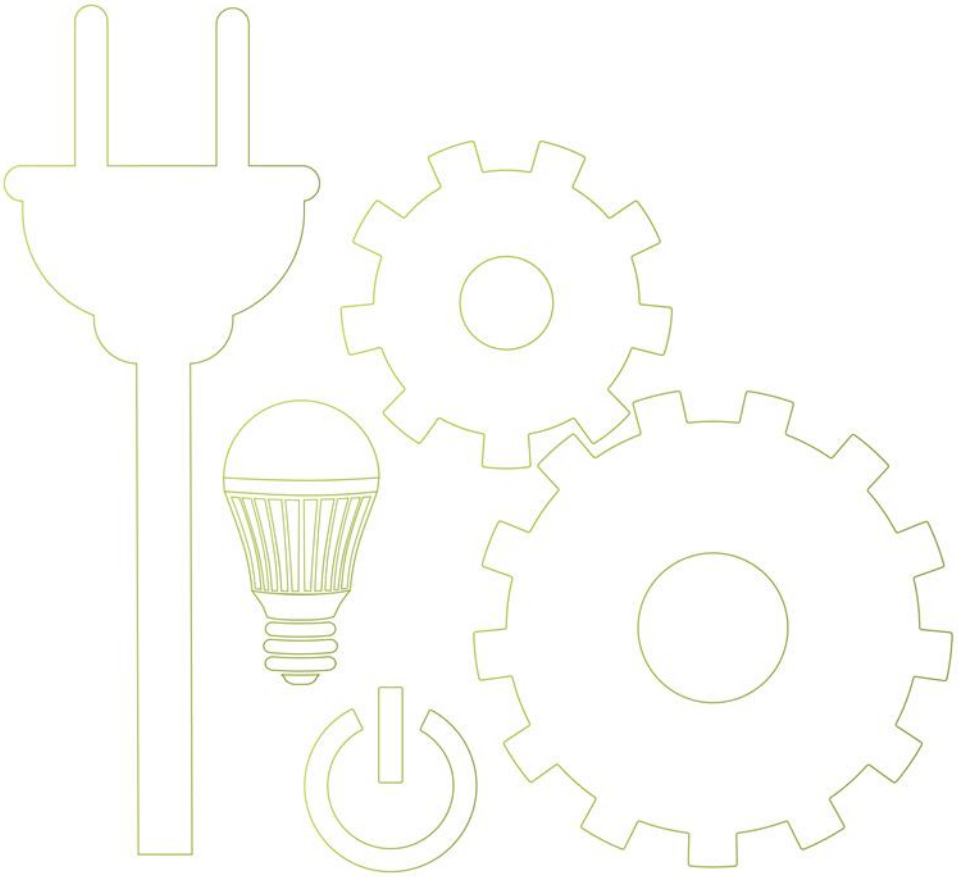
Energy Efficient End-use Equipment
International Energy Agency



Solid State Lighting Annex: Product Quality and Performance Tiers

NON-DIRECTIONAL LAMPS

Energy Efficient End-use Equipment (4E)
International Energy Agency

NOVEMBER 2016

iea Energy Technology Network

Performance Tiers Proposed by Governments Participating in the IEA 4E SSL Annex

Government officials from 13 countries participating in the International Energy Agency's Energy Efficient End-use Equipment (IEA 4E) implementing agreement have identified solid state lighting (SSL) technologies as having the potential to cut global lighting electricity consumption by 30%. While SSL technologies promise high performance, the recent experience with compact fluorescent lamps has demonstrated the need to prevent unwarranted performance claims, which can seriously damage consumer confidence and slow down market acceptance of this emerging energy-saving technology.

Twenty technical experts from the SSL Annex's eight member countries: Australia, Denmark, France, Korea, The Netherlands, Sweden, United Kingdom, and United States of America and expert member country China have worked together to develop performance tiers for Light Emitting Diode (LED) based lighting. Several performance tier levels were set to address the various priorities and needs from each country or region. This approach is expected to help participating governments to define globally consistent requirements for programmes to promote market adoption of SSL products, as well as being useful for governments planning to adopt national energy policies and regulations covering SSL technologies.

The SSL Annex has published performance tiers associated with the following LED lamps and luminaires:

1. Non-directional Lamps
2. Directional Lamps
3. Downlight Luminaires
4. Linear LED Lamps Replacing Fluorescent Tubes
5. Outdoor Lighting (Street Lighting)
6. High/Low Bay LED Luminaires (NEW)
7. Planar Luminaires (NEW)

To view these performance tiers, visit our website: http://ssl.iea-4e.org/product-performance

The SSL Annex is continuing to monitor the market and the appropriateness of these published tier levels, and fully expects that further revisions will be made in the future as SSL technology advances. The Annex appreciates your interest in this process and welcomes any suggestions or thoughts you may have on these tiers.

Best regards,

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Management Committee Chair,
SSL Annex;
Energy Efficiency Department,
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About the IEA 4E Solid State Lighting Annex

The SSL Annex was established in 2010 under the framework of the International Energy Agency's Energy Efficient End-use Equipment (4E) Implementing Agreement to provide advice to its member countries seeking to implement quality assurance programmes for SSL lighting. This international collaboration was established by the governments of Australia, Denmark, France, Japan, The Netherlands, the Republic of Korea, Sweden, United Kingdom and the United States of America. China works as an expert member of the 4E SSL Annex. Further information on the 4E SSL Annex is available from: http://ssl.iea-4e.org/

About the IEA Implementing Agreement on Energy Efficient End-Use Equipment (4E)

4E is an International Energy Agency (IEA) Implementing Agreement established in 2008 to support governments to formulate effective policies that increase production and trade in efficient electrical end-use equipment. Globally, electrical equipment is one of the largest and most rapidly expanding areas of energy consumption which poses considerable challenges in terms of economic development, environmental protection and energy security. As the international trade in appliances grows, many of the reputable multilateral organisations have highlighted the role of international cooperation and the exchange of information on energy efficiency as crucial in providing cost-effective solutions to climate change. Twelve countries have joined together to form 4E as a forum to cooperate on a mixture of technical and policy issues focused on increasing the efficiency of electrical equipment. But 4E is more than a forum for sharing information – it initiates projects designed to meet the policy needs of participants. Participants find that pooling of resources is not only an efficient use of available funds, but results in outcomes which are far more comprehensive and authoritative. The main collaborative research and development activities under 4E include:

- The Electric Motor Systems Annex (EMSA)
- The Mapping and Benchmarking Annex
- The Solid State Lighting Annex (SSL)
- The Electronic Devices and Networks Annex (EDNA)

Current members of 4E are: Australia, Austria, Canada, Denmark, France, Japan, Korea, The Netherlands, Switzerland, Sweden, UK and USA. Further information on the 4E Implementing Agreement is available from: www.iea-4e.org

Disclaimer:

The IEA 4E SSL Annex performance tiers are provided for informational purposes only. The purpose of these tiers is to provide governments and market transformation programme managers a basis on which to structure voluntary and mandatory programmes which are harmonised with other programmes around the world, all of which will help to accelerate the market for SSL technology. The final decision to publish the performance tiers is made by the participating SSL Annex governments, following an expert review and public consultation. Neither the IEA 4E SSL Annex and its participating governments, nor the IEA 4E Implementing Agreement make any warranties or guarantees as to the accuracy of data presented herein nor accept any liability for any action taken or decision made based on the contents of this document. Furthermore, it should be noted that this report is issued as advice for governments and does not necessarily reflect the views or policies of the governments who are part of the SSL Annex.

Scope of Coverage and Definitions of Performance Tiers

Scope of coverage for Non-Directional Lamps – Lamps intended as replacement lamps for all non-directional lamp shapes for operating without external ballasts at voltages of 100 to 277 VAC, or 12 to 24 VAC or VDC.

Tier 1: Minimum Acceptable Performance Level

This tier is intended to represent the minimum acceptable performance level. Products meeting this tier provide quality lighting, use less energy and last longer than the traditional lighting technologies they are intended to replace. The SSL products in this tier have/are:

- Efficacy established at a level at least comparable to high quality compact fluorescent lamps and achievable by 70-80% of non-directional SSL lamps found in the unregulated market;
- Reliability and lamp lifetimes are superior to the lighting products they are intended to replace; and
- Quality of light and the light intensity distribution perceived as roughly equivalent to the conventional technologies they are replacing.

Tier 2: Performance Required by Established Quality Programs

This tier is intended to be similar to the performance requirements for established voluntary programmes that promote quality SSL products. In addition to the objectives set out in Tier 1, the non-directional SSL lamps in this tier have/are:

- Efficacy established at a level exceeding compact fluorescent lamps and achievable by the top 20-30% of SSL products found in the unregulated market; and
- Improvement in the quality of light over Tier 1, and other critical performance aspects including lifetime and light distribution pattern.

Tier 3: Current Highest Commercially Available Performance

This tier is set at approximately the highest performing non-directional household SSL lamps available in an unregulated market at the time of publication. Products achieving these performance levels are intended to be equivalent to those participating in premium labelling programmes such as the US Department of Energy's L-Prize, the SEAD global efficiency award programme or the Japanese Top Runner programme.

Table 1. IEA 4E SSL Annex Performance Tiers for Non-Directional Lamps

Note: please see Table 2 for recommended test methods for these parameters

<table>
<tr><th>Parameter</th><th>Tier 1</th><th>Tier 2</th><th>Tier 3</th></tr>
<tr><td colspan="4">Energy-Efficiency</td></tr>
<tr><td>Minimum lamp luminous efficacy (lm/W)[1]</td><td>65 lm/W</td><td>90 lm/W</td><td>125 lm/W</td></tr>
<tr><td>Maximum Standby Power[2]</td><td>0.5 W</td><td>0.3 W</td><td>0.2 W</td></tr>
<tr><td>Claimed incandescent lamp wattage (W) equivalent based on initial light output (lumens)[3]</td><td colspan="3">For 120V mains voltage products: Incandescent Wattage$_{120V}$ = [(lumens + 187) / 15.8] or
For 230V mains voltage products: Incandescent Wattage$_{230V}$ = [(lumens + 176) / 13.9] or
With the objective of moving away from voltage-dependent lumen bins, the table to the right offers incandescent wattage equivalency for the given set of lumen outputs. Based on IEC 62612.
<table>
<tr><th>Incancescent Wattage</th><th>Light Output</th></tr>
<tr><td>10 W</td><td>100 lm</td></tr>
<tr><td>15 W</td><td>150 lm</td></tr>
<tr><td>25 W</td><td>250 lm</td></tr>
<tr><td>30 W</td><td>350 lm</td></tr>
<tr><td>40 W</td><td>500 lm</td></tr>
<tr><td>60 W</td><td>800 lm</td></tr>
<tr><td>75 W</td><td>1000 lm</td></tr>
<tr><td>100 W</td><td>1500 lm</td></tr>
<tr><td>125 W</td><td>2000 lm</td></tr>
<tr><td>150 W</td><td>2500 lm</td></tr>
</table></td></tr>
<tr><td colspan="4">Life</td></tr>
<tr><td>Luminous flux maintenance</td><td>At 6,000h ≥ 86.7% of initial
(based on L_{70} ≥ 15,000h)</td><td colspan="2">At 6,000h ≥ 89.9% of initial
(based on L_{70} ≥ 20,000h)</td></tr>
<tr><td>Early failure rate</td><td colspan="3">Either no failures at 3,000 hours or ≤10% failures at 6000 hours with a sample size of 10 units</td></tr>
<tr><td>Minimum rated lamp lifetime (F_{50})</td><td>At 15,000h, <50% have failed</td><td colspan="2">At 20,000h, <50% have failed</td></tr>
<tr><td>Endurance test[4]</td><td colspan="2">Must survive one switching cycle for every 2 hours of rated life.</td><td>Must survive one switching cycle for every hour of rated life.</td></tr>
<tr><td colspan="4">Colour</td></tr>
<tr><td>Colour rendering index (CRI)[5]</td><td>Ra ≥ 80</td><td>Ra ≥ 80, R9 > 0</td><td>Ra ≥ 85, R9 ≥ 0</td></tr>
<tr><td>Colour maintenance (Δu',v' at 6,000h)</td><td colspan="2">≤ 0.007</td><td>≤ 0.004</td></tr>
<tr><td>Chromaticity tolerance</td><td colspan="2">
<table>
<tr><th>Nominal CCT (K)</th><th>Target CCT and Tolerance (K)</th><th>Target Duv</th><th>Duv Tolerance Range</th></tr>
<tr><td>2200</td><td>2238 ± 102</td><td>0.0000</td><td rowspan="11">T_x: CCT of the source
For T_x < 2870K
0.000 ± 0.0060
For T_x ≥ 2870K
$D_{uv}(T_x) \pm 0.0060$
where
$D_{uv}(T_x) = 57700 \times (1/T_x)^2 - 44.6 \times (1/T_x) + 0.00854$</td></tr>
<tr><td>2500</td><td>2460 ± 120</td><td>0.0000</td></tr>
<tr><td>2700</td><td>2725 ± 145</td><td>0.0000</td></tr>
<tr><td>3000</td><td>3045 ± 175</td><td>0.0001</td></tr>
<tr><td>3500</td><td>3465 ± 245</td><td>0.0005</td></tr>
<tr><td>4000</td><td>3985 ± 275</td><td>0.0010</td></tr>
<tr><td>4500</td><td>4503 ± 243</td><td>0.0015</td></tr>
<tr><td>5000</td><td>5029 ± 283</td><td>0.0020</td></tr>
<tr><td>5700</td><td>5667 ± 355</td><td>0.0025</td></tr>
<tr><td>6500</td><td>6532 ± 510</td><td>0.0031</td></tr>
</table></td><td colspan="2">
<table>
<tr><th rowspan="2">Nominal CCT (K)</th><th colspan="2">Centre Point of Circle</th><th rowspan="2">Radius of Circle</th></tr>
<tr><th>CCT (K)</th><th>Duv</th></tr>
<tr><td>2200</td><td>2238</td><td>0.0000</td><td rowspan="11">0.0044 in (u',v') diagram</td></tr>
<tr><td>2500</td><td>2460</td><td>0.0000</td></tr>
<tr><td>2700</td><td>2725</td><td>0.0000</td></tr>
<tr><td>3000</td><td>3045</td><td>0.0001</td></tr>
<tr><td>3500</td><td>3465</td><td>0.0005</td></tr>
<tr><td>4000</td><td>3985</td><td>0.0010</td></tr>
<tr><td>4500</td><td>4503</td><td>0.0015</td></tr>
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<tr><td>5700</td><td>5667</td><td>0.0025</td></tr>
<tr><td>6500</td><td>6532</td><td>0.0031</td></tr>
</table></td></tr>
</table>

[1]The efficacy calculation shall be based on initial luminous flux measurements according to CIE S 025/E (or IES LM-79).

[2] This requirement for Maximum Standby Power applies to smart lamps with wireless illumination control activated in the default (factory setting) mode. These smart lamps remain 'on' while the lamps emit no light. For the default mode, all other features that provide lighting control (e.g., movement sensor) or functions (e.g., speaker) are to be deactivated. The maximum standby power requirement is based on the analysis of a small sample of domestic lamps tested in relation to the SSL Annex report http://ssl.iea-4e.org/news/stand-by-of-smart-lamps. The IEA/G20 will continue to research different types of smart lighting and provide advice to governments.

[3]The lumen (lm) values for efficacy calculation shall be initial luminous flux measurements according to CIE S 025/E (or IES LM-79).

[4]The endurance requirements are based on clause/section 11.3.3 of IEC 62612 (on/off for 30 seconds each).

[5]Please see Table 2 for a note about Colour Rendering Index

<table>
<tr><th>Parameter</th><th>Tier 1</th><th>Tier 2</th><th>Tier 3</th></tr>
<tr><td colspan="4">Operation</td></tr>
<tr><td>Luminous intensity distribution 0-180°</td><td>No less than 5% of total flux (zonal lumens) shall be emitted in the 130° to 180° zone.

No less than 35% of total flux (zonal lumens) shall be emitted in the 90° to 180° zone.</td><td colspan="2">80% of the luminous intensity measured values (candelas) shall vary by no more than 35% from the average of all measured values in the 0° to 130° zone. All measured values (candelas) in the 0° to 130° zone shall vary by no more than 60% from the average of all measured values in that zone.

No less than 5% of total flux (zonal lumens) shall be emitted in the 130° to 180° zone.</td></tr>
<tr><td>Dimmer compatibility</td><td colspan="3">Lamps may be dimmable or non-dimmable, which must be clearly indicated on the product packaging. For dimmable products, the manufacturer shall: (a) declare the conditions under which the luminaire will dim; (b) provide a web address for a webpage that lists compatible dimmer makes and models; and (c) for each compatible dimmer, the number of luminaires that can be dimmed and the range of luminous flux levels a given dimmer-luminaire combination can achieve.</td></tr>
<tr><td>Power factor (PF)</td><td colspan="3">For < 25W PF >0.50; for ≥25W PF >0.90</td></tr>
<tr><td>Harmonic distortion</td><td colspan="3">For products >25W within IEC 61000-3-2, Table 2, Limits for Class C equipment.[6]
<table>
<tr><th>Harmonic Order
n</th><th>Maximum permissible harmonic current expressed as a percentage of the input current at the fundamental frequency
(%)</th></tr>
<tr><td>2</td><td>2</td></tr>
<tr><td>3</td><td>30 - CPF *</td></tr>
<tr><td>5</td><td>10</td></tr>
<tr><td>7</td><td>7</td></tr>
<tr><td>9</td><td>5</td></tr>
<tr><td>11 ≤ n ≤ 39
(odd harmonics only)</td><td>3</td></tr>
<tr><td colspan="2">* CPF is the circuit power factor</td></tr>
</table></td></tr>
<tr><td colspan="4">Health</td></tr>
<tr><td>Dominant light modulation frequency (f)
Modulation percent at this frequency (Mod%)[7]

(Includes Flicker effects)</td><td colspan="3">
<table>
<tr><th>Dominant modulation frequency (f)</th><th>Modulation percent at f</th></tr>
<tr><td>f ≤ 90 Hz</td><td>Mod% < (0.025 x f)</td></tr>
<tr><td>90Hz < f ≤ 1250 Hz</td><td>Mod% < (0.08 x f)</td></tr>
<tr><td>f > 1250 Hz</td><td>No Mod% requirement</td></tr>
</table>
<table>
<tr><th>Dominant modulation frequency (f)</th><th>Modulation percent at f</th></tr>
<tr><td>f ≤ 90 Hz</td><td>Mod% < (0.01 x f)</td></tr>
<tr><td>90Hz < f ≤ 1250 Hz</td><td>Mod% < (0.08 x f)</td></tr>
<tr><td>f > 1250 Hz</td><td>No Mod% requirement</td></tr>
</table></td></tr>
<tr><td>Photobiological risk group (blue light and UV hazard)[8]</td><td colspan="3">For the blue light hazard: RG0 or RG1 are allowed. If an LED uses a UV-based LED chip, then it must meet UV RG0 and RG1. The risk group (RG) is assessed at 200 mm from the lamp using the general methodology of IEC 62471 and the particular prescriptions of IEC TR 62778.</td></tr>
<tr><td>Safety</td><td colspan="3">Must meet regional requirements for material safety, and mechanical and electrical appliance safety laws, including electromagnetic compatibility (EMC) requirements, and requirements for labelling / marking.</td></tr>
<tr><td colspan="4">Environment</td></tr>
<tr><td>Warranty duration</td><td>Minimum 1 year against catastrophic failure unless regional requirement is higher</td><td colspan="2">Minimum warranty of at least 1 year for every 15,000 hours or part thereof of rated lifespan unless the national or regional requirement is different</td></tr>
<tr><td>RoHS compliant</td><td colspan="3">Yes, unless other regional or national requirements apply.</td></tr>
<tr><td>Recyclable content (%)</td><td colspan="3">The manufacturer shall provide data concerning the recyclable content in percentage by weight, together with the associated recycling codes or symbols (metal, plastics, glass, etc.) of the recyclable materials. This declaration should be made in the form of a type III Environmental Product Declaration (EPD).</td></tr>
</table>

[6] For products 5W < P ≤ 25W: requirement to be developed pending amendment to 61000-3-2 – and update to these specifications will be made following release.

[7] The requirements are based on IEEE 1789-2015. The priority here is on restricting the visible modulation of light (including flicker) at frequencies ≤ 90 Hz, as more research is required on the effects of light modulation frequencies beyond 90 Hz (ie non-visible effects). NOTE1: In some particular instances, there is a strong sub-harmonic or inter-harmonic frequency in the luminance modulation waveform. In this case, the dominant light modulation frequency may not be clearly defined. The requirements should then be met for both the Fourier fundamental frequency and the sub/inter harmonic frequency. NOTE2: Due to the lack of a standard for the photometric measurement of modulated light , the SSL Annex are continuing to work on this issue, consult with stakeholders including CIE TC 1-83 (authors of CIE TN 006:2016), and will issue an update when new guidance becomes available.

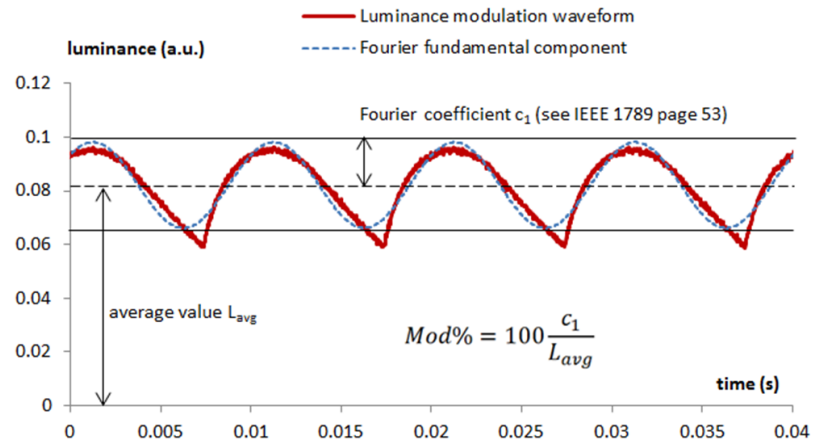
[8] The blue light hazard assessment is based on IEC 62471 and IEC TR 62778:2015.

Table 2. Performance Criteria included in the IEA 4E SSL Annex Product Tiers Documents

Criterion	What is it?	Why is it included?	Test Method
Minimum lamp luminous efficacy (lm/watt)	The ratio of the total light output of a lamp compared to power consumed (lm/watt). The higher the efficacy value, the more energy-efficient the lighting product.	This criterion is of highest importance for the consumer and society to save energy and money.	CIE S 025/E (or IES LM-79)
Maximum Standby Power	Maximum Standby Power applies to the default (factory setting) mode of smart lamps and other modes that provide a lighting control function, and which remain 'on' when emitting no light. The IEA/G20 will continue to research this topic plus other types of smart lighting and provide advice to governments.	As wireless control of lighting expands in the market, this criterion is important for the consumer and society so as to ensure minimal additional power consumption associated with new lighting control features.	IEC 62301
Claimed incandescent equivalent wattage (W) and minimal initial light output (lumens)	These levels will also assist in evaluating manufacturer claims that a given SSL product is an equivalent replacement for a typical wattage incandescent light product. These light levels are different in 120V and 230/240V markets (defined by equations). The Annex also proposes a transition to a harmonised set of lumen bins, based on an approximate averaging of the light output.	Acceptable light output levels are of highest importance for safe working and living conditions. Accurate equivalency comparison with the products that are being replaced is also important. This importance will diminish over time as manufacturers stop selling products according to claimed equivalencies and consumers select lamps on the basis of light output (lumens) rather than wattage.	
Luminous flux maintenance	The percentage of a lighting product's measured light output after a period of time compared to that light product's initial total light output	Luminous flux maintenance helps the consumer determine how long it will take a lighting product to degrade to the point that it is no longer useable. High lumen maintenance over time helps to justify the higher initial cost of SSL lighting products.	IES LM-80/TM-21 or IES LM-84/TM-28. It is expected from 2017 onwards only LM-84 / TM-28 may be accepted
Early failure rate (maximum)	The percentage of lamps in a sample that fail at a specified point in time (6000 hours).	Early failure rates should be as low as possible in order to minimise the risk that new customers to LED lighting will have a bad experience and the lamp itself will fail to achieve its full potential of energy savings. It is also an alternative indicator of longevity in the absence of a practical lifetime test.	IES LM-80

Criterion	What is it?	Why is it included?	Test Method
Minimum rated lamp lifetime (F_{50})	Lifetime is typically defined as the amount of time that it takes for 50% of a statistically significant sample to fail.	It is unrealistic to measure very long lifetimes for SSL products. Having a credible F_{50} estimation is very important, as LED lighting products must have longer lifetimes to justify the high initial cost of LED lighting. If SSL products are able to meet their lifetime claims, they can cut long-term energy consumption and save the consumer money.	
Endurance test	This criterion requires that a SSL product is rapidly switched on and off to simulate how a product will be used over its lifetime.	This criterion requires that a test is carried out to stress a SSL product over a short period of time to determine the failure rates of a product. Often, if one electronic subcomponent in a SSL product fails, the whole product fails. A stress test like this one can help verify that an SSL product will not fail when installed and used in a consumer application.	IEC 62612
Colour rendering index (CRI)	Colour rendering is a measure of how similar object colours appear under one light source as compared to the object colours under a reference light source (usually an incandescent light or daylight). Colour rendering is very important for consumer satisfaction with a lighting product. Often, a CRI of 80 is required for office work, and recommended for use in residential applications. A CRI of 90 is recommended for tasks that require high colour discrimination.	The IEA SSL Annex is aware of current investigations and discussions of shortcomings of the CRI metric that limit its ability to fully represent how humans perceive colour for SSL technology; and the potential need for both a colour fidelity metric and a colour preference metric. The IEA SSL annex is monitoring the work of the IES (in particular the release of TM-30) as well as the ongoing work in CIE, and will take this work into account in future updates of the SSL Annex performance specifications.	CIE 13.3-1995
Colour maintenance (Δ u',v' at 6,000h)	This criterion specifies the allowable shift of the light colour of a SSL package as it ages, based on either using IESNA LM-80/TM-21 or IESNA LM-84/TM-28.	This criterion ensures that as a light product ages, the perceived colour of light does not shift from warm- white to cool-white or develop a green or pink tint. If an SSL lamp or luminaire in a large installation is replaced by a new light product of the same model, this criterion ensures that the new product's colour will be similar to those installed around it.	IES LM-80/TM-21 or IES LM-84/TM-28. It is expected from 2017 onwards only LM-84 / TM-28 may be accepted
Chromaticity tolerance	This criterion specifies the allowable deviation in light's colour. Technically, it is the distance of a light's chromaticity from the Planckian (black body) locus and target CCT.	This criterion is of high importance to ensure that the light from an LED product does not have an unacceptable pink or green tint. This criterion attempts to ensure that all lamps and luminaires of the same claimed colour temperature appear to be the same colour when installed.	ANSI C78.377-2015

Criterion	What is it?	Why is it included?	Test Method
Luminous intensity distribution 0-180°	This criterion describes the measured distribution of light of a lighting product.	It is of high importance to measure this as many LED products being sold now poorly approximate the light distribution of the conventional products they claim to replace.	CIE S 025/E
Dimmer compatibility	This criterion evaluates whether a SSL light source will operate well with the current stock of installed dimmers.	Dimmer compatibility is of high importance for the consumer as many SSL products are often not completely compatible with commonly available dimmers. As manufacturers are still trying to define and adopt a new dimming standard, the dimmer compatibility of SSL products is likely to continue to be a problem.	
Power factor	Power factor is the ratio of the active power flowing to the load over the apparent power of the circuit (see IEC IEV ref 131-11-46). We recognise that in many cases the IEC requirements on total harmonic distortion (THD) will lead to a higher power factor (PF) than the minimum level required in the performance tiers, but we follow IEC standards and believe the most critical electrotechnical requirements are set through the THD requirements.	For the Electrical power supplier, power factor is of high importance. For street lighting and commercial or industrial lighting; customers may be subject to a penalty charge if power factor is below 0.9. The importance of high power factor may vary depending on the nature of the power distribution network.	IEC 61000-3-2
Harmonic distortion	The total harmonic distortion of the current is the RMS-sum of all the harmonic currents divided by the current at the fundamental frequency (50 Hz or 60 Hz). $$THD = \frac{\sqrt{\sum_{n=2}^{\infty} I_n^2}}{I_1}$$	Harmonic distortion measures how the lighting product might affect the quality and safety of the electrical utility's grid. The total harmonic distortion is important to maintain the quality and safety of the electrical grid. High frequency harmonic currents emitted by electrical devices such as lamps may trigger circuit breakers, may cause overheating in cables (lost energy) and electrical distribution devices and may cause a loss of reliability of switch pulse information.	IEC 61000-4-7

Criterion	What is it?	Why is it included?	Test Method
Dominant light modulation frequency (*f*) Modulation percent at this frequency (Mod%) (Includes Flicker effects)	The criteria here are based on the IEEE 1789 standard, section 8. The criteria are related to fast periodic changes - less than 1 second - of the luminance of a light source (including flicker). The dominant light modulation frequency is usually the Fourier fundamental frequency of the luminance modulation waveform. (Please see diagram and Mod% equation below; also see the spreadsheet on the SSL Annex website to facilitate the Fourier calculation)	This is an important item for both consumer satisfaction and consumer acceptance of SSL products. Some consumer may have severe health reactions to flickering light sources of certain frequencies ranging from low-grade headaches to extreme seizures. Modulated light can also alter the perception of the motion of objects and produce ghost images in the visual field. The requirements minimize these effects. While more research is required on health effects at non visible modulation frequencies beyond 90 Hz, the priority here is on restricting flicker, occurring at modulation frequencies less than 90 Hz.	There is no standard test method at this time. IEEE 1789 is not a test standard. CIE TN 006:2016 Section 4 gives a useful indication of the experimental determination of the light modulation waveform and the calculation of its Fourier spectrum.
			
Photo-biological risk group (blue light and UV hazard)	Photobiological risk groups are defined in IEC 62471, with additional information given in IEC TR 62471-2 and IEC TR 62778. There is a potential risk of retinal damage when the blue light radiance is too high. The criterion sets a limit to the blue light dose that the retina can receive.	This criterion is very important for consumer safety. Blue light can cause irreparable damage to eyesight at high doses. Products need to be evaluated to determine their appropriate photobiological risk group.	IEC 62471-2/ CIE S 009 and IEC TR 62778
Safety	This criterion specifies that a product meets mechanical and electrical safety requirements and marking requirements.	All products must meet all safety regulations in an economy.	IEC 60598 series
Warranty duration	This criterion specifies the duration in years from the date of installation of a SSL product.	It is very important that consumers have a guarantee that SSL products will perform as claimed.	

Criterion	What is it?	Why is it included?	Test Method
RoHS compliant	The EU's Regulation of Hazardous Substances (RoHS), Delegated Directive (EU) 2015/863 of 31 March 2015, prevents the use of certain hazardous materials in new electrical and electronic equipment placed on the European market.	This criterion requires products meet requirements that limit the use of certain hazardous materials when sold in the EU. Non-EU countries may use other, similar requirements.	
Recyclable content (%)	This criterion defines how much of the SSL product must be recyclable: • Recyclable content, expressed in percentage by weight (wt%) • The nature of the recyclable materials, stated by recycling codes or recycling symbols	This criterion is important to manage electronic equipment waste and reduce the environmental burden of these products. Ideally, products would be designed to be easily recycled when they fail.	ISO 14021; ISO 14025:2006