

Solid State Lighting Annex: Performance Tiers for Directional Lamps

ANNEX ADOPTED TIER LEVELS

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

AUGUST 2012



August 2012

Re: Publication of Solid State Lighting (SSL) performance tiers proposed by governments participating in the International Energy Agency's 4E SSL Annex

To Whom It May Concern:

Government officials from 13 countries participating in the International Energy Agency's Energy Efficient End-use Equipment (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 nine member countries (Australia, Denmark, France, Japan, The Netherlands, South Korea, Sweden, United Kingdom, and United States of America) have worked together to develop performance tiers for Light Emitting Diode (LED) based lighting, a type of SSL. Several performance tier levels were set to address the various priorities and needs from each country. This approach is expected to help participating governments to define minimum performance of SSL products in their national energy policies and regulation.

In August 2012, the SSL Annex published four performance tiers associated with LED lamps and luminaires. The four performance tier documents are:

1. Non-directional Lamps for Indoor Residential Applications
2. Directional Lamps for Indoor Residential Applications
3. Downlight Luminaires
4. Linear Fluorescent LED Replacement Lamps

Following this cover letter, the performance tiers for directional lamps for indoor residential applications can be found. If you wish to view the other three performance tiers that were finalised, please visit this website: <http://ssl.iea-4e.org/task-1---quality-assurance>

The SSL Annex is continuing to monitor the market and the appropriateness of these published tier levels, and fully expects that additional levels will be added 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,

Nils Borg
Operating Agent
IEA 4E SSL Annex 2010-2014

Peter Bennich
Management Committee Chair
IEA 4E SSL Annex 2010-2014



Performance Tiers for Directional Lamps for Indoor Residential Applications

Tier	Tier 0	Tier 1	Tier 2	Tier 3
If claiming equivalence to filament lamp wattages (by lamp type)	N/A: a large number of these products will be used in off grid applications where light has never been used before. Equivalency in these applications has no meaning.	Watts MR11 MR16 AR111 R PAR (W) (lm) (lm) (lm) (lm) (lm)	Watts MR11 MR16 AR111 R PAR (W) (lm) (lm) (lm) (lm) (lm)	Watts MR11 MR16 AR111 R PAR (W) (lm) (lm) (lm) (lm) (lm)
		20 390 250 380 120 92	20 390 250 380 120 92	20 390 250 380 120 92
		25 564 170 150	25 564 170 150	25 564 170 150
		30 660 200	30 660 200	30 660 200
		35 650 490 930 250	35 650 490 930 250	35 650 490 930 250
		50 780 1030 400 540	50 780 1030 400 540	50 780 1030 400 540
		60 700 800	60 700 800	60 700 800
		75 1300 850 1030	75 1300 850 1030	75 1300 850 1030
		100 1200	100 1200	100 1200
		120 1500	120 1500	120 1500
150 1600 1370	150 1600 1370	150 1600 1370		
200 2270	200 2270	200 2270		
240 3100	240 3100	240 3100		
Center beam luminous intensity	N/A	For MR or PAR lamps with a beam angle <65°, center beam intensity should meet equivalent levels using the online tool: http://www.energystar.gov/ia/products/lighting/iledl/IntlLampCenterBeamTool.zip	For MR or PAR lamps with a beam angle <65°, center beam intensity should meet equivalent levels using the online tool: http://www.energystar.gov/ia/products/lighting/iledl/IntlLampCenterBeamTool.zip	For MR or PAR lamps with a beam angle <65°, center beam intensity should meet equivalent levels using the online tool: http://www.energystar.gov/ia/products/lighting/iledl/IntlLampCenterBeamTool.zip
Minimum lamp luminous efficacy (lm/W)	50 lm/W	≤ 20/8 inches (63mm): >35 lm/W > 20/8 inches (63mm): >40 lm/W	≤ 20/8 inches (63mm): >45 lm/W > 20/8 inches (63mm): >50 lm/W	≤ 20/8 inches (63mm): >55 lm/W > 20/8 inches (63mm): >60 lm/W
Color temperature target (K) and tolerance	N/A	follow ANSI C78.377, excluding flexible CCT 2700K (2725 ± 145) 3000K (3045 ± 175) 3500K (3465 ± 245) 4000K (3985 ± 275) 5000K (5028 ± 283) 5700K (5665 ± 355) 6500K (6530 ± 510)	follow ANSI C78.377, excluding flexible CCT 2700K (2725 ± 145) 3000K (3045 ± 175) 3500K (3465 ± 245) 4000K (3985 ± 275) 5000K (5028 ± 283) 5700K (5665 ± 355) 6500K (6530 ± 510)	follow ANSI C78.377- 2011 Table 6A, for 4-step quadrangle excluding flexible CCT 2700K (2723 ± 82) 3000K (2940 ± 98) 3500K (3397 ± 125) 4000K (4036 ± 154) 5000K (4991 ± 220) 5700K (5665 ± 270) 6500K (6432 ± 340)
Chromaticity tolerance (Du'v')	N/A	follow ANSI C78.377, excluding flexible CCT 0.000 ± 0.006 0.000 ± 0.006 0.000 ± 0.006 0.001 ± 0.006 0.002 ± 0.006 0.002 ± 0.006 0.003 ± 0.006	follow ANSI C78.377, excluding flexible CCT 0.000 ± 0.006 0.000 ± 0.006 0.000 ± 0.006 0.001 ± 0.006 0.002 ± 0.006 0.002 ± 0.006 0.003 ± 0.006	follow ANSI C78.377- 2011 Table 6A, for 4-step quadrangle excluding flexible CCT 0.0006 ± 0.0033 -0.0008 ± 0.0033 -0.0002 ± 0.0033 0.0016 ± 0.0033 0.0033 ± 0.0033 0.0024 ± 0.0033 0.0071 ± 0.0033
Color spacial uniformity	N/A	The variation of chromaticity across the beam and field angles shall be within 0.007 from the weighted average point on the CIE 1976 (u'v') diagram	The variation of chromaticity across the beam and field angles shall be within 0.007 from the weighted average point on the CIE 1976 (u'v') diagram	The variation of chromaticity across the beam and field angles shall be within 0.004 from the weighted average point on the CIE 1976 (u'v') diagram
Color Maintenance (Δ u',v' at 6,000h)	N/A	<0.007	<0.007	<0.004
Luminous intensity distribution 0-180°	N/A	Must be provided by manufacturer and 50% of flux shall be in declared beam angle	Must be provided by manufacturer and 50% of flux shall be in declared beam angle	Must be provided by manufacturer and 50% of flux shall be in declared beam angle
CRI	N/A	≥80	≥80, R9> 0	≥80, R9> 0
Lag start time	N/A	<0.5sec until continous light output	<0.5sec until continous light output	<0.5sec until continous light output
Lumen Maintenance (Minimum time to L70)	At 5,000h, Lumen Maintenance > 70% of initial	At 15,000h, Lumen Maintenance > 70% of initial	At 15,000h, Lumen Maintenance > 70% of initial	At 25,000h, Lumen Maintenance > 70% of initial
Minimum Rated Lamp lifetime (B50)	At 5,000h, 50% of population will be operative.	At 15,000h, 50% of population will be operative.	At 15,000h, 50% of population will be operative.	At 25,000h, 50% of population will be operative.
Flicker (Flicker index)	At full power (no dimming), percent flicker (calculated as (max-min)/(max+min) luminous flux) ≤ 10%	At full power flicker index ≤ 0.3	At full power flicker index ≤ 0.3	At full power flicker index ≤ 0.3
Glare Luminance (cd/m ²)	N/A	Above 60 degrees, no more than 10,000 candela/m ²	Above 60 degrees, no more than 10,000 candela/m ²	Above 60 degrees, no more than 10,000 candela/m ²



Performance Tiers for Directional Lamps for Indoor Residential Applications

Tier	Tier 0	Tier 1	Tier 2	Tier 3
Minimum power Factor	Current Crest Factor (calculates as I_{peak}/I_{rms}) ≤ 3	Low voltage lamps exempt. $\leq 5W$: no requirement; $>5W$, PF >0.50	Low voltage lamps exempt. $\leq 5W$: no requirement; $>5W$, PF >0.50	Low voltage lamps exempt. $\leq 5W$: no requirement; $>5W$, PF >0.50
Harmonic distortion	N/A	EAC 7.3A/B FCC CFR47 Section 15 and 18. Dimmers are considered incidental radiators and they need to be tested as SSL products act as antennae for the dimmers' EMI/RFI.	EAC 7.3A/B FCC CFR47 Section 15 and 18. Dimmers are considered incidental radiators and they need to be tested as SSL products act as antennae for the dimmers' EMI/RFI.	EAC 7.3A/B FCC CFR47 Section 15 and 18. Dimmers are considered incidental radiators and they need to be tested as SSL products act as antennae for the dimmers' EMI/RFI.
Dimmer compatibility	N/A	Lamps may be dimmable or non-dimmable. Product packaging shall clearly indicate whether the lamp is dimmable or not dimmable. If a product is declared as dimmable, manufacturer shall also declare the conditions under which a lamp will operate as declared, and shall provide a web address for a website that lists dimmer makes and models with which the lamp is compatible. For each compatible dimmer, the manufacturer must also list the minimum and maximum number of lamps that can be satisfactorily dimmed with a given dimmer and the minimum relative luminous flux level a given dimmer-lamp combination can achieve.	Lamps may be dimmable or non-dimmable. Product packaging shall clearly indicate whether the lamp is dimmable or not dimmable. If a product is declared as dimmable, manufacturer shall also declare the conditions under which a lamp will operate as declared, and shall provide a web address for a website that lists dimmer makes and models with which the lamp is compatible. For each compatible dimmer, the manufacturer must also list the minimum and maximum number of lamps that can be satisfactorily dimmed with a given dimmer and the minimum relative luminous flux level a given dimmer-lamp combination can achieve.	Lamps may be dimmable or non-dimmable. Product packaging shall clearly indicate whether the lamp is dimmable or not dimmable. If a product is declared as dimmable, manufacturer shall also declare the conditions under which a lamp will operate as declared, and shall provide a web address for a website that lists dimmer makes and models with which the lamp is compatible. For each compatible dimmer, the manufacturer must also list the minimum and maximum number of lamps that can be satisfactorily dimmed with a given dimmer and the minimum relative luminous flux level a given dimmer-lamp combination can achieve.
Photobiological hazard class (UV & blue light)	RG0 or RG1 at 200 mm	RG0 or RG1 at 200 mm	RG0 or RG1 at 200 mm	RG0 or RG1 at 200 mm
Safety marking	Must meet regional requirements for marking, if they exist, for non-grid connected devices	Must meet regional requirements for marking (ANSI/UL 1993 or CE Mark)	Must meet regional requirements for marking (ANSI/UL 1993 or CE Mark)	Must meet regional requirements for marking (ANSI/UL 1993 or CE Mark)
Warranty Duration	Minimum 1 year warranty against catastrophic failure unless regional requirement is higher	Minimum 1 year warranty against catastrophic failure unless regional requirement is higher	Minimum warranty of at least 1 year for every 15,000 hours of rated lifespan unless the national or regional requirement or business practice is different.	Minimum warranty of at least 1 year for every 15,000 hours of rated lifespan unless the national or regional requirement or business practice is different.
RoHS Compliant	Yes	Yes	Yes	Yes
Recyclability (%)	Yes, following the principles of self-declaration found in ISO 14021	Yes, following the principles of self-declaration found in ISO 14021	Yes, following the principles of self-declaration found in ISO 14021	Yes, following the principles of self-declaration found in ISO 14021
Endurance Test	Using section 10.2 of IEC 62612 (on/off for 30 seconds each), product must survive one cycle for every hour of rated life.	Using section 10.2 of IEC 62612 (on/off for 30 seconds each), product must survive one cycle for every hour of rated life.	Using section 10.2 of IEC 62612 (on/off for 30 seconds each), product must survive one cycle for every hour of rated life.	Using section 10.2 of IEC 62612 (on/off for 30 seconds each), product must survive one cycle for every hour of rated life.

* The lumen (lm) values are initial values.

‡ Flicker index defined by Area 1/(Area 1+Area2); replaced by new metric under development by IEEE PAR1789 which accounts for frequency, when available

Definitions of Performance Tiers and Criteria (Aug. 2012)

Tier 0: Minimum Acceptable Performance for Off-Grid Applications

This tier is intended to be the minimum acceptable performance when products are used for off-grid applications. Products in this tier are safe to use and reliably provide basic lighting. They use less energy and last longer than basic incandescent sources. SSL products in this tier have/are:

- Efficacies that enable significantly longer battery life and more efficacious than technologies currently being used.
- Light output sufficient for basic domestic applications such as reading or studying.
- Provide basic lighting with longer operating lifetimes than incandescent sources.
- Safe to use.

Tier 1: Minimum Acceptable Performance for Grid-Connected Applications

This tier is intended to be the minimum acceptable performance when products are used for grid connected applications. Products in this tier reliably provide basic lighting and use less energy and last longer than incandescent sources. SSL products in this tier have/are:

- Efficacies providing significant energy savings relative to incandescent lamps. In the case of linear fluorescent replacements, these SSL products perform at the level of an electronically ballasted T8 fluorescent lamp.
- Reliability and lifetimes are superior to the lighting products they are intended to replace.
- Total light output and intensity distribution should be roughly similar to the products they are intended to replace.
- Safe to use.

Tier 2: Performance Required by Established Quality Programs

This tier is intended to be similar or equal to the performance required for established voluntary programs for quality LED products, such as the EU Quality Charter, the US Energy Star or Japan's Green Procurement Law. SSL products in this tier have/are:

- Efficacies providing similar energy use relative to CFL products or in the case of linear fluorescent, these SSL products perform at the level of a high-performing, electronically ballasted T8 fluorescent lamp.
- Reliability and lifetimes are superior to the lighting products they are intended to replace.



- Light output, quality of light and intensity distribution should be similar to the products they are intended to replace.
- Safe to use.

Tier 3: Current Highest Commercially Available Performance

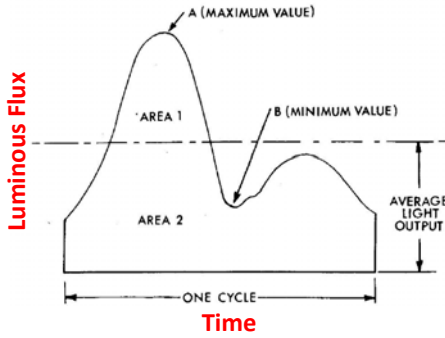
This tier is intended to represent the highest performing products available on the market in late 2011 and early 2012. It is similar to the performance required for program for the most efficient LED products, such as the US Department of Energy's L-Prize, the SEAD program or the Japanese Top Runner program. SSL products in this tier have/are:

- Efficacies providing significant energy savings relative to CFL products. In the case of linear fluorescent, these SSL products perform at the level of a T5 linear fluorescent lamp.
- Reliability, quality of light and lifetimes are superior to the lighting products they are intended to replace.
- Light output and intensity distribution are similar to the products they are intended to replace.
- Safe to use.

Table 1. Performance Criteria included in the IEA 4E SSL Annex Product Tiers Documents

Criterion	What is it?	Why is it included?
Minimum light output (lm) and equivalent wattage	The luminous flux (lm) quantifies the total amount of light emitted by a light source or product. The minimum light output requirement ensures that the SSL product's total light output is at least the same as the light output from an incandescent light source. 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.	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.
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.
Minimum fixture luminous efficacy (lm/watt)	The ratio of the total light output of an entire fixture compared to the power consumed (lm/watt).	This is a very important criterion. If a very efficient light source is installed in an inefficient light fixture, a large part of the light will be lost inside the fixture. As a result, even with a very efficient light source, there will be no efficiency gains or energy saved.
Correlated colour temperature (CCT) in degrees Kelvin (K)	The temperature of the lighting product in relation to the Planckian (black body) locus. CIE 15:2004 defines how to measure this parameter. ANSI C78.377 defines the target colour temperatures and allowable tolerances.	The CCT metric helps consumers select the appropriate product depending on their light colour preference and match lights' colour across different manufacturers' lighting products. This way, when different manufacturers' light products are used in the same space there is not an unintended mix of cool- white lighting with warm-white lighting.
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 index is defined in CIE 13.3-1995.	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.
Safety marking	This criterion specifies that a product meets electrical safety requirements and marking requirements.	All products must meet all safety regulations in an economy.

Criterion	What is it?	Why is it included?
Minimum rated lamp lifetime (B_{50})	Lamp lifetime is typically defined as the amount of time that it takes for 50% of a statistically significant sample of lamps to fail.	It is unrealistic to measure very long lifetimes for SSL products. Having a credible B_{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.
Minimum lumen maintenance (time to L_{70})	A lighting product's time to L_{70} indicates the amount of time it takes for a lighting product's total light output to degrade to 70% of the light product's initial total light output.	Lumen 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.
RoHS compliant	The EU's Regulation of Hazardous Substances (RoHS) Directive prevents the use of certain hazardous materials in new electrical and electronic equipment placed on the European market after 1 July 2006.	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.
Photo-biological hazard class (UV & blue light)	These hazard classes have been defined in IEC 62471 and this criterion specifies the allowable amount of high frequency "blue light" (ultra violet light) that a SSL product shall emit.	This criterion is very important for consumer safety. High frequency blue light can cause irreparable damage to eyesight. Products need to be evaluated to determine their appropriate photo-biological hazard class.
Minimum power factor	Power factor is the ratio of the real power flowing to the load over the apparent power of the circuit.	For the Electrical power supplier, this is of very high importance. However, for residential customers there has not been established any significant relation between the power factor of small electronic loads like SSL and the grid power factor.
Harmonic distortion	Harmonic distortion measures how the lighting product will affect the quality of the electrical utility's grid. Harmonic distortion is the mathematic ratio of the sum of the powers of all harmonic components to the power of the fundamental frequency.	The total harmonic distortion important to maintain the quality of the electrical grid. High harmonic distortion may cause a loss of reliability of switch pulse information.
Dimmer compatibility	This criterion evaluates whether a SSL light source will operate well with installed dimmers used for incandescent light sources.	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.

Criterion	What is it?	Why is it included?
Chromaticity tolerance (Du'v')	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. Chromaticity allowances follow those in ANSI C78.377.	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 of the same claimed colour temperature appear to be the same colour when installed.
Colour spatial uniformity	This criterion specifies a maximum allowable variation in the colour of light emitted at different angles. (The metric used is a chromaticity tolerance over an angular range).	It is of high importance to ensure that there are not extreme, perceptible colour variations in the light output of a lamp. For directional lamps, it is often possible to see blotches of different coloured light within a beam.
Flicker (flicker index)	This criterion measures the perceived photometric "flicker" of a light source. Flicker index defined by $(\text{Area 1} / (\text{Area 1} + \text{Area 2}))$; replaced by new metric under development by IEEE PAR1789 which accounts for frequency, when available. 	This is an important item for both consumer satisfaction and consumer acceptance of SSL products. Some consumers may have severe health reactions to flickering light sources of certain frequencies ranging from low-grade headaches to extreme seizures. Flicker can also make rapidly moving objects seem like they are standing still, or leave after images of bright points in the visual field. The requirements minimize these stroboscopic effects.
Luminous intensity distribution 0-360°	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.
Centre beam luminous intensity	This is a measurement of the intensity of the light on the optical beam axis for reflector/directional lamps or fixtures with beam angles < 65° that have a light output distribution pattern that is very high at the centre of the beam of light emitted from the lamp/product.	This is an important criterion to evaluate the performance of directional lamps/products (Reflector replacement lamps like an "MR" or "PAR" lamp or downlight fixture).

Criterion	What is it?	Why is it included?
Glare luminance (cd/m ²)	This performance criterion defines the total luminance level where the visual contrast between task and light source are so high that the task cannot be distinguished. Alternatively, it is when the amount of light becomes physically painful to experience or makes it difficult to work.	High importance for the consumer's security, health, productivity and comfort.
Recyclability (%)	This criterion defines how much of the SSL product must be recyclable.	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.
Warranty duration	This criterion specifies the duration in years from the date of manufacture of a SSL product.	It is very important that consumers have a guarantee that SSL products will perform as claimed.
Lag start time (ms)	This performance item measures the amount of time for a lighting product to begin emitting light after power is turned on.	For all applications, it is very important that the starting time of a lighting product is very short, both for emergency situations, but also for consumer acceptance.
Colour maintenance ($\Delta u', v'$ at 6,000h)	This criterion specifies the allowable shift of the light colour of a SSL product as it ages.	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 a light product in a large installation is replaced by a new light product, this criterion ensures that the new product's light colour will be similar in colour to the other lights installed in the same space.
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.