Questions and Answers from *Lamp Product Performance Tests and Interpretation of Results* webinar presented on 5 March 2015

Q: Can Correlated Colour Temperature (CCT) and Colour Rendering Index (CRI) be used as parameters for testing, seeing as colour is an important factor for lamps used in homes?

Yes, these are very important parameters and are used as parameters for testing light colour quality, however they are not critical for energy efficiency testing (although colour temperature may influence light output and therefore efficacy). For measurement of energy efficiency, the lumen output and power input of a lamp are measured, the quotient being the efficacy or lumens per watt. Other important energy efficiency and/or energy consumption related parameters are lumen maintenance and lifetime, due to its impact on the cost benefit calculation.

There are many parameters that are used to assess the performance of lamps. Testing can encompass safety and/or performance criteria. Some of the parameters used to assess lamp performance are:

- Safety (electrical and mechanical/physical)
- Photometric parameters (or performance criteria, including: luminous efficacy)
- Colorimetric parameters (or light quality criteria, including: colour rendering, correlated colour temperature, and colour consistency)
- Toxic and hazardous compounds content (including mercury)
- Other health issues such as flicker and ultraviolet (UV) emission levels
- Other lamp performance and operational characteristics (start-up time, lumen maintenance and average life, switching cycles)

For more information, please see section 2.3.2 *Screening or Check Testing* in Chapter 4 of UNEP en.lighten's guide, *Achieving the Global Transition to Energy Efficient Lighting Toolkit*.[1]

Q. What is the difference between standards published by the CIE and the IEC?

The Commission Internationale de l´Eclairage (CIE) standards are primarily concerned with the science and application of lighting, including for example measurement of lumens and colour parameters, as well as lighting requirements. The International Electrotechnical Commission (IEC) standards are primarily product standards which look at testing for safety and performance of products (and often reference CIE standards). CIE and IEC collaborate in a number of areas, including quantification of uncertainties in solid state lighting measurement methodologies and photobiological safety of lamps. All of these international standards are voluntary, until a government makes a legal reference and it becomes required.

[1] Link to Toolkit: http://www.enlighten-initiative.org/ResourcesTools/EfficientLightingToolkit.aspx

Q. Are there any new developments on test methods for accelerated lifetime testing of LED lamps?

Due to the very long lifetime associated with quality LED lighting, an accurate accelerated lifetime test has been an active area of research for more than a decade. There are test methods that focus on predictive lifetimes by operating LED lamps in high ambient temperature environments (e.g., 60°C), and some which look at applying a high number of switching cycles, with careful manipulation of the 'on' and 'off' duration to create thermal expansion and cooling of lamp components. There is, as yet, no internationally agreed method of accelerated lifetime test, however it remains a very active area of research and new literature is being published regularly. For example, the International Solid State Lighting Alliance has published an accelerated test method for LED lifetime testing[2]. Another association-level standard for accelerated LED lifetime testing is CALT 001-2014[3], prepared by the National Quality Inspection Center Lighting & Electrical Technology Alliance. Another example, from the USA, is the test methods developed by the Illuminating Engineering Society of North America (IESNA)[4], known as IESNA-LM-80 and IESNA-LM-84, which provide guidance and specifications for measuring and recording the lumen maintenance or ageing of LED light sources for third generation SSL products, which facilitates calculation of the lifetime of LED luminaires.

Q. What is the status of lighting test laboratories in India?

India is one of the global leaders in manufacturing lighting products, and has a long tradition of high quality test laboratories. India is a signatory to the Asia-Pacific Laboratory Accreditation Cooperation (APLAC) and has had laboratories participate in LED lamp proficiency tests administered under the auspices of APLAC. For a list of lighting laboratories active in India – both private and public – the most expedient way would be to contact the National Accreditation Board for Testing and Calibration Laboratories (NABL http://www.nabl-india.org) and ask for their advice. A list of test laboratories (not exclusively lighting, but some of these will have lighting test capability) can be found by clicking on this link. To get an understanding of the status of test laboratories in other countries, please see the Asia Pacific Economic Community (APEC) report which assesses test laboratory capacity for multiple products in the region, including lighting.[5]

Q. Where is information available on quality LED products?

There are many sources of information available on quality LED products. These sources each serve different purposes and audiences. For example, these may be targeted to consumers to help them make informed decisions; they support green procurement activities; and they list certified quality products to help inform policy or retail decision making.

Some examples of sources to look for include:

- ***The lites.asia Consumer Guide to Buying LEDs*:** This guide is designed to provide governments, suppliers, retailers and other stakeholders with an independent and unbiased basic text to use in

[2] Available online at: http://www.isa-world.org/show.php?contentid=142
[3] Available online at: http://www.sqi.com.cn/SQI_Web/SQI_NewsDetails.aspx?NGUID=b129a4c1-bd54-4499-b659-2a1639fb675b
[4] More details are available on the IESNA website at: http://www.ies.org/
[5] Available on the CLASP website at: http://www.clasponline.org/en/Resources/Resources/PublicationLibrary/2014/APEC-Assessment-of-Testing-Capacity.aspx

publications to guide consumers in selecting a good quality LED products for appropriate applications. It provides basic advice on how to select quality LEDs by looking out for certain important LED product features. The Guide is available for download on the *lites.asia* website at: http://www.lites.asia/downloads/led-consumer-guide

- The **International Energy Agency 4E Solid State Lighting Annex**: This government-led collaborative initiative of 9 countries has developed generic quality and performance tiers for various solid state lighting products. It has also studied the life-cycle assessment and health impact analyses of solid state lighting products and progressed testing of LED products through interlaboratory comparisons. More information, including the reports which detail these tiers, is available on the Annex website at: http://ssl.iea-4e.org/task-1-quality-assurance

- ***The US Lighting Facts Database*:** This is a programme of the US 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. More information, as well as the database, is available at: http://www.lightingfacts.com/

- ***The DesignLights Consortium Qualified Product List:*** The DesignLights Consortium promotes quality, performance and energy efficient commercial sector lighting solutions through collaboration among its federal, regional, state, utility, and energy efficiency program members; luminaire manufacturers; lighting designers and other industry stakeholders throughout the US and Canada. The DLC Qualified Products List captures easily searchable manufacturer and model identifying information, as well as verified tested performance or rated performance information for each product. Users include energy efficiency programme managers or administrators from utilities, as well from state-level government. More information, and access to the Qualified Products List, is available on their website at: https://www.designlights.org

- ***The European Union's PremiumLight Project***: This project offers a range of resources to inform the take up of highly efficient LED light bulbs. These resources include: testing lamps to showcase the best performing products; providing assurance on product quality; eradicating consumer confusion on lighting products though provision of best-practice advice; and empowering and training retailers to advise consumers, disseminate marketing materials, promote great products and increase knowledge and sales of efficient products. Finally, it engages and advises the service sector, local authorities, businesses and housing associations to be a strong driver of the shift towards better quality efficient lighting products. Information on the project is available at: http://www.premiumlight.eu/

- ***ENERGY STAR for Lighting***: This US programme offers multiple sources of information on quality LED products. The *ENERGY STAR Light Bulb Purchasing Guide* is available to help with procurement and retail decisions, and the programme offers expert advice on how to choose appropriate lighting products. In addition to offering tools to help calculate the savings that can be made by switching to more efficient products, it also contains a list of all ENERGY STAR certified products that meet the quality and energy efficiency criteria of the programme, in the ENERGY STAR Database. More information is available on the ENERGY STAR website at: http://www.energystar.gov/index.cfm?c=lighting.pr_lighting_landing

- ***Australian Lighting Council's SSL Quality Scheme***: This is a voluntary industry scheme which provides confidence to the market that a luminaire carrying the Scheme's label matches certain performance claims made by the supplier. More information can be found on their website at: http://www.lightingcouncil.com.au/site/ssl/overview.php

Q. Where can I find support in Nepal to test the mercury content, wattage and efficiency of lamps?

We are uncertain about the test laboratory facilities in Nepal, but would suggest you contact the appropriate Ministries in the Nepalese government to ascertain their list of facilities. You may also wish to contact Kathmandu University, specifically the Department of Electrical and Electronic Engineering (click here for a link to their website) to ask for their guidance on this question.

You may also wish to consider using other testing laboratories in the region. As mentioned above, a study carried out by APEC lists test laboratories in the region that are capable of testing for lighting products[6]. National accreditation bodies can also provide information. For details of those that are signatories of the Asia-Pacific Laboratory Accreditation Cooperation (APLAC) Mutual Recognition Arrangement see www.aplac.org/aplac_mra.html.

Q. The mercury content allowable under the Minamata Convention is higher than the EU's Restriction of Hazardous Substances value per CFL unit. Is there any way to reduce the allowable limit of mercury under the Convention?

Mercury content of CFLs is a health and safety concern for consumers. Many voluntary and regulatory programmes set a maximum mercury content level for CFLs. Of the programmes that regulate mercury content, most have set the mercury content limit at 5.0 mg for CFLs that have input power less than 25 W. In Europe, the requirement is more stringent at 2.5 mg per CFL (less than <30W) after 31 December 2012 (see Annex III, item 1(a) in this recast of the RoHS Directive). It is not possible to change the allowable limit under the Minamata Convention at this time, as this is an internationally negotiated document and countries are signing up to the stated requirements. However, a national government can choose to set levels that are lower (i.e., have less mercury per CFL) than the Minamata convention.

For more information on mercury in CFLs, please see Chapter 5 of UNEP en.lighten's guide, *Achieving the Global Transition to Efficient Lighting Toolkit* which discusses *Safeguarding the Environment and Health*. This chapter provides references to international best practices for regulating hazardous substances in lighting products.

Q. When will the UNEP MVE Guide on Lamp Testing be published?

It is scheduled for publication in July 2015 and will be made available on the *lites.asia* and en.lighten websites. An email notification will be sent out to all stakeholders registered on the *lites.asia* network. Should you wish to join the network, you can register on the *lites.asia* website at www.lites.asia/registration.

[6] Available on the CLASP website at: http://www.clasponline.org/en/Resources/Resources/PublicationLibrary/2014/APEC-Assessment-of-Testing-Capacity.aspx

Q. What is an example of a preliminary assessment in a screening test?

The following is an example of how a screening test can provide a preliminary assessment of the performance of a lamp sample. The purpose of screening tests is to enable market regulators to conduct more targeted full verification tests.

Assume that you are a government enforcement officer in charge of market MVE in your country. Your annual MVE testing budget will only support laboratory testing of 100 lamps, and your regulations require that 20 lamps of one model are tested in order to assess compliance.

Without using a screening test approach, you would simply conduct a full compliance assessment (determining pass/fail) on five lamp models, purchasing and testing 20 units of model. That would represent a total of 100 lamps, and your entire test budget for lighting. However, in your national market, you may have several hundred different models on offer, thus testing only five would limit your impact on the market and your ability find non-compliant models.

However, if you were to apply a screening test approach, then you would take small samples of many different models, and use those indicative test results to guide your full compliance verification testing. For example, you might choose to test 2 units of 20 different models, so 40 lamps in total. Based on those test results, the three worst-performing lamps could then be selected for a full verification test – with sample sizes of 20 lamps purchased and tested. Thus your testing budget of 100 lamps would have been used on 20 models (40 lamps) in a screening test and 3 models (60 lamps) in a full compliance test.

It is important to remember that a screening test only provides indicative test results, and when you conduct testing on the full sample of 20 lamps, you may find a different result. Screening testing is useful to better target compliance testing, however screening test results are only indicative. Also, the unit test cost of a single lamp may be higher for 2 units of 20 different lamps than it is for 20 units of 2 different lamps. Regardless of this fact, MVE is still more cost-effective when used in conjunction with a screening test approach.

Q. How many samples of a product model would you recommend to test in both a screening test and a full verification test?

For a full verification test, the number of samples used should adhere to the sample requirements of the test standard used – however, some governments have chosen to increase the sample size. For example, in the US and Europe, the regulatory test standards require a minimum of 20 samples for photometric, colorimetric and electrical parameters, but the IEC sample sizes are lower. That said, it should be noted that some tests can damage the sample (switching withstand and mercury content for example), thus separate samples should be used for each of the tests where this is the case.

For screening tests, sample sizes can be smaller as the objective of these tests is to get an indicative result, not a definitive one. In addition, screening tests can look at only a few key parameters rather than all requirements that may be covered under a regulation. Thus, screening testing could involve complete testing a few units, or testing 20 units for only a fewer key parameters.

Another low-cost alternative to establishing screen-testing facilities is to conduct document-based testing, which involves the careful review of documents submitted by manufacturers for product registration to identify products with non-compliant results. This approach requires no investment in testing facilities, and

does not require actual testing unless indications of non-compliant products are found. These screening or 'light touch' tests cannot be used as a foundation for legal action, or enforcement. Rather, they can be used to inform which products to target with full verification testing. For more information on capacity building for efficient lighting MVE programmes, see the presentation delivered by UNEP consultant, Steve Coyne, at the *lites.asia* meeting in Kuala Lumpur in April 2014. To download a copy of this presentation, click here.

Q. Are there any international standards for the ageing room for lifetime testing?

When conducting the initial seasoning and lifetime testing, lamps need to be operated for extended periods of time. These room where the lamps are operated on test racks are called 'ageing rooms'. There are a number of different international standards that establish the ambient conditions that must be maintained while the lamps are operating – addressing parameters such as air temperature, air flow rate, quality of power supply and so on.

At the international level, the standards published by the IEC that relate to ageing room conditions can be found in IEC 60969 and LM 65 for CFL, IEC-PAS 62612 and LM 80 for LEDs. They normally regulate the temperature, air flow rate, power supply accuracy, and determination of lifetime, amongst other parameters. More details on these standards will be available in the upcoming UNEP en.lighten guides, *Guide on Testing the Performance of Lamps and Interpreting and Using the Results* (scheduled for publication in July 2015), and *Product Selection and Procurement for Lamp Performance Testing*.

Q. As Myanmar, Laos and Cambodia are starting to consider MEPS and S&L programmes, has there been support from CLASP and UNEP on testing existing lighting on these markets?

Yes, under the Southeast Asia efficient lighting MVE project supported by the Australian government, UNEP has initiated the testing of 100 models of CFL and LED lamps by the Global Efficient Lighting Test Centre in Beijing, China. Participating countries include Cambodia, Indonesia, Laos, Philippines, Thailand and Vietnam. The test results will be available in 2015. The MVE project also includes the development of five guides on different areas of lighting MVE, as well as the development of a baseline and market surveillance plan, and a regional product registry prototype, all intended to support efficient lighting MVE on these markets.

Q. When is a lamp determined as 'dead'? Is this when the light ceases to switch on (giving zero light output) or is this dependent on a there being a certain percentage of light output (for example 50% of the initial light output)?

A lamp can be considered as 'dead' when it does not work properly, or has failed a specific performance test. Some specific performance definitions for LEDs and LED modules can be found in IEC TS 62504 'Terms and Definitions for LEDs and LED modules in general lighting.' In the absence of any legal or programmatic requirements, the lighting industry's guidelines (for example, *A Guide to the Specification of LED Lighting Products* by the Lighting Industry Liaison Group) suggest that lamp life can be defined by the following conditions:

- Light Loss – at L70 or L90 (70% or 90% of initial light output); and
- Physical failures

Depending on light source type, a 'dead' or 'failed' lamp that suffers from these conditions means that the lamp's light output falls below a certain threshold as compared to its initial light output level (e.g. less than 50%) or gives off no light at all, has suffered mechanical/physical/electrical failure; or Its service is impaired by malfunctions (such as flickering), at which point the lamp can no longer be used for general lighting service.

Official definitions for 'lamp failure' can be found in the following standards. Generally, condition 1 tends to be more applicable to longer-lived lamps such as CFLs and LEDs, as they can dim overtime rather than 'burn out.'

For the topic 'life of lamps', different definitions and terms are in use, depending on lamp type, lamp manufacturer and geographical region. This can lead to misunderstandings for the user. The essential definitions are given below (see also EN 12464-1, EN 12665 and CIE 97):

- Life, general term: time during which a lamp is operated until its failure.
- Average life: mean value of the electrical life of a quantity of lamps, operated at standardised conditions after 50% lamp failure.
- Failure rate B_{xx}: Percentage of failed lamps, e.g. B_{10} (10% failure).

Q. Where a standard requires a lamp to be aged for 100 hours under normal operation of the lamp, does this mean ageing with or without the switching cycle ('on' or 'off') of the CFL?

Test standard IEC 60969 requires the CFL to be aged for 100 hours before the initial test in order to stabilise operating conditions within the lamp, including the mercury vapour pressure and phosphor coating. In the revised version of IEC 60969 Annex G states that for lamp aging and life testing, lamps shall be repeatedly cycled for 2 hours and 45 minutes on followed by 15 minutes off.

Other standards, like the China national standard (GB/T 17263), the Australian and New Zealand Standard as/NZS 4847.1, and the US ENERGY STAR specification (*ENERGY STAR® Program Requirements Product Specification for Lamps (Light Bulbs) Eligibility Criteria Version 1.1*), have specific requirements on the cycles. The China and Australian/New Zealand standards requires 2 hours and 45 minutes 'on' and 15 minutes 'off' with lamps to be aged for 100 operating hours; while the ENERGY STAR specification requires 180 minutes 'on' and 20 minutes 'off' (the requirement comes from LM 65).