing.

2.5.1 STAGES OF TESTING

Figure 2 illustrates the typical test process for lamps. For the actual testing stages (*Initial Test, Lifetime Test* and *Lumen Maintenance Test*) the process is clearly outlined and defined in the individual test standards. Care should be taken to explicitly follow the steps outlined in the selected standard. Further guidance on the first two stages, *Prepare Samples* and *Ageing*, is given in this section as these are not clarified in the test standards.

Figure 2
Flow chart of testing stages with some parameters measured during testing

PREPARE TEST SAMPLES

- Select appropriate test standard and appropriate parameters
- Acquire samples according to sampling protocol
- Mechanical and physical inspection
- Prepare samples per standard

↓

AGEING (SEASONING)

- Lamps in ageing room
- LEDs do not need ageing prior testing

↓

INITIAL TEST

- Performed in testing room with Integrating sphere or goniophotometer to measure:
  - Electrical parameters: Power* and Power Factor
  - Photometric parameters: Light Output*
  - Colormetric parameters: CRI and CCT

↓

LIFETIME TEST

- Carried out in the ageing room
- LEDs normally require a much longer lifetime testing period than CFLs
- Some programmes/alliances are trying to develop accelerated lifetime test method
- Currently no lifetime test methods have been globally recognized

↓

LUMEN MAINTENANCE TEST

- Samples placed in the ageing room to operate to a certain time period
- 1,000 hours, and/or 2,000 hours, etc
- Then moved to testing room to:
- Test for Light Output
- Calculate Lumen Maintenance

Note: Key parameters for energy efficiency programmes are shown in bold. *Power and Light Output are used to calculate Luminous Efficacy. This partial list is intended to be illustrative.

PREPARE SAMPLES

The first step in the testing process is to obtain sufficient lamp samples for testing. The number of samples is generally dictated by the governing test standard or regulation.[14] Where and how to obtain the lamps is dictated by the objectives of the testing process, which could include:

- Characterising the products in a market;
- Estimating the compliance levels of regulated products for authorities; or
- Providing required evidence for an enforcement action.

The MVE framework, or programme entry conditions, may also define the sampling approach to be used in certain situations.

Theoretically, lamp production is sufficiently standardised such that measuring energy performance should be consistent for an entire model run. In practice, however, energy performance differs among lamps of the same product model. This is especially true for CFLs and LEDs, which involve a complex production process. Any sampling methodology must take these factors into account.

Sample size refers to the number of identical lamps of the same model that must be tested at the same time, plus the total number of lamps needed to conduct all relevant tests. The combined test results from individual samples are then averaged, or calculated using other methodologies, to form the final test results for a particular lamp model. Sampling is required because testing for certain factors, such as lifetime, can be time consuming and costly, and other factors, such as mercury content, require the destruction of the lamp samples. It is therefore impractical, or impossible, to test each individual lamp before it is allowed to enter the market.

Most energy efficiency regulations for lighting products incorporate sampling requirements. Requirements for sample size may vary based on regulatory requirements and differ among test standards. In the European Union, for example, the test regimen requires a minimum sample of 20 units of a model tested to determine the energy performance of the model in general.[15] Other regulations require ten samples.

For detailed guidance on selecting products for performance testing see UNEP-GEF en.lighten initiative guidance note, *Product Selection and Procurement for Lamp Performance Testing*.

LAMP AGEING (SEASONING

Lamps should be aged (reach a relatively stable state before testing) to avoid notable performance fluctuation during testing. Ageing is not a test per se, but rather a preparatory stage before measurement testing.[16] The ageing period differs depending on lamp technology.

Various standards outline different requirements for how ageing should be conducted; some requirements can be tailored based on actual need. Some requirements include:

- **Surroundings**, i.e. whether ageing should be performed in a lifetime test room;
- **Direction of lamp bases**, i.e. whether lamps should be in base-up or base-down position;
- **On-off intervals**, i.e. whether the lamps shall not be continuously on for 100 or 1,000 hours, but switched on and off with certain intervals.
- **Test equipment requirements**, such as allowable voltage fluctuation of the power supply.
- **Environmental requirements**, such as temperature and airflow rate, etc.

For example, CFL and incandescent lamps are normally aged for 100 hours. LED lamps, on the other hand, do not require significant ageing, only a period sufficient for the device to reach stable operation. LM-79 and CIE S 025 for LEDs have different requirements for testing, based on when the device being tested reaches stable performance.

2.5.2 KEY TEST EQUIPMENT

Specialised equipment is needed to determine a lamp's luminous flux. Two key devices are used for this purpose: an integrating sphere (often simply referred to as a sphere) and a goniophotometer (often abbreviated to gonio). Each is used to measure the light output from a specific light source type, or to meet particular measurement requirements, such as colour performance. These devices and their uses are described in more detail below. Other types of equipment would be required to measure other specific parameters, but are not covered in this guide.[17]

INTEGRATING SPHERES

The first crucial component of lighting testing equipment is an integrating sphere, a hollow spherical cavity, with viewing/measuring port(s) equipped with photodetector(s), as shown in Figure 3. Integrating spheres can range in size, depending on the dimensions of the lamps to be

14 Note that IES LM-79 does not specify number of samples. IES TM-21 specifies the number of LED samples for projecting life time of LED packages.
15 See Annex IV of Commission Regulation (EU) No 1194/2012. (European Commission 2012b)
16 If some lamp samples fail or stop working properly during the aging period, this is not considered as failing the test. The failed test samples can be replaced and aged again.
17 Further information and guidance on the use of key test equipment can be found in the UNEP-GEF en.lighten initiative guidance note, *Good Practices for Photometric Laboratories*.

tested. Generally, lamps that distribute their light in all directions (omnidirectional), such as incandescent lamps, can easily be measured using an integrating sphere.

While total lumen output for directional lamps can also be measured in a goniophotometer, the integrating sphere has been the preferred apparatus to measure total luminous flux from electric lamps for general lighting service. An integrating sphere provides a fast method of comparing the lumen output of different lamp types, at a lower cost than a goniophotometer. Tests using an integrating sphere do not always produce certain and precise results, but they can provide a good indication of whether a lamp would fail or pass a more accurate and comprehensive test. Integrating spheres are widely used in the lamp industry, especially for manufacturing quality control.

Integrating spheres can be equipped with either a photometer head (V(λ)-corrected detector) or a spectroradiometer, which is becoming a common practice. The use of a spectroradiometer enables the measurement of colour quantities and facilitates more accurate measurement of total luminous flux.

GONIOPHOTOMETERS

The second key measurement apparatus is a goniophotometer, as shown in Figure 4. A goniophotometer is required to measure luminous intensity distributions and is commonly used to measure light sources and lamp designs with more complex output, such as directional lamps and lighting fixtures. Goniophotometers can scan the whole sphere (360 degrees) of flux radiating from the light source. In some cases, the goniophotometer uses a mirror, mounted on an arm rotating around the stationary light source and reflecting the light to a photometer, which sends the data to attached recording equipment.

A comprehensive goniophotometer scan yields a very accurate measurement of the lamp or luminaire output, but the process is not always easy and can be slow and expensive.

Figure 3
Three metre integrating sphere
(Photograph courtesy of VSL, Delft)

Figure 4
Goniophotometer at Electrical and Electronics Institute laboratory, Thailand (Photograph courtesy of Marie Leroy, UNEP)

2.5.3 TESTING COMPETENCY

To provide consistent, accurate, and reliable test results, laboratories need to gain certain competencies, obtain qualifications (e.g. accreditation), and maintain them. Staff training and inter-laboratory comparison testing are crucial activities for achieving this goal:

STAFF TRAINING

Laboratory personnel require training on both test standards and performance standards to comprehend the meaning of the parameters involved, why they are important, and how to test them correctly and accurately. This specialised training can be carried out in-house or contracted out to trained independent experts.

Box 6 | **Policymaker resource: Building expertise at the Global Efficient Lighting Center**

The Global Efficient Lighting Centre (GELC) in Beijing, China, is a non-profit organisation that is accredited to provide specialised lighting testing, training, advice, quality control, and capacity-building support to developing and emerging countries. The centre was established as a UNEP Collaborating Centre for Energy Efficient Lighting to promote the rapid development of energy efficient lighting technologies around the world. Countries can access support from GELC through the UNEP-GEF en.lighten initiative. This includes a range of training opportunities, as well as some compliance testing exercises. However, current support does not extend to ongoing verification activities.

For more information, see:
http://www.gelc.com/
or contact the UNEP en.lighten initiative.

ACCREDITATION

Obtaining laboratory accreditation is a specialised process and requires a competent and recognised accreditation body to carry it out. In general, there are two types of laboratory accreditation programmes: calibration laboratory accreditation and testing laboratory accreditation:

- **Calibration laboratory accreditation** is provided to laboratories for the measurement of specific quantities, e.g. luminous flux, with claimed uncertainties, regardless of product;

- **Testing laboratory accreditation** is provided for testing specific products, e.g. fluorescent lamps, with a specific test method standard for the product type to determine compliance.

While there are many accreditation bodies globally, only a limited number of them provide testing laboratory accreditations for lighting products.

Testing laboratory accreditation is required for verification testing for lighting products. Accreditation is given on a test-by-test basis, not on a facility basis. It is important for the applicant laboratory to understand the requirements for accreditation.

There are well established and accepted international requirements for accreditation bodies, which are dictated in the ISO guide, ISO/IEC Guide 58:1993, *Calibration and testing laboratory accreditation systems — General requirements for operation and recognition.* This guide stipulates that the accreditation body should be an independent organisation capable of auditing and assessing the proposed laboratories. If an accreditation body (national or international) is designated to support an energy efficient lighting programme, it must have established competencies to accredit laboratories conducting each of the specific product tests being considered as part of the testing laboratory accreditation before it can issue accreditation for those tests.

More information on laboratory accreditation can be found in Annex A and in the UNEP-GEF en.lighten initiative guidance note, *Good Practices for Photometric Laboratories.*

LABORATORY PROFICIENCY TESTING

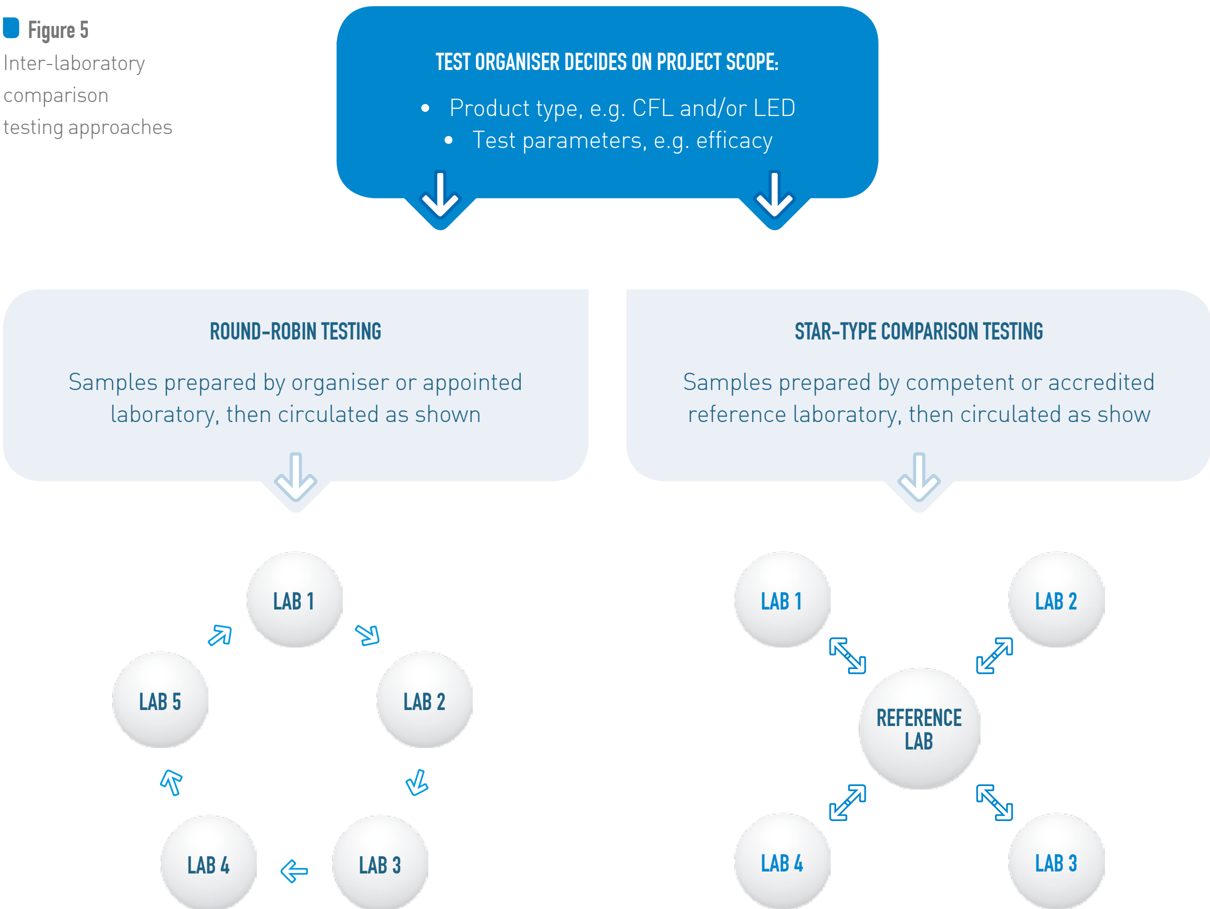
Proficiency testing is used to determine if a laboratory has the technical capabilities to conduct certain tests. In proficiency testing, samples of common products (e.g. CFLs or LED lamps) are used as comparison artefacts. Inter-laboratory comparisons are commonly used to implement proficiency testing. These test the degree to which the applicant laboratory's measurement results agree (or do not agree) with those of the reference laboratory (also known as the 'master testing laboratory') or with the average of other participants' findings, when measuring the comparison artefacts using a standard test method. Generally, the organisers determine the measurement parameters and test standard for the proficiency testing, such as photometric or electrical testing. There are two major types of inter-laboratory comparisons: round-robin and star-type comparison testing.

- **Round-robin testing:** In this case, a sample, or several samples, are selected and circulated around participating laboratories so that all laboratories measure the same samples.[18] These results are then compared to an agreed-upon norm, such the average of all participants' measurements. The participants' results may also be compared with those of a reference laboratory that has tested the same samples.
- **Star-type comparison testing:** In this case, the reference laboratory prepares and tests a group of samples. These samples are then equally divided among the participating testing laboratories. The participating testing laboratories receive and test the samples at the same time, then send them back to the reference laboratory. The participating laboratories' test results are compared with those of the reference laboratory.

By analysing the test results from each laboratory, inter-laboratory comparison organisers are able to identify those laboratories that can competently conduct the chosen test procedures and those that need to correct procedures and move to re-certify.

Figure 5 shows these two approaches diagrammatically and Table 4 provides a comparison of the two approaches.

Figure 5
Inter-laboratory comparison testing approaches



19 Samples for round-robin testing are typically selected based on their stability and possibly also on a significant parametric feature (e.g. low power factor or high correlated colour temperature). The purpose of introducing these kinds of testing artefacts is to test (push) the extremes of the lighting product performance range to identify any limitations in the test equipment/procedure.

Table 4

Comparison of round-robin and star-type approaches to inter-laboratory comparison

	Advantages	Disadvantages
Round-robin testing	Because all laboratories test the same samples, it is easier and more direct to compare test results. Round-robin testing is more flexible (the number of participating testing laboratories can range from two to more than 100). It is suitable for robust artefacts that are not likely to be damaged or drift during circulation.	Longer testing process. Any sample breakage during circulation would necessitate re-circulation of a new sample, i.e. all measurements before the breakage would be wasted. This is often the case with incandescent and fluorescent lamps.
Star-type comparison testing	Shorter testing process. Any sample breakage occurring in one laboratory will not influence the results of other testing laboratories. The results can be more reliable than those from round-robin testing, as the samples travel to fewer locations and are subjected to fewer handling instances that can disturb the sample.	Reliance on one master laboratory. If the reference laboratory fails, the whole project fails.

Box 7 Case study: Laboratory proficiency testing

In 2011, under the International Energy Agency (IEA) Implementing Agreement on Energy Efficient End-use Equipment (4E) framework, the Solid State Lighting Annex, which assists country governments in promoting quality assurance of LED lighting products worldwide, launched an initiative to support harmonisation of solid state lighting testing around the world. The objective of the testing was to address the lack of a global laboratory performance assessment scheme. In practical terms, this was a large-scale, international inter-laboratory comparison test of solid state lighting products

Altogether, 54 laboratories from 18 countries participated directly in the study, comparing measurements of photometric, colorimetric, and electrical quantities of several types of solid state lighting products. Proficiency test data was also collected from an additional 56 laboratories to feed into the study. Five different types of artefacts were used in this inter-laboratory comparison: omnidirectional LED lamps, directional LED lamps, low-power-factor LED lamps, high correlated colour temperature (CCT) LED lamps/luminaires, and incandescent lamps operated on AC voltage, with a few optional types. The study also compared measurement of luminous flux, luminous efficacy, active power, root mean square current, power factor, chromaticity x and y, CCT and colour rendering index (CRI).

In order to involve many participating laboratories worldwide, this comparison exercise was operated by four nucleus laboratories:

- VSL BV, The Netherlands - operated by Dutch Metrology Institute;
- National Lighting Test Centre, China - operating agent of GELC;
- National Metrology Institute of Japan, Advanced Industrial Science and Technology;
- NIST, United States.

This project provided many laboratories in many countries with new knowledge and experience in proficiency testing for measuring solid state lighting products. It also established a basis to promote solid state lighting laboratory testing accreditation worldwide in support of harmonising regulations and government programmes to further accelerate the development of this technology.

The final report from the project is available at:
http://ssl.iea-4e.org/testing-standards/laboratory-comparability

3 INTERPRETATION OF TEST RESULTS

Performance testing results need to be as accurate as possible. They are used for a number of purposes, including enforcement actions which require strong supporting evidence to withstand scrutiny and legal challenges. This chapter provides an introduction to the interpretation of test results,[19] provides guidance on the concept of uncertainty, addresses the traceability of measurements, and discusses the determination of 'pass' or 'fail' conditions.

Performance testing results are used to assess whether products comply with energy efficient lighting programme requirements and form the basis of lighting policies, which rely on these results to inform on market trends or to estimate achievable energy savings potentials. They are also used to inform enforcement actions. As these actions can include drastic measures, including the removal of products from the market, the evidence (i.e. the test results) must be robust enough to withstand scrutiny and legal challenges.

Many factors can affect the final results of a tested lamp. Even if the same lamp is measured several times, in the same way, and in the same conditions, a different value may result each time. It is therefore important for policymakers to understand testing results and their limitations.

3.1 UNCERTAINTY

Uncertainty is a key factor that affects all test results. Uncertainty is not any type of mistake, but rather an intrinsic unknown that accompanies all test results. Both laboratory technicians and experts who draft test standards strive to minimise uncertainty in order to achieve the test result that is closest to the true value.

An evaluation of uncertainty is a general requirement for all measurements, as well as a critical requirement for laboratories that conduct calibration testing. However, evaluating uncertainty can be difficult and resource intensive, particularly for lighting products, for which a large number of samples must be tested to assess many different factors. In addition, including strict uncertainty requirements in all product test reports can place considerable burden on testing laboratories, and can lead to higher costs of testing, which could in turn increase the cost of the product to consumers.

Several existing standards can relieve the burden on testing laboratories for evaluating uncertainty. The key points from these are listed in Table 5.

When reviewing uncertainty, policymakers will need to consider how stringent the requirements should be and whether any of the standards or guides listed in Table 5 can be applied. The level of stringency should depend on the strictness of compliance assessments, as well as the technical competency and capabilities of testing laboratories in the region. All test engineers should understand exactly what uncertainty in measurements means and be trained on uncertainty evaluation. Some basic guidance is given below.

It is important not to confuse the terms 'uncertainty' and 'error':

- Error is the difference between the measured value and the 'true value'[20] of the parameter being measured;
- Uncertainty is a quantification of the doubt about the measurement result.

Errors and uncertainties can come from:

- The measuring instrument;
- The lamp being measured;
- The measurement process;
- 'Imported' uncertainties;
- Operator skill;
- Sampling issues;
- The testing environment.

19 This discussion is intended to serve as a beginner's guide for those individuals who need to know about measurements, namely technicians and managers in testing and calibration laboratories, research scientists, those involved in compliance checking activities and policymakers. It is recommended that policymakers and compliance personnel familiarise themselves with these topics, and seek additional information from experts.

20 As noted, no measurement can be exact. The 'true value' is the actual parameter, which is represented by the measured value plus the uncertainty.

Known errors can be corrected, but an error whose value is not known is a source of uncertainty. There are two types of uncertainty[22]: **Type A** (inherent) and **Type B** (external), which are explained in Table 6.

Table 5

Key points relating to uncertainty in existing standards

Standard[21]	Key Points Relating to Uncertainty
ISO 17025	• If a well-established test standard is used, the uncertainty reporting requirement is satisfied; • A test method is deemed 'well-established' if it controls uncertainty contributions from major components of testing, such as test equipment, environment, and personnel.
IEC Guide 115	• If an appropriate test standard is used, the uncertainty statement may not be needed.
NVLAP testing accreditation for LM-79	• The United States ENERGY STAR programme accepts test results from laboratories accredited by NVLAP; • Standard LM-79 does not require the uncertainty statement in test reports, unless required by the user.
CIE S 025	• Uncertainty reporting is required, but is not stringent; • Test reports can include the uncertainty values of similar products (where full uncertainty analysis has been conducted) to avoid having to carry out full analysis of uncertainty values for each individual tested sample; • Contains calculated uncertainty allowances for LED lighting products, if all tolerance requirements of the test standard are met; • Regulators can see the approximate level for uncertainties in measurements if CIE S 025 is strictly used.

Table 6

Types of uncertainty

Type A (Inherent) Uncertainty
Occurs when the same measurement is carried out many times on the same product, but the **result of each measurement varies from one to the other** to some extent. Such variation demonstrates that **no single measurement could represent the true value of the measured sample. The average of 'many' measurements** is believed to be closer to the true value.

Type B (External) Uncertainty
Defined as the **variation derived from external factors.** For example, if a power meter is used to measure the power consumption of a lamp, and the power meter's measuring accuracy is within 0.2%, the measured test result may vary from the true value of the power consumption. The **accuracy of the equipment is the cause of uncertainty.**

The uncertainty of a measurement can provide an indicator of its quality. Because there is a margin of doubt regarding any measurement, two numbers are needed to quantify the uncertainty. Typically, measurements are reported as the measured result, together with a plus (+) or minus (-) range of uncertainty figure, e.g. 'The length of the lamp was 20 cm ±1 cm.' Section 3.3 explains how to take laboratory uncertainty into account when interpreting test results for compliance purposes.

A laboratory should have its own estimates for both Type A and Type B uncertainty, as well as an estimate of the combined uncertainty. These estimates are normally used for accreditation and inter-laboratory comparison tests only. Both inherent and external uncertainty can be reduced by:

- Providing professional training for personnel;
- Selecting equipment with high degree of accuracy;
- Ensuring consistency of the testing environment; and
- Testing multiple samples and averaging or grouping the results.

21 See Annex D for full references to each standard listed, including where they can be located online for access or purchase.
22 NIST 2015

3

3.2 TRACEABILITY OF MEASUREMENTS

The traceability[23] of measurements is another critical factor in any measurement result, especially those results that are used in legal proceedings, for example, if a manufacturer is accused of non-compliance.

The term 'measurement traceability' refers to an unbroken chain of comparisons relating an instrument's measurements back to one of the seven international standard units such as the candela (i.e. all of the calibration/measurement equipment used in a test procedure are themselves in calibration and referenced). Calibration to a traceable standard, i.e. tuning a piece of equipment to a certain standard, can determine an instrument's contribution to the uncertainty of a test measurement.

3.2.1 THE IMPORTANCE OF TRACEABILITY

The performance of test equipment can change over time. These changes are mainly due to:

- Environmental conditions (such as humidity, dust, or heat);
- Frequent and/or intensive use; or
- Degradation due to age.

Whatever the cause of performance variation, laboratory equipment managers must meter and calibrate their test equipment on a regular basis (and sometimes on an as-needed basis) to ensure that test results are as accurate as possible. Normally, most equipment requires calibration, or validation by an independent calibration laboratory, at least once a year. For some very frequently used and/or important equipment, it could be every six months. If a piece of equipment is found not to work properly during normal use, calibration is needed to adjust it back to its normal functioning status.

3.2.2 SETTING THE STANDARD FOR MEASUREMENT TRACEABILITY

Metering and calibration (resulting in traceability) should be conducted at qualified metrology institutes on a national or international level. In many countries, national standards for weights and measures are maintained by a national metrology institute, which provides the highest level of standards for the calibration or measurement traceability infrastructure in that country. Some examples of national metrology institutes are set out in Table 7.

Table 7

Examples of national measurement institutes

Country	Institute
Australia	National Measurement Institute
China	National Institute of Metrology
Germany	Physikalisch-Technische Bundesanstalt
United Kingdom	National Physical Laboratory
United States	National Institute of Standards and Technology (NIST)

Further information on measurement traceability can be found in the UNEP-GEF en.lighten initiative guidance note, *Good Practices for Photometric Laboratories.*

3.3 DETERMINATION OF PASS AND FAIL

Broadly, testing results indicate whether the sample conforms with energy efficiency regulations, but policymakers are responsible for deciding how to interpret these results into a 'pass' or 'fail' for the product model. This interpretation must bear in mind that test results can be affected by Type A and Type B uncertainties, as described above.

PASS: Indicates lamp samples conform to MEPS and programme specifications;
FAIL: Indicates lamp samples don't conform to MEPS and programme specifications.

Both uncertainty and errors can be minimised by testing a sample set of products, as highlighted in the discussion on sampling in Section 2.5. This also reduces the possibility of testing either a 'rogue' or 'golden' sample (in which a sample is either not part of the norm, or is hand-picked by the manufacturer), which can lead to skewed and unrepresentative test results.

23 Traceability can be defined as an unbroken record of documentation ('documentation traceability') or an unbroken chain of measurements and associated uncertainties ('metrological traceability'). As used here, the word 'traceability' always means 'metrological traceability.'

The compliance of a product model can be determined by calculating:

- The ***average*** measured value of the selected model samples, to determine whether or not the average results 'pass' the test; and/or
- The ***percentage*** of the sample lamps that have passed or failed, to make a decision based on the quantity of products that 'pass' the test. (The relevant test standard or regulatory instrument usually specifies the sample size and how the resulting data is to be processed.)

The combined result can then be compared to the performance requirement levels or labelling programme specification levels, taking the quantified uncertainty range (as explained in Section 3.1) into account to determine whether the product model is compliant.

Policymakers can develop or implement existing guidelines to help determine pass and fail results, such as those prepared by the International Laboratory Accreditation Cooperation (ILAC).[24] In accordance with the ILAC guidelines, the following simple method can be used for determining whether a product passes or fails:

1. Define the acceptance limit based on performance requirements or specifications;
2. Assign 'pass' or 'fail' status by comparing all measured points to the acceptance limits;
3. Note the plus and minus uncertainty thresholds associated with the measured value.

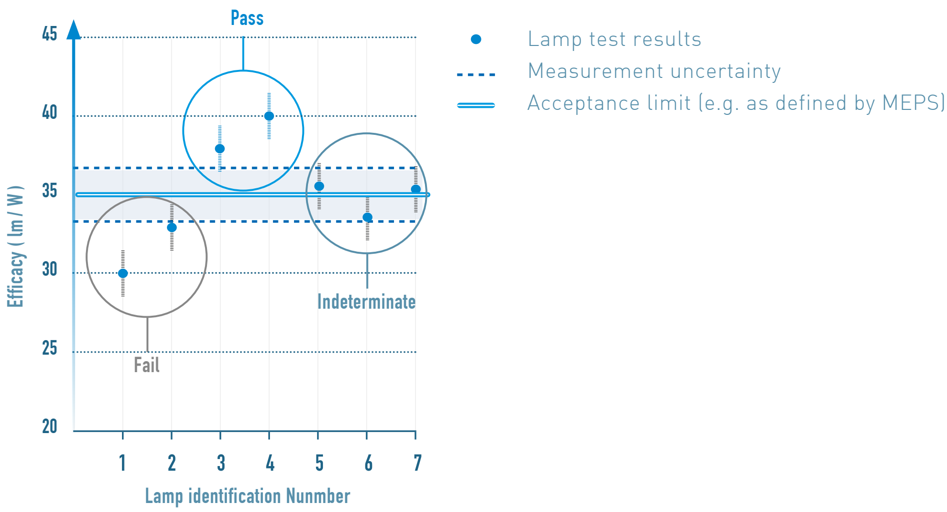
This can be plotted graphically, as shown in figure 6

As Figure 6 shows, by applying ILAC guidelines, policymakers can predict three potential outcomes from testing:

1. **PASS:** Test results meet, or exceed, the required performance requirements or specification level by more than the laboratory's plus threshold for uncertainty.
2. **FAIL:** Test results fall below the required level by more than the laboratory's minus uncertainty threshold.
3. **INDETERMINATE:** Test results do not fall outside of the laboratory's uncertainty band, i.e. the results are within the plus or minus range of uncertainty around the required performance level. Policymakers must then determine the next course of action to assess compliance of the product. Usually, re-testing is recommended.

The more complex the test procedure, and the more sensitive the energy-performance results are to the test conditions (such as light output under different temperature conditions, especially for LEDs), the greater the likely variability from one test to another, and from one sample to another. For this reason, policymakers can build verification tolerances into energy efficient lighting regulations or operating policies that allow for variation due to laboratory uncertainty between the reported performance measurement and the actual measurement to be taken into account when deciding upon compliance action. However it should be made clear to manufacturers and importers that any provision for laboratory uncertainty does not apply as a general tolerance in the application of minimum performance levels.

Figure 6
Example of compliance and measurement uncertainty. Source UNEP 2014



24 ILAC-98: 03/2009, *Guidelines on the Reporting of Compliance with Specifications.* http://anab.org/media/1086/g8-statements-of-compliance.pdf.

4 USING TEST RESULTS

A comprehensive and reliable testing process and the resulting valid product test data are critical for energy efficient lighting policy and compliance frameworks to effectively accomplish their objectives. This chapter outlines how test results can be used to inform these activities toward ongoing policy development. It also explains how regional resource sharing can maximise the impact of testing.

The use to which product testing data is put will typically be defined when setting the objectives of a performance testing programme. For example, in a compliance framework, product testing normally forms the basis for determining whether energy performance claims have been met, thus ensuring compliance and programme integrity. Policymakers can also use product testing data to establish market performance baselines, inform cost-benefit calculations and estimate the environmental impacts of policies.

4.1 TEST RESULTS FOR COMPLIANCE ACTIVITIES

Market sampling and testing are key steps in the process of determining whether energy performance claims have been met in a verification framework. Products that are subject to energy performance requirements do not always carry performance declarations in the form of labels. Even if products are labelled, periodic verification of claims about these products' energy performance is critical for maintaining high levels of confidence in the programme for consumers, manufacturers, and other stakeholders.

Testing can be used to provide policymakers and compliance authorities with a market view of compliance levels, as well as to warn manufacturers and suppliers that authorities are conducting checks.

As introduced in Section 2.1, there are two main forms of compliance tests:

- **Screen-tests** are typically used to provide a preliminary assessment of whether products are likely to fail a full verification test;
- **Full procedure verification tests** are carried out in accordance with regulations by an accredited laboratory. This level of testing is usually required to support subsequent legal enforcement action.

The use of the results of screen-tests and full verification tests is explored in more detail below.

4.1.1 SCREEN-TESTS

Generally, the results of screen-tests are used to identify likely cases of non-compliance. The results are unlikely to be subjected to full legal scrutiny, and thus a reduced, and therefore lower cost, testing approach can be used.

Screen-testing may involve using a smaller number of samples to be tested and/or reducing the number of cycles or test durations relative to the full testing procedure. In short, the specified screen-test procedures are normally used only to provide a quick and reasonable indication of compliance with regulated performance parameters. In some cases, it might also be possible for less senior staff to carry out some of the simpler test procedures.

Screen-testing for lamps may also focus on only one or two key regulated parameters that do not require lengthy testing periods, such as:

- Total luminous flux or efficacy (for those devices that can utilise relative photometry);
- Start-up time or warm-up time (if applicable);
- Colour temperature (if applicable);
- CRI (if applicable);
- Abbreviated switching cycles (if applicable).[25]

A European project known as Ecopliant, which focused on increasing levels of compliance monitoring across the European Union, has identified several countries that use screen-testing techniques to help identify potential cases of non-compliance (See Box 8).

25 Some regulations allow testing for a limited number of parameters to be used for compliance purposes if the standard is properly followed, and used the specified sample size. Other regulations require that a full test procedure must be followed to prove non-compliance.

Box 8 **Case study: European Ecodesign Compliance Project — Ecopliant**

Ecopliant is a project focused on identifying best practices for compliance monitoring activities in the European Union. It found that several countries use screen-testing techniques to assess compliance of domestic lighting products, such as:

- A reduced number of parameters were tested, namely:
  - Lumen per watt,
  - Warm-up time;
- A simplified test method was applied using a small integrating sphere;
- A non-accredited laboratory was used:
  - Testing was carried out on the enforcement authority's premises by internal enforcement authority staff.

The full report describing these findings is available on the Ecopliant website at: http://www.ecopliant.eu/wp-content/uploads/2013/10/D1.3-Product-Targeting-Techniques.pdf (Ecopliant 2014)

Results from screen-tests can typically indicate overall product quality or energy performance. For example, if a number of samples of the same model fail an abbreviated switching test, this can be indicative of the model's expected longevity in actual use. Similarly, if the luminous efficacy results for a lamp model are below the regulated levels, it may indicate other shortcomings and justify the need for a full verification test.

4.1.2 FULL VERIFICATION TESTS

Market surveillance authorities must be mindful that full verification test results are likely to be used in enforcement actions or other follow-up activities, which require strong evidence to support potential legal enforcement actions. Therefore, the appropriate compliance process must be precisely followed, including the sampling methodology and reporting of comprehensive results. Full procedure verification tests demand that the specified procedure for measurement of each regulated parameter is followed precisely in an accredited laboratory. The laboratory must document that all measurements, test conditions, and records required in the test procedure have been followed. In cases where enforcement actions or sanctions are necessary, the results must sufficiently demonstrate non-compliance beyond the bounds of uncertainty.

Full procedure verification tests can be expensive (and lengthy, where parameters such as lumen maintenance or goniophotometer testing are involved), especially for the full suite of tests that may be required in an enforcement action. It is possible that these results will be challenged, and in some cases, lead to re-testing. Therefore these types of tests should be used prudently, i.e. where their impact is likely to be the greatest, while ensuring that both the process and results are sound.

4.2 TEST RESULTS FOR DEVELOPING REGULATIONS AND COST-BENEFIT CALCULATIONS

Accurate and timely product data, some of which can be derived from product testing activities, are essential for designing, evaluating, and revising product performance standard and labelling thresholds.[26]

Five general areas of product-related data can inform this development process:

1. **Market:** General and specific market data is required to assess the potential impacts of policies and optimise programme design. Required data inputs include annual sales volume of lamps, prices, production volumes, and import and export volumes;
2. **Engineering:** A comprehensive database of technical and energy characteristics for typical (baseline) lamps is needed to define the relationship between cost and efficiency for the lamps;
3. **Usage:** Indicates how lamps are used by end-users, as well as where and over what period of time;
4. **Behavioural:** Addresses purchasing decisions, as well as the attitudes toward energy-efficiency expressed by the consumers, users, retailers and manufacturers;
5. **Other:** Data and forecasts for energy prices, information on utility generating sources and fuel mix, national energy statistics, emissions, and other factors.

When available, the above data set can provide a clear picture of the market and users. This can help to inform regulators on setting appropriate standard levels, consider how these levels could affect the market, and discern or confirm any product trends. However, it is not often possible to have a complete data set, and in such cases policymakers must use best estimates based on the available resources.

26 For a comprehensive discussion on characterising the market and on setting MEPS for lamps, please refer to the UNEP-GEF en.lighten initiative guidance notes, *Developing Minimum Energy Performance Standards for Lighting Products* and *Efficient Lighting Market Baselines and Assessment respectively.*

While engineering data can be obtained from published product specifications, more objective (and often more detailed) data can be obtained through product testing. However, policymakers should be aware that this data can be time consuming to obtain (e.g. lifetime testing can take months or even years). Engineering data can serve as one of the key data sets to inform the development of energy efficiency regulations. For example, a continuous curve that describes the minimum required efficacy of products based on their rated power can be extremely useful in determining MEPS levels for lamps.

Establishing the minimum performance levels requires precise knowledge of the efficacies of products in the market to ensure that MEPS are up to date and will result in maximum energy savings. Additionally, the minimum performance level can be adjusted up or down (making the requirements more or less stringent) based on evidence from manufacturers, energy efficiency advocates and other stakeholders. These adjustments will have significant impacts on national energy and climate change goals, so it is best to ensure detailed test data and evidence is used at all times when establishing the levels. An example of the performance levels for Europe is shown in Figure 7.[27]

Lamp lifetime, and other lamp parameter, test results are used to determine and refine estimates of life-cycle costs and payback periods. Critical representative lamp data is required for analysing the costs and benefits of various lamp technologies, including:

- The energy used by the lamp (measured in watts);
- The ability of the lamp to produce the amount of light required;
- 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).

This analysis process is carried out for the different lamp types under various levels of regulatory stringency.[28] Generally, a government will select a MEPS level that is technologically feasible, economically justified, and will result in significant energy savings through the removal of the least efficient products from the market. This process is fully dependent on having robust engineering data from a comprehensive and transparent lamp testing process.

In addition, there are other benefits from collecting performance data as discussed in Box 9. A detailed example of how Australia used testing data to inform their policy approach is given in Annex C.

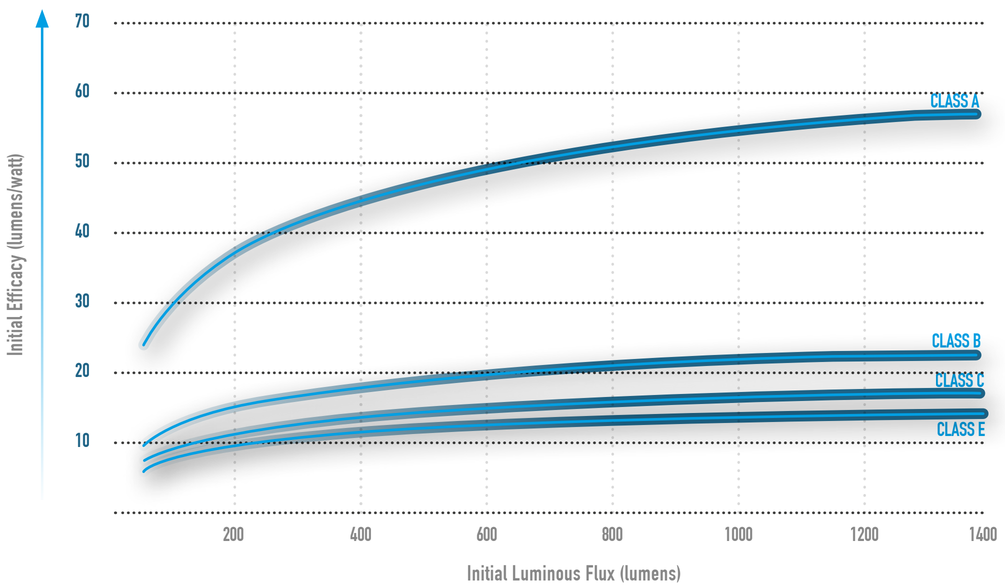


Figure 7
Efficacy performance levels for European Union energy labels of omnidirectional lamps

Source: European Commission 2012a

27 Note that for LEDs, a straight line may be used as their performance limits are different to other lamp technologies, such as incandescent technology.
28 For example, most early standards required CFLs to have a minimum lifetime of 6,000 hours. But as products improved, some standards evolved to require CFLs with a lifetime of 8,000 or even 10,000 hours, further improving the cost-effectiveness of these lamps and their life-cycle costs.

Box 9

Policymaker tip: Using test data to improve consumer uptake of new lighting technologies

Data on how new lamps may perform relative to incumbent products can help to ease market transformation. Labelling or point of sale information that includes photometric data regarding lighting distribution (useable light area) along with other parameters (where available) helps policymakers boost consumer satisfaction with energy efficient alternatives. For example, some early models of CFLs and LED lamps were not able to match the uniform output of the incandescent lamps that they were intended to replace. Consumers complained that these lamps had 'dark spots' or cast uneven light, even if their measured light output equalled or surpassed the output of comparable incandescent lamps. While not as critical as efficacy data, collecting performance data aids governments and manufacturers in anticipating or preventing potential negative reactions by consumers, and address problems before the product reaches the market, which ensures increased consumer satisfaction and thus higher market uptake of energy efficient products.

4.3 RESOURCE SHARING

Market monitoring and verification activities are likely to operate under resource limitations. It therefore makes economic sense for authorities with overlapping testing responsibilities to avoid duplication by sharing intelligence, experience, and results. This is particularly applicable where the responsibility for market monitoring and verification is not centralised.

In addition, bilateral, multi-lateral, or regional collaboration can lead to joint or comparable product testing (as discussed in Section 2.2.3) and can also lead to collaborative data gathering for market characterisation (estimates of installed stock, end users, energy use, product types, etc).

These joint activities can allow governments to increase monitoring and verification frameworks while using fewer resources, thereby minimising the risk of non-compliance with energy efficiency regulations in the regional market. Regional resource sharing is especially beneficial where countries use many of the same, or similar, product models. For example, if countries are sharing testing data, there is no need to duplicate testing across borders, which drives up costs and makes trade more difficult. See Box 10 for other ideas on resource sharing.

Box 10

Policymaker tip: Resources that can be shared between countries

1. Product registration systems: If there is an energy efficient lighting programme in place that requires product registration for entry into the market, the registration data could be shared across borders to assess whether any non-compliant products are being 'dumped' into neighbouring markets. The market baselines among participating countries may be very easily comparable. A common registration system also provides a good foundation for joint or regional activities. Further guidance on the development and operation of product registration systems can be found in the UNEP-GEF en.lighten initiative guidance note, *Developing Lighting Product Registration Systems.*

2. Test results: Sharing test results is the most efficient way to locate non-compliant products on the market. If Country A finds a non-compliant model in its market, neighbouring countries in the region may find the same, or similar models, in their national market. These countries are encouraged to pool their resources, either using each other's test results or carrying out joint testing of the product. Note that national regulations may restrict the sharing of such data, or require an agreement to be made between agencies on how the data is to be shared, used and kept confidential.

3. Coordinated MVE planning: Partner countries can agree to each focus their efforts on different types of lighting products. For example, Country A tests CFLs and Country B tests LEDs. They then share the test results with each other.

5 RECOMMENDATIONS

Developing a performance testing programme to inform the creation of lighting policy and regulatory frameworks and addressing the related technical and quality issues is a multi-step process, which requires careful and considered implementation. The key recommendations for achieving this are outlined in this chapter.

Many variables can affect the key decisions in building, or sustaining, such programmes and it is wise to consider each variable as it relates to your country's:

- Government structure and policy framework;
- Lighting product marketplace and stakeholder involvement;
- Resource availability and economic stability;
- National culture as it relates to lighting.

It is recommended that policymakers follow these primary steps toward programme development:

1. Decide what types of lighting products will be regulated and monitored, such as:

- Incandescent light bulbs;
- CFLs;
- LED lamps.

Next, remember that testing lighting products is key to effective policy development and the operation of MVE programmes. Consider:

2. How performance testing data will be used, whether to:

- To inform market trends;
- Estimate potential and achievable energy savings;
- Verify compliance with regulations and informing enforcement actions.

3. Which parameters should be included, such as:

- Light output (total luminous flux);
- Electrical power (consumption or rated power);
- Luminous efficacy;
- Lifetime;
- Lumen maintenance (luminous flux maintenance factor).

Assess how much testing is required for your programme, based on your manufacturing base, regional lighting activities, and other factors. Estimate available testing laboratory capacity to support your programme at start-up and over the long term – within your country and the broader region.

4. Decide whether testing will be conducted using:

- National (government-funded) testing facilities for lighting;
- For-profit testing laboratories (in-country or internationally-based);
- Shared testing laboratory services at a regional level.

Consistent and reliable test results are vital to effective programmes.

5. Ensure that test results are accurate and interpreted correctly. Consider:

- Testing processes and methodologies;
- Certain competencies and qualifications (accreditation);
- Inter-laboratory comparison testing;
- Staff training;
- Traceability of measurements;
- Understanding of uncertainty.

Collaborating with other countries can save many resources and boost economies, and harmonisation is an important element for enabling a fair and thriving market.

6. Consider what international resources and opportunities are available for sharing, such as:

- Uniform, or harmonised, testing procedures and parameters for lighting products;
- Best practices and experience of other countries;
- Existing internationally accepted standards' and the resources available from their sponsoring institutions.

6 RESOURCES

To support countries and regions in the development of efficient lighting activities and strategies, the UNEP-GEF en.lighten initiative, CLASP and other organisations offer a wide array of practical tools. The most relevant of these are described below.

UNEP-GEF EN.LIGHTEN INITIATIVE PUBLICATIONS

Achieving the Transition to Energy Efficient Lighting Toolkit – delivers best practice guidance for policy development and provides technical and practical tools for those directly involved in national phase-out activities. This toolkit is available online in five languages: Arabic, English, French, Russian and Spanish.

http://www.enlighten-initiative.org/ResourcesTools/EfficientLightingToolkit.aspx

Developing Minimum Energy Performance Standards for Lighting Products: Guidance Note for Policymakers - illustrates how to develop MEPS for lighting products. It is a practical resource for governments on the processes to follow when establishing MEPS in a national or regional market.

http://www.enlighten-initiative.org/ResourcesTools/Publications.aspx

Developing Lighting Product Registration Systems: Guidance note – provides practical guidance and examples to energy efficiency programme administrators on how to develop, operate and maintain a registration system for lighting products.

http://www.enlighten-initiative.org/ResourcesTools/Publications.aspx

Efficient Lighting Market Baselines and Assessment: Guidance note – provides practical guidance to policymakers and energy efficiency programme administrators on how to determine national baselines, use this data for market monitoring purposes, and how to monitor the market to continuously update the baselines.

http://www.enlighten-initiative.org/ResourcesTools/Publications.aspx

Enforcing Efficient Lighting Regulations: Guidance note – presents best practices for enforcing energy efficiency regulations for lighting products. It can be used as a practical resource by policymakers and enforcement bodies when developing or revising their enforcement regime.

http://www.enlighten-initiative.org/ResourcesTools/Publications.aspx

Good Practices for Photometric Laboratories: Guidance note – provides guidance on the operation of photometric laboratories to ensure that testing results are fully supported by evidence of the legitimacy of the measurement values obtained and to give confidence in the accuracy of these results and conformance with test procedures/conditions.

http://www.enlighten-initiative.org/ResourcesTools/Publications.aspx

Performance Testing of Lighting Products: Guidance note - outlines the process for carrying out energy efficiency performance testing for lamps, and how to interpret and use the data. It is a practical resource for energy efficiency policymakers and programme administrators.

http://www.enlighten-initiative.org/ResourcesTools/Publications.aspx

Product Selection and Procurement for Lamp Performance Testing: Guidance note – provides guidance on the steps required when selecting and procuring residential lamps to undergo performance testing, including defining the product scope, selection methodology, and the procurement and tracking protocol.

http://www.enlighten-initiative.org/ResourcesTools/Publications.aspx

Global Compact Fluorescent Lamp Check Test Results and Analysis Report – provides results and analysis of the safety, performance and mercury content of 47 models of CFLs tested at the Global Efficient Lighting Centre in 2013. The lamps were sampled in 10 countries (Azerbaijan, Chile, Costa Rica, Dominican Republic, Guinea-Bissau, Lebanon, Panama, Tonga, Tunisia and Uruguay) with the support of the UNEP en.lighten initiative.

http://www.enlighten-initiative.org/ResourcesTools/Publications.aspx

Inter-laboratory Comparison Testing of Light Emitting Diode (LED) Lamps - presents the results of an inter-laboratory comparison testing exercise undertaken by six laboratories in Southeast Asia in 2015 (in accordance with ISO/IEC 17043, *Conformity assessment - General requirements for proficiency testing*), with the Global Efficient Lighting Centre as the nucleus laboratory. (Publication expected end 2015).

http://www.enlighten-initiative.org/ResourcesTools/Publications.aspx

Lamp Sampling in Cambodia, Indonesia, Lao PDR, the Philippines, Thailand and Viet Nam – presents a summary of a 2014 lamp sampling exercise coordinated by the International Institute for Energy Conservation to identify and sample compact fluorescent and LED lamps in six target countries. The objective of the exercise was to provide participating agencies with guidance on, and experience in, conducting a retailer survey, lamp purchasing and witnessing, and packing and shipping; and to sample lamps for subsequent testing undertaken by the Global Efficient Lighting Centre.

http://www.enlighten-initiative.org/ResourcesTools/Publications.aspx

Southeast Asia Compact Fluorescent Lamp Performance and Mercury Testing and Analysis Report – presents the results and analysis of testing undertaken by the Global Efficient Lighting Centre on CFLs purchased in six Southeast Asian countries (Cambodia, Indonesia, Lao PDR, Philippines, Thailand and Viet Nam in 2014. (Publication expected end 2015)..

http://www.enlighten-initiative.org/ResourcesTools/Publications.aspx

Southeast Asia Light Emitting Diode Lamp Performance Testing and Analysis Report – presents the results and analysis of testing undertaken by the Global Efficient Lighting Centre on LED lamps purchased in six Southeast Asian countries (Cambodia, Indonesia, Lao PDR, Philippines, Thailand and Viet Nam in 2014. (Publication expected end 2015).

http://www.enlighten-initiative.org/ResourcesTools/Publications.aspx

CLASP PUBLICATIONS

Energy Efficiency Labels and Standards: A Guidebook for Appliances, Equipment and Lighting – provides guidance for government officials and others responsible for developing, implementing, enforcing, monitoring, and maintaining labelling and standards-setting programmes.

http://clasp.ngo/Resources/Resources/StandardsLabelsGuidebook

Compliance Counts: A Practitioner's Guidebook on Best Practice Monitoring, Verification, and Enforcement for Appliance Standards & Labeling - provides guidance on designing and implementing effective compliance frameworks, and directs the reader to references and other relevant resources.

http://clasp.ngo/Resources/MVEResources/MVEGuidebook

Assessment of Opportunities for Global Harmonization of Minimum Energy Performance Standards and Test Standards for Lighting Products - presents an assessment of test procedures and MEPS globally and identifies key gaps and similarities between them. It also examines the opportunities for the alignment of various economies to one global test procedure, and corresponding MEPS, for CFLs and LEDs and provides recommendations on possible steps to encourage and accelerate the global uptake of energy-efficient lighting technologies.

http://clasp.ngo/Resources/Resources/PublicationLibrary/2011/Global-Harmonization-Lighting-MEPS-TestStandards

Assessment of Verification Testing Capacity in the APEC Region and Identification of Cost Effective Options for Collaboration- presents the results of a comprehensive survey of APEC countries to identify qualified testing facilities and analyse cost-effective policy options for conducting compliance testing.

http://clasp.ngo/Resources/MVEResources/MVEPublicationLibrary/APEC-Assessment-of-Testing-Capacity-Facilitates-Compliance-Collaboration

EXPERTISE AND COLLABORATIVE PROGRAMMES

The UNEP-GEF en.lighten initiative Centre of Excellence – comprised of a network of over 50 lighting experts representing over 30 countries – offers recommendations, technical guidance and efficient lighting expertise to assist countries in the shift to energy efficient lighting. The Centre is based in Paris, France.

http://www.enlighten-initiative.org/

Online support centre, 'en.lightened learning': provides targeted technical advice and contains forecasting tools, publications and guidance documents. It also includes a series of informational webinars that provide more detailed guidance on specific aspects of MVE including:

- *Best Practices for Enforcing Efficient Lighting Regulations;*
- *CIE Test Method Standard for LED Lamps;*
- *Communication of Lighting Product Performance Standards and Labelling Programmes to Supply Chain Providers;*
- *Developing a Legislative Framework to Support Successful Monitoring, Verification and Enforcement Activities for Energy Efficient Lighting;*
- *Evaluation Indicators for Energy Efficient Lighting MVE Policy;*
- *How to Create and Operate a Lighting Product Registration System;*
- *Lamp Product Performance Tests and Interpretation of Results;*
- *Lighting Product Benchmarking as an Energy Baseline for Change;*
- *Lighting Product Registration Systems: Design and Operation;*
- *Market Baselines and Surveillance for Efficient Lighting Products;*
- *Testing Lamp Efficacy, Lumen Maintenance, Rated Life and Uncertainties.*

http://learning.enlighten-initiative.org/

UNEP Collaborating Centre for Energy Efficient Lighting, China - GELC offers a wide range of technical services to developing countries including laboratory training and establishing systems for lamp quality control.

http://www.enlighten-initiative.org/About/GlobalEfficientLightingCentre.aspx

lites.asia - is a network of lighting efficiency regulators and policy makers in the Asia region. Since its formation in 2009, membership of the lites.asia network has increased to over 700 participants from 30 economies, with delegates actively participating in IEC meetings, sharing knowledge on local standards and labelling electronically and in regional meetings, plus a number of other cooperative actions. The *lites.asia* website contains a range of resources on lighting efficiency and regulation including presentations from regular regional meetings and collaborative projects and survey results.

http://www.lites.asia/

Australian and New Zealand Energy Efficiency (E3) Program - is a cooperative government programme that applies a combination of MEPS and energy rating labelling to a range of energy using products including lighting in order to inform consumers and increase the range of efficient products in the market. The Energy Rating website contains a range of reports on lighting related baseline data and analysis for the Australian and New Zealand markets, as well as a publically accessible database of registered lighting products.

http://www.energyrating.gov.au/

CLASP - Works to improve the environmental and energy performance of appliances and related systems, lessening their impacts on people and the world around us. CLASP develops and shares practical and transformative policy and market solutions in collaboration with global experts and local stakeholders. It is a non-profit international organisation promoting energy efficiency standards and labels for appliances, lighting, and equipment. Since 1999, CLASP has worked in over 50 countries on six continents pursuing every aspect of appliance energy efficiency, from helping to structure new policies to evaluating existing programmes.

http://www.clasponline.org/en

The Clean Energy Ministerial's Clean Energy Solutions Center - offers no-cost expert policy assistance, webinars and training forums, clean energy policy reports, data, and tools provided in partnership with more than 35 leading international and regional clean energy organizations.

https://cleanenergysolutions.org/

IEA - the International Energy Agency (IEA) is an autonomous organisation which works to ensure reliable, affordable and clean energy for its 28 member countries and beyond. The IEA's four main areas of focus are: energy security; economic development; environmental awareness; and engagement worldwide. Founded in response to the 1973/4 oil crisis, the IEA's initial role was to help countries coordinate a collective response to major disruptions in oil supply through the release of emergency oil stocks. It has a staff of 260 professionals (energy analysts, modellers, data managers/statisticians, technicians, secretaries and support staff) working together on global energy challenges..

http://www.iea.org/

IEA 4E Solid State Lighting Annex – the Solid State Lighting Annex was established in 2009 under the framework of the International Energy Agency's Efficient Electrical End-Use Equipment (4E) Implementing Agreement to provide advice to its ten member countries seeking to implement quality assurance programmes for solid state lighting. This international collaboration brings together the governments of Australia, China, Denmark, France, Japan, The Netherlands, Republic of Korea, Sweden, United Kingdom and United States. China works as an expert member of the Annex. The Annex website provides information on recommended performance specifications for LED lighting, as well as reports and advice on LED product testing, lighting and health and lifecycle analysis..

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

LED Lighting Facts - LED Lighting Facts® is a programme of the United States Department of Energy that showcases LED products for general illumination from manufacturers who commit to testing products and reporting performance results according to industry standards. Their website contains information on their verification testing policy, a list of accredited laboratories in the United States and a list of products with their energy performance information. This is a useful web portal for policymakers and programme administrators to inform themselves about efficient lighting policies and testing.

http://www.lightingfacts.com/

SEAD Initiative - The Super-efficient Equipment and Appliance Deployment (SEAD) Initiative is a voluntary collaboration among governments working to promote the manufacture, purchase, and use of energy-efficient appliances, lighting, and equipment worldwide. SEAD is an initiative under the Clean Energy Ministerial and a task of the International Partnership for Energy Efficiency Cooperation.

www.superefficient.org.

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http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32012R1194

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Electropedia.
http://www.electropedia.org/iev/iev.nsf/index?openform&part=845

NIST 2015
Essentials of expressing measurement uncertainty.
http://physics.nist.gov/cuu/Uncertainty/basic.html

UNEP 2012
Achieving the Global Transition to Energy Efficient Lighting Toolkit.
http://enlighten-initiative.org/CountrySupport/EfficientLightingToolkit.aspx

UNEP 2014
Lamp Efficacy, Lumen Maintenance, Lamp Life and Measurement Uncertainties
http://learning.enlighten-initiative.org/Webinars2014.aspx#

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en.lighten
http://enlighten-initiative.org

ANNEX A

INTERNATIONAL LABORATORY ACCREDITATION

The International Laboratory Accreditation Cooperation (ILAC) was formed more than 30 years ago for both laboratory and inspection accreditation bodies to help remove technical barriers to trade. Its goals are:

- Developing and harmonising laboratory and inspection accreditation practices;
- Promoting laboratory and inspection accreditation to industry, governments, regulators and consumers;
- Assisting and supporting developing accreditation systems;
- Global recognition of laboratories and inspection facilities via the ILAC Arrangement.

Accreditation bodies are established in many economies with the primary purpose of ensuring that conformity assessment bodies are subject to oversight by an authoritative body.

In 2000, ILAC's 36 full members, consisting of laboratory accreditation bodies from 28 economies worldwide, signed a mutual recognition arrangement (the ILAC Arrangement) in Washington DC to promote the acceptance of technical test and calibration data for exported goods. The arrangement came into effect on 31 January 2001 and was extended in October 2012 to include the accreditation of inspection bodies. It now includes more than 80 bodies.

In conjunction with ILAC, specific regions have established their own accreditation co-operations, notably:

- African Accreditation Cooperation - Africa;
- Arab Accreditation Cooperation - the Gulf Region;
- Asia Pacific Laboratory Accreditation Cooperation - Asia-Pacific;
- European Accreditation – Europe;
- Inter American Accreditation Cooperation - the Americas;
- Southern African Development Community in Accreditation - Southern Africa.

These regional co-operations work in harmony with ILAC and are represented in ILAC's Executive Committee. ILAC is encouraging the development of such regional cooperations in other parts of the globe.

Further resources and information and a full listing of ILAC members are available at www.ilac.org.

ANNEX B

TABLE OF KEY PARAMETERS

Parameter	Definition	Explanation	How it is Measured	Notes
Light Output (total luminous flux)	Quantity derived from radiant flux ϕe by evaluating the radiation according to its action upon the CIE standard photometric observer. Unit: lm (IEC)	Light output describes the total amount of light radiating from the light source into the surrounding space. Total luminous flux is the measured quantity of visible light to humans from a particular light source or lamp, and characteristics that can influence this visibility.	The main measurement methodologies for total luminous flux are specified by IEC-60969, CIE 84, CIE DIS 25, and IES LM-79, using an integrating sphere or a goniophotometer	This is a measurement of the product's ability to perform its function, namely to produce visible light. It is therefore one of the most important parameters that needs to be measured and/or rated for lighting products. Compared to a goniophotometer, the use of an integrating sphere is a more time efficient and cost effective method for measuring the light output of most light sources.
Power (consumption or rated power)	Power is defined as the electric power required by the lighting product to work properly and continuously. Unit: watts	Rated or input power is the total amount of power that is used by a light source or system to deliver its light output. It indicates the amount of electrical power required by such a device in an electrical circuit.	Power is measured by a power meter. When a lamp's light output is measured, so are its electrical parameters.	Power is an essential measurement for the calculation of luminous efficacy.
Luminous Efficacy	Quotient of the luminous flux emitted by the power consumed by the source. Unit: lm/W ; symbol: ηv; η (IEC).	Luminous efficacy represents the ability of a light source to convert electrical energy into visible light for a particular application.	Efficacy is a calculated or derived value, but it requires precise measurements of a light source's light output and power consumption.	Many MEPS and labelling programmes establish energy efficiency requirements based on initial luminous efficacy.
Lifetime	The total time for which a lamp has been operated before it becomes useless, or is considered to be so according to specified criteria.	Lamp life is usually expressed in hours. Lifetime, as reported by manufacturers, reflects the calculation of the product lifetime, which is usually based on the median of a sample, and can be the point at which light output falls below a certain level.	Lamps are operated under controlled conditions (in an ageing room) until they fail.[29] Samples and duration are specified by a number of standards, depending on the type of light source.	A characterisation of lifetime is needed so that various light sources and their operational cost over time can be compared. Lifetime testing can take a long time. Currently, there is no globally recognised acceleration method for lifetime testing for fluorescents or LEDs.

29 'Fail' has specific definitions depending on the technology. For example, other than a catastrophic failure, some standards define LEDs lamps 'end of life' or failure as the point at which their light output falls below 70% of the initial value.

Parameter	Definition	Explanation	How it is Measured	Notes
Lumen Maintenance (luminous flux maintenance factor)	Ratio of the luminous flux of a lamp at a given time in its life to its initial luminous flux, the lamp being operated under specified conditions. This ratio is generally expressed in percentages.	Lumen maintenance determines how much of a lamp's light output remains after a period of controlled operation, as compared to when the lamp was new.	Lamps are put in an ageing room to operate, and their light outputs are measured at specific time periods. The periods vary among standards. Some may require the test at 2,000 hours, others at 4,000 hours, and some may require more than one test, e.g. at both 1,000 hours and 4,000 hours. IEC 60969 requires a lumen maintenance test at 2,000 hours for CFLs. For LEDs, LM-80, which deals with lifetime testing for LEDs, calls for measurements at certain intervals.	For all lighting products, light output decreases as operational hours increase. Regulating this parameter helps to ensure that lamps degrade in light output slowly, and also to improve long term performance and consumer satisfaction. Lumen maintenance could also be regarded as efficacy maintenance. While some electrical parameters (including power) do not change noticeably, light output can change significantly over time.

ANNEX C

HOW AUSTRALIA DEVELOPED AND UPDATED ITS LIGHTING POLICY USING TEST DATA AND MARKET CONDITIONS[30]

Australia has regulations requiring mandatory energy labels to be displayed on a range of electrical products offered for sale. In addition, the government regulates a number of products based on MEPS. These regulations specify the labelling and efficiency requirements for appliances and lighting, and allow for penalties if a party does not comply with these requirements.

In February 2007, the Australian Government announced it intended to phase out the use of incandescent lamps in Australia. The objectives were to eliminate inefficient incandescent lamps from the Australian marketplace to lower energy use and consumer costs, as well as to reduce peak energy demand and greenhouse gas emissions. To date, it is estimated that the phase-out of incandescent lamps, along with state-based energy efficiency obligation schemes, is helping to save around 2.6 terawatt hours of electricity each year. These savings are equivalent to the total annual electricity consumption of 150,000 homes.[31]

The agencies responsible for developing policies started the process by surveying lighting policies around the world[32]. The intent was to align, if possible, with the policies of other economies with similar market conditions and programme objectives. The Government was aware of consumer reservations toward energy efficient products, especially those intended to replace incandescent lamps. Policymakers wanted to ensure the supply of high-quality replacement products.

To develop the appropriate policies, the Australian Government needed to be able to measure and decide on performance levels for various lighting products on the market. Fortunately, policymakers were able to take advantage of programmes already in place. Since 1991, Australia has had a national testing programme that is designed to assure product quality and maintain the credibility of labelling and MEPS programmes for both consumers and manufacturers. The testing programme evaluates the accuracy of performance data, MEPS levels, and labelling claims, as well as identifying the rate of compliance by suppliers. Appliances are purchased from retail outlets and tested in accredited independent laboratories (both within Australia and overseas) to verify the claims associated with the energy label and MEPS.

The test data also informed the MEPS development process (as shown in Figure 8) and facilitated the identification of product performance trends. Additionally, Australia made provisions to accept test data from CFLs certified by the Efficient Lighting Initiative and the United Kingdom Energy Savings Trust. This decision prevented the Australian Government from having to temporarily expand testing capacity to meet the initial rush of lamp testing, thus saving time, costs and resources.

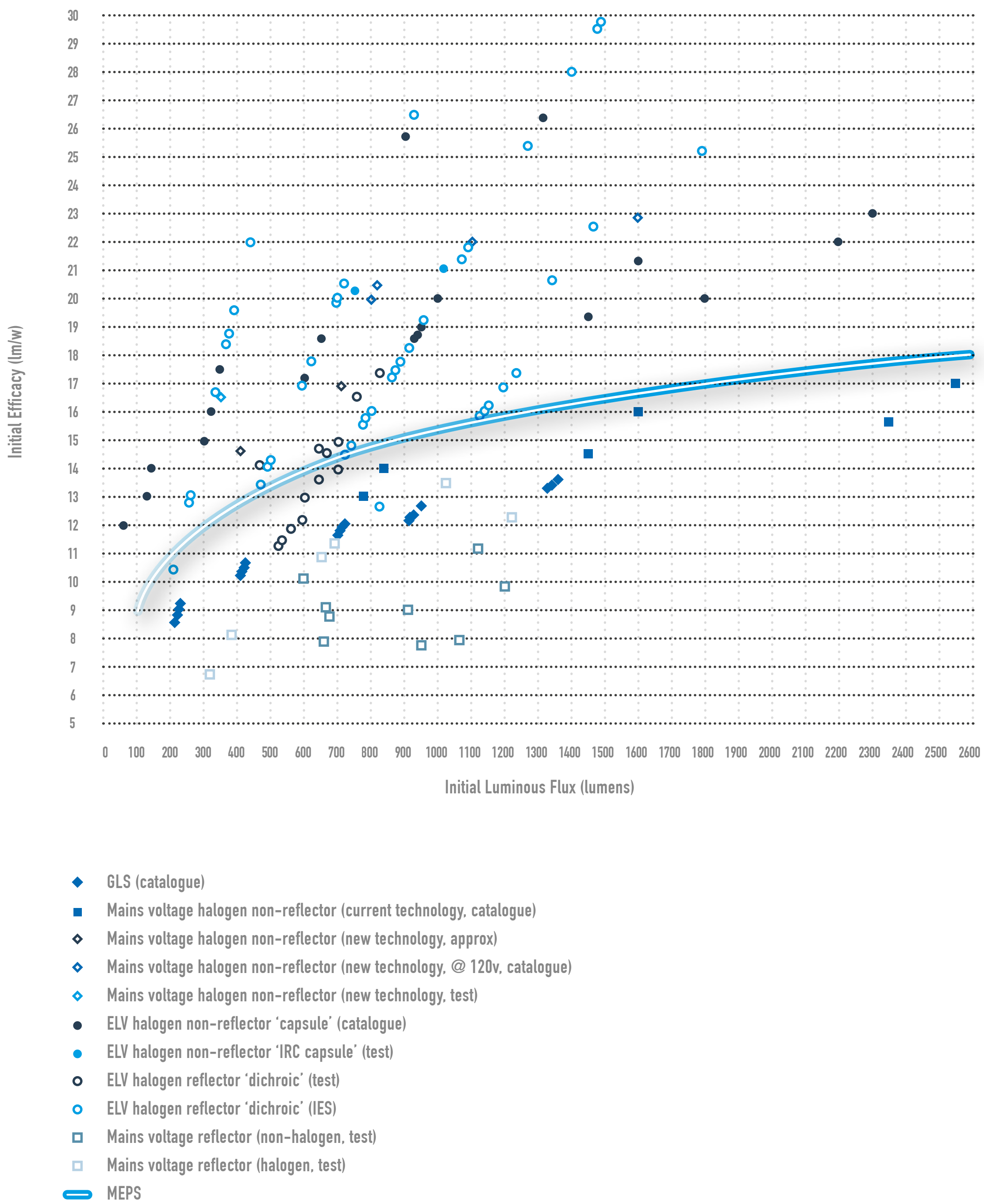
As a result, the Government was able to use shared data, and worked with the Australian lighting industry and other stakeholders to set appropriate requirements for lamp efficacies that would eliminate the most inefficient lamps from the market. Because its policies were leading market developments, the Government developed a flexible programme that could respond to market conditions. Specifically, responsible agencies would annually monitor and review technological advances in lamps, and less inefficient lamps would not be phased out unless there was a more efficient and viable alternative available. The review and scheduling of lamp phase outs was also carried out in consultation with stakeholders.

Details on the current progress of the phase out are available on the Australian Energy Rating website at: http://www.energyrating.gov.au/products-themes/lighting/

30 Based on presentations and personal communications with representatives of the Department of Industry, Innovation and Science.
31 Equipment Energy Efficiency Program 2015
32 In 2005, there were about 57 different schemes for promoting CFLs around the world; all using different specifications. In response, the Australian Government called a meeting of manufacturers, policymakers, NGOs and experts to work together to agree on common test methodologies and performance levels.

Figure 8

Lamp performance data used by the Australian government to set the minimum energy performance standard
Source: Australian Greenhouse Office 2007



ANNEX D

DETAILS OF SELECTED INTERNATIONAL AND REGIONAL STANDARDS AND PERFORMANCE SPECIFICATIONS

Standards Body	Standard Number	Full Standard Name	Accessible From
American National Standards Institute (ANSI)	**C78.5-2003**	Specifications for Performance of Self-ballasted Compact Fluorescent Lamps	http://webstore.ansi.org/RecordDetail.aspx?sku=ANSI+C78.50-2014
Standards Australia (AS/NZS)	**4847.1**	Self-ballasted lamps for general lighting services - Test methods - Energy performance	http://infostore.saiglobal.com/EMEA/Details.aspx?ProductID=1402154
	4847.2	Self-ballasted lamps for general lighting services - Minimum Energy Performance Standards (MEPS) requirements	http://infostore.saiglobal.com/EMEA/Details.aspx?ProductID=1402155
	4934.1:2014	Incandescent lamps for general lighting service Part 1: Test methods – Energy performance	http://infostore.saiglobal.com/EMEA/Details.aspx?ProductID=1724864
	4934.2-2011 (AS only)	Incandescent lamps for general lighting services Part 2: Minimum Energy Performance Standards (MEPS) requirements	http://infostore.saiglobal.com/EMEA/Details.aspx?ProductID=1461311
International Commission on illumination (CIE)	**13.3**	Method of Measuring and Specifying Colour Rendering Properties of Light Sources	http://www.techstreet.com/cie/products/1209965
	15	Colorimetry, 3rd edition	http://www.techstreet.com/cie/products/1210118
	18.2	The Basis of Physical Photometry Publication	http://www.techstreet.com/cie/products/1209967
	63	The Spectroradiometric Measurement of Light Sources	http://www.techstreet.com/cie/products/1210127
	84	Measurement of Luminous Flux (1st Edition)	http://www.techstreet.com/cie/products/49369
	97	Maintenance of indoor electric lighting systems	http://www.techstreet.com/cie/products/1252706
	121	The photometry and goniophotometry of luminaires	http://www.techstreet.com/cie/products/1210042
	S 025/ E:2015	Test Method for LED Lamps, LED Luminaires and LED Modules	http://www.techstreet.com/cie/products/1893005

Standards Body	Standard Number	Full Standard Name	Accessible From
China National Standards (GB Standards)	**GB/T 17263-2013**	Self-ballasted [fluorescent] lamps for general lighting service.Performance requirements	http://www.cssn.net.cn/templateHtml/CN-GB/6799366.html?drm_flag=&HasElec=1 (Chinese)
	GB 19044-2013	Minimum allowable values of energy efficiency and the energy efficiency grades of self-ballasted fluorescent lamps for general lighting service	http://www.cssn.net.cn/templateHtml/CN-GB/6709948.html?drm_flag=&HasElec=1 (Chinese)
	GB/T 24908-2014	Non-directional self-ballasted LED-lamps for general lighting services. Performance requirements	http://www.cssn.net.cn/templateHtml/CN-GB/6933286.html?drm_flag=&HasElec=1 (Chinese)
	GB 30255-2013	Minimum allowable values of energy efficiency and energy efficiency grades of non-directional self-ballasted LED-lamps for general lighting services	http://www.cssn.net.cn/templateHtml/CN-GB/6804166.html?drm_flag=&HasElec=1 (Chinese)
Efficient Lighting Initiative (ELI)	**ELI Voluntary Standard**	EU Voluntary Standard, March 2011	www.efficientlighting.net.cn (Chinese)
European Commission (EU, EC)	**No 244/2009**	Implementing Directive 2005/32/EC of the European Parliament and of the Council with regard to ecodesign requirements for non-directional household lamps	http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32009R0244
International Energy Agency 4E SSL Annex	**Voluntary performance tiers**	Directional Lamps for Indoor Residential Applications	http://ssl.iea-4e.org/product-performance
		Downlight Luminaires	
		Linear Fluorescent LED Lamps (non retrofit)	
		Non-directional Lamps for Indoor Residential Applications	
		Replacement Linear Fluorescent LED Lamps (retrofit 360°)	
		Street Lighting/Outdoor Lighting	

Standards Body	Standard Number	Full Standard Name	Accessible From
International Electrical Commission (IEC)	**60064**	Tungsten filament lamps for domestic and similar general lighting purposes - Performance requirements	https://webstore.iec.ch/publication/493
	60081	Double-capped fluorescent lamps - Performance specifications	https://webstore.iec.ch/publication/664
	60357	Tungsten halogen lamps (non vehicle) - Performance specifications	https://webstore.iec.ch/publication/1856
	60969	Self-ballasted lamps for general lighting services - Performance requirements	https://webstore.iec.ch/publication/4070
	62612:2013	Self-ballasted LED lamps for general lighting services with supply voltages → 50 V - Performance requirements	https://webstore.iec.ch/publication/7259
	Guide 115	Application of uncertainty of measurement to conformity assessment activities in the electrotechnical sector	https://webstore.iec.ch/publication/7524
Illuminating Engineering Society (IES), North America	**LM 45**	Electrical and Photometric Measurement of General Service Incandescent Filament Lamps	http://www.techstreet.com/ies/products/1681746
	LM 65	Life Testing of Single-Based Fluorescent Lamps	http://www.techstreet.com/ies/products/1893208
	LM 66	Electrical and Photometric Measurements of Single-Based Fluorescent Lamps	http://www.techstreet.com/ies/products/1893249
	LM 79	Electrical and Photometric Measurements of Solid-State Lighting Products	http://www.techstreet.com/ies/products/1566105
	LM 80	Approved Method: Measuring Lumen Maintenance of LED Light Sources + Addendum A	http://www.techstreet.com/ies/products/1587325
	LM 84	IES Approved Method for Measuring Luminous Flux and Color Maintenance of LED Lamps, Light Engines, and Luminaires	http://www.ies.org/store/product/ies-approved-method-for-measuring-luminous-flux-and-color-maintenance-of-led-lamps-light-engines-and-luminaires-1339.cfm
	TM 21	Projecting Long Term Lumen Maintenance of LED Light Sources	http://www.techstreet.com/ies/products/1810146

Standards Body	Standard Number	Full Standard Name	Accessible From
Bureau of Indian Standards (IS)	**IS 15111 (part 2) 2002**	Self ballasted lamps for general lighting services - part 2 performance requirements	http://infostore.saiglobal.com/EMEA/Details.aspx?ProductID=1059622
International Organization for Standardization (ISO)/IEC	**17025:2005**	General requirements for the competence of testing and calibration laboratories	http://www.iso.org/iso/catalogue_detail.htm?csnumber=39883
	Guide 58:1993	Calibration and testing laboratory accreditation systems -- General requirements for operation and recognition	http://www.iso.org/iso/iso_catalogue/catalogue_ics/catalogue_detail_ics.htm?csnumber=21678
United Kingdom Energy Saving Trust	**Lamp Spec, V7.0-2010**	Lamp Specification Version 7.0 – 2010	Available on application to the Energy Saving Trust http://www.energysavingtrust.org.uk
United States ENERGY STAR	**Lamps V1.1**	Lamps Program Requirements Version 1.1	https://www.energystar.gov/products/certified-products/detail/7627/partners

ANNEX E

NATIONAL TESTING LABORATORY CONSIDERATIONS

Factor	Particular Considerations
Location	In-country testing facilities offer the advantages of easier communications with suppliers, and easier implementation of testing tasks such as fair sampling from the market, and transportation and delivery of goods.
Capability	A lighting testing laboratory must have the capabilities and specialised equipment to perform complex tests to obtain photometric and colorimetric measurements. Comprehensive testing may also include parameters for safety and environmental impact, such as the presence of mercury and other materials specified in legislation, e.g. those covered by the Restriction of Hazardous Substances Directive in the European Union.[33] Policymakers will need to decide whether to build the capacity to test for these related factors, which require additional equipment, building space, and staff training.
Required Equipment	The equipment required will depend on the level of desired laboratory capacity. Typically, two specialised measurement apparatuses are required to measure the light output of lamps: an integrating sphere and a goniophotometer. Depending on the lamp performance parameters to be measured and the chosen measurement standards, one or both apparatuses will be needed. (See section 2.5.1. for more information on these equipment types.) Additional equipment such as meters, associated probes, lamp aging facilities, and other calibration equipment and tools are also needed.
Staff Training and Management	Laboratory staff and management operating the laboratory will need to comply with the International Organization for Standardization (ISO) standard, ISO 17025,[34] which specifies the management and technical requirements for a laboratory. This regulation also forms the basis of laboratory accreditation (see below). Policymakers may wish to provide for laboratory training programmes to ensure compliance with ISO 17025. Such a programme might include: • Familiarising staff with specific performance standards; • Teaching staff how to take measurements in accordance with established test standards; • Conducting field training at other laboratories; • Providing on-site training from external experts.
Accreditation	Generally, a testing laboratory must be accredited by an internationally recognised accreditation body to provide test results that will be widely recognised. Accreditation covers laboratory management and technical competence, as per ISO 17025 (or its national equivalent) and specific test standards for the type of product covered.[35] Depending on the type of programme chosen, the laboratory may also need to meet additional requirements, qualifications, or ratings. Annex A provides a list of international accreditation bodies.

33 *The Restriction of the Use of Certain Hazardous Substances (RoHS) in Electrical and Electronic Equipment (EEE) Directive* (2011/65/EU). http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2011:174:0088:0110:EN:PDF

34 ISO/IEC 17025:2005, *General requirements for the competence of testing and calibration laboratories*

35 Note: Testing laboratory accreditation programmes for the specific type of lighting product (e.g. LED lamps and LED luminaires) are required for activities such as MVE.

ABOUT THE UNEP DIVISION OF TECHNOLOGY, INDUSTRY AND ECONOMICS

Set up in 1975, three years after UNEP was created, the Division of Technology, Industry and Economics (DTIE) provides solutions to policy-makers and helps change the business environment by offering platforms for dialogue and co-operation, innovative policy options, pilot projects and creative market mechanisms.

DTIE plays a leading role in three of the seven UNEP strategic priorities: **climate change, chemicals and waste, resource efficiency.**

DTIE is also actively contributing to the **Green Economy Initiative** launched by UNEP in 2008. This aims to shift national and world economies on to a new path, in which jobs and output growth are driven by increased investment in green sectors, and by a switch of consumers' preferences towards environmentally friendly goods and services.

Moreover, DTIE is responsible for **fulfilling UNEP's mandate as an implementing agency for the Montreal Protocol Multilateral Fund** and plays an executing role for a number of UNEP projects financed by the Global Environment Facility.

The Office of the Director, located in Paris, coordinates activities through:

- **The International Environmental Technology Centre** - IETC (Osaka), which promotes the collection and dissemination of knowledge on Environmentally Sound Technologies with a focus on waste management. The broad objective is to enhance the understanding of converting waste into a resource and thus reduce impacts on human health and the environment (land, water and air).
- **Sustainable Lifestyles, Cities and Industry** (Paris), which delivers support to the shift to sustainable consumption and production patterns as a core contribution to sustainable development.
- **Chemicals** (Geneva), which catalyses global actions to bring about the sound management of chemicals and the improvement of chemical safety worldwide.
- **Energy** (Paris and Nairobi), which fosters energy and transport policies for sustainable development and encourages investment in renewable energy and energy efficiency.
- **OzonAction** (Paris), which supports the phase-out of ozone depleting substances in developing countries and countries with economies in transition to ensure implementation of the Montreal Protocol.
- **Economics and Trade** (Geneva), which helps countries to integrate environmental considerations into economic and trade policies, and works with the finance sector to incorporate sustainable development policies. This branch is also charged with producing green economy reports.

DTIE works with many partners (other UN agencies and programmes, international organizations, governments, non-governmental organizations, business, industry, the media and the public) to raise awareness, improve the transfer of knowledge and information, foster technological cooperation and implement international conventions and agreements.

For more information,
see **www.unep.fr**

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UNEP

This guidance note focuses on the performance testing of lighting products, and the interpretation of the results of those tests, as a tool for increasing energy efficiency. It is primarily aimed at countries that wish to implement new, or revised, testing procedures and use test data to support the development of their energy efficient lighting policies and compliance programmes. It serves as a practical resource for governments on recommended processes to follow for testing products, interpreting testing results, and using them to inform policy. It offers both specific and general recommendations that policymakers, laboratory personnel, and other stakeholders can use in developing testing programmes.

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