

Solid State Lighting Annex: Quality and Performance Requirements

LED Lighting Products

Energy Efficient End-use Equipment (4E)
International Energy Agency
SSL Annex Task 6

OCTOBER 2022

Quality and Performance Requirements for LED Lighting Products Proposed by IEA 4E SSL Annex Governments

BACKGROUND: In 2009, government officials from 13 countries participating in the International Energy Agency’s Energy Efficient End-use Equipment (IEA 4E) implementing agreement identified solid state lighting (SSL) technologies as having the potential to cut global electricity consumption for lighting by 30%. While SSL technology promised high performance, experiences at that time with poor quality compact fluorescent lamps demonstrated the need to try and prevent SSL products from following the same path. Governments wanted to try and ensure SSL technology performed well and didn’t make unwarranted claims, so as to avoid damaging consumer confidence and slowing down market acceptance and transition to SSL.

Technical experts from the SSL Annex’s ten member countries past and present¹ have worked together to develop multiple editions of quality and performance requirements for Light Emitting Diode (LED) based lighting products. The requirements include several performance tiers that have been developed to address the various programmes and priority needs from each country or region. Since the SSL Annex’s initial activities, identification of other relevant matters has provided impetus to offer expanded guidance on product performance, particularly in relation to health, circular economy and electrical characteristics.

These quality and performance requirements are intended to offer a consistent set of evidence-based specifications that will support and accelerate market adoption of LED lighting products. They are intended to assist both governments who are looking to adopt regulations for these products as well as organisations managing market transformation programmes working to accelerate market adoption of LED lighting products around the world.

The efficacy levels set out in this document are recommended for programmes with commencement dates in the year 2024. This marks a one-year advancement from the commencement date proposed in the public draft of this document, which was released in November 2020; and accounts for delays in issuing this final documentation. A two-year lead time is in recognition of the fact that programmes, once initiated, take several years to implement, including providing a sufficient notification period for the lighting supply chain to prepare.

Some additional updates based on revisions subsequent to the public draft document are included in this final version in response to product developments and performance data obtained in the intervening time period.

1. The maximum standby power consumption requirements have been reduced.
2. The maximum intrinsic short-term flicker, P_{st}^{LM} , requirements have been reduced.

Minor adjustment has been made to efficacy requirements of some tiers in two of the LED retrofit lamp categories (non-directional and linear LED lamps).

A supplementary technical support document² to this quality and performance requirements document has been published offering additional explanations and insights into (a) the sources of

¹ Australia, Canada, Denmark, France, Japan (past), Korea, The Netherlands (past), Sweden, United Kingdom, and United States of America (past) and expert member country China (past)

² “Technical Support Document of Supplementary Material for the Quality and Performance Requirements” at <https://www.iea-4e.org/wp-content/uploads/2022/11/Task-6-LED-Lighting-Product-Tiers-Appendices-October-2022-final.pdf>

product performance data analysed, (b) the methodology used to quantify and forecast the performance requirements, (c) the rationalised product categories, and (d) the updates and clarifications to the measurement quantities.

The SSL Annex is continuing to monitor the market and the appropriateness of these published quality and performance requirements, and fully expects that further revisions will be made in the future as SSL technology continues to advance. The SSL Annex appreciates your interest in this process and welcomes any comments you may have on this document.

-- IEA 4E Solid State Lighting Annex

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 promote energy efficient lighting and to implement quality assurance programmes for SSL lighting. This international collaboration currently consists of the governments of Australia, Denmark, France, the Republic of Korea, Sweden and the United Kingdom. Information on the 4E SSL Annex is available from: <https://www.iea-4e.org/ssl/>

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

Fifteen countries from the Asia-Pacific, Europe and North America have joined together under the forum of 4E to share information and transfer experience in order to support good policy development in the field of energy efficient appliances and equipment. 4E focuses on appliances and equipment since this is one of the largest and most rapidly expanding areas of energy consumption. With the growth in global trade in these products, 4E members find that pooling expertise is not only an efficient use of available funds, but results in outcomes that are far more comprehensive and authoritative. Launched in 2008, in view of its achievements during the first and second five-year terms, the IEA endorsed 4E's application for a third term that will run to 2024. <https://www.iea-4e.org/>

Disclaimer

The IEA 4E SSL Annex quality and performance requirements provide governments and market transformation programme managers with a basis on which to structure voluntary and mandatory programmes which are harmonised with other programmes around the world. This harmonisation will help to accelerate the market transition to SSL technology. The final decision to publish the quality and performance requirements is made by the Management Committee of the SSL Annex, 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 do they 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.

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1. LED Quality and Performance Requirements - Intent of Performance Tiers

The intent of these tiered performance levels is to provide a consistent set of evidence-based specifications to support and accelerate the market transition to LED lighting products. They are intended to assist regulators, policy-makers and others who seek to transform lighting markets with options that will inform the development of energy-efficient lighting product regulations or incentive-based programmes. These can range from Minimum Energy Performance Standards (MEPS) for a particular market through to voluntary, high-performance product programmes (e.g., endorsement labels or green procurement specifications).

Where possible, the quality and performance requirements recommended in this document have been configured to allow simpler, less resource-intensive testing. Countries, when considering the implementation of any performance requirements, should always take into account the resource requirements associated with compliance testing in order to ensure the objectives and integrity of the programme. Developers of country-specific programmes are advised to develop an understanding of their national context through local market analysis and expert technical advice.

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:

- Efficacy established at a level achievable by 2024 by 70-80% of SSL products of this category found in the unregulated market worldwide;
- Reliability and product lifetimes that are superior to the lighting products they are intended to replace; and
- Quality of light and the light intensity distribution accepted as a satisfactory equivalence to the conventional lighting technologies they are replacing.

Tier 2: Performance Level Required by Quality and Certification Programmes

This tier is intended to be similar to the performance requirements for established voluntary premium labelling, green procurement specification and incentive-based programmes that promote high-quality SSL products such as the EU Ecolabel or Design Lights Consortium's Premium Classification. In addition to the objectives set out in Tier 1, the SSL products in Tier 2 have:

- Efficacy established at a level achievable by 2024 by the top 20-30% of SSL products found in the unregulated market worldwide; and
- Improvement in the quality of light over Tier 1, and other critical performance aspects including lifetime and light distribution.

Tier 3: Current Highest Commercially Available Performance Level

This tier is set at approximately the highest performing SSL products (top 5%) expected to be available in the market worldwide in 2024. Products achieving these performance levels are intended to be equivalent to those participating in peak award programmes such as the SEAD³ global efficiency awards.

³ Super-Efficient Equipment and Appliance Deployment Initiative: <https://superefficient.org/>

2. Product Classifications

The performance requirements are intended to be applied to the general lighting product types set out in this section and section 3. More specialised and niche products designed for specialist applications may not be able to comply with all requirements and these products should be considered as potential exclusions when developing the scope of coverage for a performance programme or regulation.

Directional Lamp

A lamp, which in any plane perpendicular to the light emitting face (i.e. C-plane), has a beam angle⁴ $\leq 90^\circ$ and a field angle⁵ $\leq 120^\circ$.

Non-directional Lamp

A lamp which is not a directional lamp.

Strip Light

A narrow, flexible or rigid, circuit board containing on-board control unit circuitry and surface mounted LEDs. It is energised by a separate and independent control gear/power supply.

Integrated LED Luminaire

1. Satisfies Type A or Type B LED luminaires specified in the scope of IEC 62722.2.1, or
2. Uses individual LED packages in place of a LED module and does not include IEC standardised lamp holders.

Integrated Downlight

1. Satisfies the definition of an Integrated LED Luminaire in this document, and
2. Small luminaire concentrating the light, usually recessed in the ceiling [[IEC IEV Ref 845-10-15](#)].

Planar (or Panel) LED Luminaire

1. Satisfies the definition of an Integrated LED Luminaire in this document,
2. Consists primarily of a frosted waveguide material as the emitting surface, and
3. Has a maximum thickness (i.e., product height) ≤ 30 mm.

Linear Batten LED Luminaire

1. Satisfies the definition of an Integrated LED Luminaire in this document,
2. Characterised as a long, rectangular-shaped luminaire, usually surface-mounted, and
3. Has a maximum thickness (i.e., product height) > 30 mm.

⁴ **Beam angle** is the angle between two imaginary lines in a plane through the optical beam axis, such that these lines pass through the centre of the front face of the device and through points at which the luminous intensity is 50% of the centre beam intensity. Note 1: The beam angle is a full angle measure, not a half angle measure. Note 2: The beam angle is expressed in degree (°).

⁵ **Field angle** is the angle between two imaginary lines in a plane through the optical beam axis, such that these lines pass through the centre of the front face of the device and through points at which the luminous intensity is 10% of the centre beam intensity. Note 1: The field angle is a full angle measure, not a half angle measure. Note 2: The field angle is expressed in degree (°).

Linear Troffer LED Luminaire

1. Satisfies the definition of an Integrated LED Luminaire in this document,
2. Characterised as a long, rectangular-shaped luminaire, usually installed with the opening flush with the ceiling [[IEC IEV Ref 845-30-19](#)], and
3. Has a maximum thickness (i.e., product height) > 30 mm.

High bay/Low bay LED Luminaire

1. Satisfies the definition of an Integrated LED Luminaire in this document, and
2. Characterised as an indoor luminaire intended for mounting at heights ≥ 6 m.

Area (Floodlight) Integrated Luminaire

1. Satisfies the definition of an Integrated LED Luminaire in this document, and
2. Designed for floodlighting, usually capable of being pointed in any direction [[IEC IEV Ref 845-30-33](#)]

Roadway Integrated Luminaire

1. Satisfies the definition of an Integrated LED Luminaire in this document, and
2. Designed for street and roadway lighting, for the purposes of providing illumination for drivers and pedestrians.

3. Scope of Coverage for Product Categories

Category 1: Residential Lighting Products

1. Non-directional and directional LED lamps intended for general lighting service
 - a. Operating at voltages of 100 to 347 V AC, or 12 to 50 V AC or V DC
 - b. Initial luminous flux ≥ 60 lm and $< 2,600$ lm
 - c. Base types (Number denotes sizing designation, noting that this list is illustrative rather than exhaustive. There may be additional, uncommon base types that may be considered.)

i.	Edison screw:		E10, E11, E12, E14, E17 E26, E27 E39, E40
ii.	Bayonet:		B15d B22d
iii.	Bi-pin:	 	GU4, GU5.3, GX5.3, G6.35 GU10, GZ10, GU24, GX53
iv.	Wedge:		G9
v.	Double ended:	 	R7s

2. LED strip light
 - a. Operating at voltages of 100 to 347 V AC, or 12 to 50 V AC or V DC
 - b. Initial luminous flux of ≥ 300 lm per linear metre
 - c. Indoor IP rating: IP20
 - d. In a form

- i. Flexible



- ii. Rigid



3. Integrated LED Downlight Luminaires

- a. Operating at voltages of 100 to 347 V AC, or 12 to 50 V AC or V DC
- b. Initial luminous flux of ≥ 60 lm and $< 2,600$ lm
- c. A small direct lighting unit where the light emitting elements are integrated (e.g., an LED package, LED module or LED Light Engine) but unit is not a directional LED lamp
- d. Can be recessed, surface mounted, or suspended and directs the light downward
- e. Operated with either:

- i. an integrated driver



- ii. a separate LED driver



- f. Excluding those not intended for general lighting service

Category 2: Commercial and Industrial Lamps

These products are typical of LED retrofit lamps for linear fluorescent and HID lamps.

1. Double-capped linear LED lamps

- a. Operating at voltages of 100 to 347 V AC, or 12 to 50 V AC or V DC
- b. With tube lengths from 400 mm - 2400 mm inclusive
- c. Either linear or U-bend forms (Circular forms may also be included in this category)
- d. With caps:
 - i. intended for replacing fluorescent lamps (as defined in IEC 60081) with the same caps (as defined in IEC 60081), or

Miniature bi-pin and medium bi-pin



G5
G13

Single pin



FA6
FA8

Recessed double-contact



R17d

- ii. listed in Annex A of IEC 60838-2-3 ED. 1.0 B:2016 "Miscellaneous lampholders - Part 2-3: Particular requirements - Lampholders for double-capped linear LED lamps"

- e. Excluding those not intended for general lighting service.

2. Single-capped High Luminous Flux LED Lamps

- a. Operating at voltages of 100 to 347 V AC
- b. With caps E26, E27, E39, E40
- c. Initial luminous flux ≥ 2600 lm
- d. Intended as:

- i. LED retrofit for all high luminous flux lamp technologies (including high intensity discharge, CFL, and incandescent lamps)



Category 3: Commercial and Industrial Indoor Luminaires

1. Integrated LED Luminaires

- a. Operating at voltages of 100 to 347 V AC, or 12 to 50 V AC or V DC
- b. Initial luminous flux of ≥ 500 lm
- c. Integrated LED luminaires intended as an alternative to tubular fluorescent based general purpose troffer and batten luminaires (mounted either as surface, recessed or suspended) in the forms of:

- i. Integrated LED Panel (or Planar form)



- ii. Integrated LED Batten



- iii. Integrated LED Troffer



2. LED Retrofit Kits for Fluorescent Troffer Luminaires

- a. Operating at voltages of 100 to 347 V AC, or 12 to 50 V AC or V DC
- b. Initial luminous flux of ≥ 500 lm
- c. LED Retrofit Kits intended as a replacement for fluorescent lamps and ballasts without replacing the entire general-purpose troffer luminaire (mounted either as surface, recessed or suspended), in the forms of

- i. Individual LED strips and driver



- ii. Backing plate with LED strips and driver



- iii. Complete internal housing with LED sources and driver



3. High bay/Low bay Integrated LED Luminaires

- a. Operating at voltages of 100 to 480 V AC
- b. Initial luminous flux of ≥ 5000 lm
- c. Integrated LED luminaires intended as an alternative to lamp-based luminaires:

- i. High bay and low bay luminaires



Category 4: Outdoor Luminaires

This category excludes luminaires with the intended purpose of meeting specific environmental requirements such as protection of wildlife breeding habitats and dark sky conditions for astronomical observation sites (e.g. amber LED outdoor luminaires).

1. Roadway Integrated LED Luminaires
 - a. Operating at voltages of 100 to 347 V AC
 - b. Initial luminous flux of ≥ 2000 lm
 - c. Integrated LED luminaires intended as an alternative to HID, induction or fluorescent roadway luminaires



2. Area (Floodlight) Integrated LED Luminaires
 - a. Operating at voltages of 100 to 347 V AC
 - b. Initial luminous flux of ≥ 3000 lm
 - c. Integrated LED luminaires intended as an alternative to lamp-based luminaires:

Floodlights



4. Quality and Performance Requirements for 2024 Commencement

Table 1. IEA 4E SSL Annex Quality and Performance Requirements for 2024

	Product & Parameter	Tier 1	Tier 2	Tier 3
Energy-Efficiency				
Minimum luminous efficacy, η				
CAT 1: Residential Lighting Products	Non-directional lamp	105 lm/W	150 lm/W	180 lm/W
	<i>Concessions (additive):</i> Lumens < 400 lm CCT < 2300 K CRI \geq 90	subtract 10 lm/W subtract 10 lm/W subtract 10 lm/W		
	Directional lamp	80 lm/W	115 lm/W	130 lm/W
	<i>Concessions (additive):</i> Beam Angle < 20° CCT < 2300 K CRI \geq 90	subtract 10 lm/W subtract 10 lm/W subtract 10 lm/W		
	Downlight and downlight retrofit kits	90 lm/W	115 lm/W	130 lm/W
	<i>Concession:</i> Retrofit kits	subtract 10 lm/W		
	Strip light	80 lm/W	90 lm/W	100 lm/W
	<i>Concession:</i> CCT < 2300 K	subtract 10 lm/W		
CAT 2: Commercial & Industrial Lamps	Double-capped linear lamp	125 lm/W	175 lm/W	205 lm/W
	<i>Concession:</i> CCT < 2300 K	subtract 10 lm/W		
	Single-capped high luminous flux lamp	105 lm/W	140 lm/W	155 lm/W
	<i>Concession:</i> CCT < 2300 K	subtract 10 lm/W		
CAT 3: Commercial & Industrial Luminaires	Linear, troffer, and commercial retrofit kits	110 lm/W	150 lm/W	170 lm/W
	Panel (planar)	90 lm/W	130 lm/W	150 lm/W
	High bay, low bay, and industrial retrofit kits	125 lm/W	155 lm/W	185 lm/W
CAT 4: Outdoor Luminaires	Roadway and area (floodlight)	110 lm/W	150 lm/W	170 lm/W
Maximum non-networked standby power mode power consumption				
All	All	0.2 W	0.15 W	0.1 W
Maximum networked standby power mode power consumption				
All	All	0.2 W	0.15 W	0.1 W

	Product & Parameter	Tier 1	Tier 2	Tier 3
Lifetime				
Minimum rated lifetime (F₅₀)				
CAT 1	Lamp	15 000 h	20 000 h	30 000 h
	Downlight & retrofit kits	30 000 h	40 000 h	50 000 h
	Strip Light	15 000 h	20 000 h	30 000 h
CAT 2	Double-capped linear lamp	25 000 h	35 000 h	50 000 h
	Single-capped high luminous flux lamp	15 000 h	20 000 h	30 000 h
CAT 3	Linear, troffer, planar, & retrofit kits	50 000 h	60 000 h	75 000 h
	High bay, low bay, & retrofit kits	50 000 h	60 000 h	75 000 h
CAT 4	Roadway, area (floodlight)	50 000 h	60 000 h	75 000 h
Minimum luminous flux maintenance (L_x @ 6 000 h)				
CAT 1	Lamp	86.7%	89.9%	93.1%
	Downlight & retrofit kits	93.1%	94.8%	95.8%
	Strip Light	86.7%	89.9%	93.1%
CAT 2	Double-capped linear lamp	91.8%	94.1%	95.8%
	Single-capped high luminous flux lamp	86.7%	89.9%	93.1%
CAT 3	Linear, troffer, planar, & retrofit kits	95.8%	96.5%	97.2%
	High bay, low bay, & retrofit kits			
CAT 4	Roadway, area (floodlight)	95.8%	96.5%	97.2%
Maximum early failure rate (F_x @ 3 000 h, via switching cycles)				
All	All	10%		
ALTERNATE: Minimum luminous flux maintenance when combined test with maximum early failure rate (L_x @ 3 000 h, via switching cycles)				
CAT 1	Lamp with rated lifetime < 25 000 h	$L_x \% = 100 * e^{-\frac{(3\ 000 * \ln(0.7))}{L_{70}}}$ where L ₇₀ is the rated lifetime (in hours)		
CAT 2	Lamp with rated lifetime < 25 000 h	$L_x \% = 100 * e^{-\frac{(3\ 000 * \ln(0.7))}{L_{70}}}$ where L ₇₀ is the rated lifetime (in hours)		

	Product & Parameter	Tier 1	Tier 2	Tier 3																																																																				
Colour																																																																								
Minimum colour rendering index (CRI)																																																																								
CAT 1	Lamp Downlight & retrofit kits Strip Light	R _a : 80	R _a : 80 and R9: 0	R _a : 85 and R9: 50																																																																				
CAT 2	Double-capped linear lamp Single-capped high luminous flux lamp																																																																							
CAT 3	Linear, troffer, planar, & retrofit kits	R _a : 80	R _a : 80 and R9: 0	R _a : 85 and R9: 50																																																																				
	High bay, low bay, & retrofit kits	R _a : 80	R _a : 80 and R9: 0																																																																					
CAT 4	Roadway, area (floodlight)	R _a : 70																																																																						
Maximum chromaticity tolerance limits																																																																								
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CAT 1	Lamp Downlight Strip Light	No requirement recommended		0.004																																																																				
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CAT 3	Linear, troffer, planar, & retrofit kits High bay, low bay, & retrofit kits																																																																							
CAT 4	Roadway, area (floodlight)	No requirement recommended		0.007																																																																				

	Product & Parameter	Tier 1	Tier 2	Tier 3	
Operation					
Minimum initial luminous flux - Equivalent incandescent wattage claim only					
CAT 1	Non-directional lamp		Claimed Equivalent Incandescent Lamp Wattage (W)	Claimed Equivalent Halogen Lamp Wattage (W)	LED Lamp, Minimum Luminous Flux (lm)
			15	11	135
			25	18	250
			40	28	470
			60	42	800
			75	52	1000
			100	70	1500
150	105	2450			
CAT 2	Single-capped high luminous flux lamp		Claimed Equivalent Incandescent Lamp Wattage (W)	Claimed Equivalent Halogen Lamp Wattage (W)	LED Lamp, Minimum Luminous Flux (lm)
			200	140	3450
Luminous intensity distribution – Omni-directional claim only					
CAT 1	Non-directional lamp	No requirement recommended	No less than 5% of total flux (zonal lumens) shall be emitted in the 130° to 180° γ -angle zone. No less than 35% of total flux (zonal lumens) shall be emitted in the 90° to 180° γ -angle zone.	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° γ -angle zone.	
CAT 2	Non-directional lamp Single-capped high luminous flux lamp			All measured values (candelas) in the 0° to 130° γ -angle 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.	
Luminous intensity distribution – Beam Angle					
CAT 1	Directional lamp Downlight	No requirement recommended	50% of flux shall be in declared beam angle		
CAT 2	Directional lamp Single-capped high luminous flux lamp				

	Product & Parameter	Tier 1	Tier 2	Tier 3
Dimmer compatibility requirements				
ALL	All	<p>Lamps/luminaires may be dimmable or non-dimmable, which must be clearly indicated on the product packaging.</p> <p>For dimmable products, the manufacturer shall:</p> <ol style="list-style-type: none"> (1) declare the conditions under which the lamp/luminaire will dim, and (2) provide a web address for a webpage that lists compatible dimmer makes and models, and for each: <ol style="list-style-type: none"> (a) the number of lamps/luminaires that can be dimmed, and (b) the range of luminous flux levels a given dimmer-luminaire combination can achieve. <p>New dimmable self-ballasted lamps are recommended to meet the requirements of IEC TR 63037, and new phase-cut dimmers are recommended to meet the requirements of IEC TR 63036.</p>		
Minimum displacement factor, $K_{displacement}$ ($\cos \varphi_1$)				
ALL	All	<p>Power ≤ 2 W: No limit</p> <p>2 W < Power ≤ 10 W: $K_{displacement} \geq 0.5$</p> <p>Power > 10 W: $K_{displacement} \geq 0.9$</p>		
Harmonics				
ALL	All	Meet the requirements of IEC 61000-3-2 Clause 7.4		
Health				
Maximum intrinsic short-term flicker, P_{st}^{LM}, at full load				
ALL	All	0.5		
Maximum intrinsic Stroboscopic Visibility effect Measure, SVM, at full load				
CAT 1	Lamp Downlight Strip Light	0.4		
CAT 2	Double-capped linear lamp Single-capped high luminous flux lamp			
CAT 3	Linear, troffer, planar, & retrofit kits High bay, low bay, & retrofit kits			
CAT 4	Roadway, area (floodlight)			
No requirement at this time.*				

* The quantity SVM was developed using photopic conditions, and its application to mesopic conditions has not been demonstrated. The appropriate metric for roadway and outdoor lighting conditions requires further research.

	Product & Parameter	Tier 1	Tier 2	Tier 3
Health				
Maximum photobiological risk group				
CAT 1	Lamp Downlight Strip Light	Blue light hazard: RG1 unlimited (lamps); RG1 (luminaires) UV hazard: RG1 unlimited (lamps); RG1 (luminaires)		
CAT 2	Double-capped linear lamp Single-capped high luminous flux lamp	Blue light hazard: RG1 unlimited (lamps) UV hazard: RG1 unlimited (lamps) Must have markings on product when Blue Light Hazard or UV hazard is above RG1 (luminaires)		
CAT 3	Linear, troffer, planar, & retrofit kits High bay, low bay, & retrofit kits			
CAT 4	Roadway, area (floodlight)			
Safety requirements				
ALL	All	Must meet all national and/or regional requirements for product safety, material safety, photobiological safety, and mechanical and electrical appliance safety laws, including electromagnetic compatibility (EMC) requirements, and requirements for labelling / marking.		
Environment				
Hazardous substance requirements				
ALL	All	Compliant with the European Restriction of Hazardous Substances (RoHS) regulation, unless other regional or national requirements apply.		
Recyclability requirements				
ALL	All	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).		
Component replaceability requirements				
CAT 1	Lamp Strip Light	No requirement recommended		
	Downlight	No requirement recommended	Must meet removability and exchangeability requirements for light source(s) and control gear	
CAT 2	Double-capped linear lamp Single-capped high luminous flux lamp	No requirement recommended		
CAT 3	Linear, troffer, planar, & retrofit kits High bay, low bay, & retrofit kits	No requirement recommended	Must meet removability and exchangeability requirements of light sources and control gear for product types included in international standards	
CAT 4	Roadway, area (floodlight)			
Warranty				
Warranty duration requirements				
ALL	All	Minimum 1 year against catastrophic failure unless regional requirement is higher	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	

Annex 1 Explanation of Parameters and Required Test Methods

Table 2. Parameters included in the IEA 4E SSL Annex Quality and Performance Requirements

N.B. The explanations of the performance parameters in this table are provided for a layperson without professional or specialised knowledge in lighting. Formal definitions of these terms can be found in the CIE electronic International Lighting Vocabulary (eILV) (<http://cie.co.at/e-ilv>) and/or the IEC's Electropedia (<https://www.electropedia.org/>).

Parameter	What is it?	Why is it included?	Test Method
Luminous efficacy (lm/W)	Luminous efficacy of a lamp (or luminaire) is calculated by dividing the total light output of the lamp (or luminaire) by its total power consumption. The units are lumens per watt (lm/W). 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 or EN 13032-4)
Non-networked Standby Power	Standby Power applies to the default (factory setting) mode of smart lamps (with any software updates) and other modes that provide a lighting control function which is not triggered via a communication network, and which remain 'on' when emitting no light.	As integrated wireless and sensor control of lighting products 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, importantly while the product is not producing light.	IEC 63103
Networked Standby Power	Networked Standby Power applies to the default (factory setting) mode of smart lamps (with any software updates) and other modes that provide a lighting control function which is triggered via a communication network, and which remain 'on' when emitting no light.	As communication network control of lighting products 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, importantly while the product is not producing light.	IEC 63103
Claimed incandescent or halogen equivalent wattage (W) and minimal initial light output (lumens)	These levels will assist in evaluating manufacturer claims that a given SSL product is an equivalent replacement for a typical wattage incandescent or halogen light product. The Annex has transitioned to a harmonised set of lumen bins which are voltage independent, 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 therefore important. This importance is expected to 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 light output after a specified period of time compared to that light product's initial light output.	Luminous flux maintenance helps the consumer determine how long it will take a lighting product to diminish to the point that it is no longer providing useable lighting. High lumen maintenance means the product will have a longer service life and also, over time, helps to justify the higher initial cost of SSL lighting products.	See Annex 2 for options

Parameter	What is it?	Why is it included?	Test Method
Early failure rate	The percentage of lamps in a sample that fail by a specified point in time that is early in their expected operating life (e.g. 6,000 hours).	Early failure rates should be as low as possible to minimise the risk that the lamp will fail to achieve its full potential of energy savings and as well as customers migrating to LED lighting will not have a bad experience. It is also an alternative indicator to lamp longevity in the absence of a practical lifetime test.	IES LM-84 or Annex V of EU Reg 2020/2019
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 to provide the expected light output.	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 recover their higher initial cost when compared to alternative light sources. If SSL products are able to meet their lifetime claims, they can cut long-term energy consumption and save the consumer money.	
Endurance test	<p>This criterion requires that an SSL product is rapidly switched on and off to simulate how a product will be used over its lifetime.</p> <p>The product undergoes operation during various stressful conditions to evaluate its operational durability. The operating conditions could entail switch cycling and/or elevated or extreme temperature cycling.</p>	This criterion requires that a test is carried out to stress an SSL product over a short period of time to determine the failure rates of a product. Often, if one electronic subcomponent in an 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 or Annex V of EU Reg 2020/2019
Colour rendering index (CRI)	Colour rendering is a measure of how similar the colours of objects appear when illuminated by the light source as compared to illumination by a reference light source of the same colour appearance (examples of which include an incandescent light and sunlight). Colour rendering is very important for consumer satisfaction with a lighting product, in terms of naturally rendering colours of objects in our environment. 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 ongoing investigations and discussions on shortcomings of the CRI metric that limit its ability to fully represent how humans prefer the rendering of the colour of objects illuminated by SSL technology; and the potential need for both a colour fidelity metric and a colour preference metric ⁶ . The IEA SSL Annex acknowledges CIE developing and publishing CIE 224:2017 “CIE 2017 Colour Fidelity Index for accurate scientific use” and the alignment of IES on the colour fidelity metric (in TM-30-18) The IEA SSL Annex will continue to monitor 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

⁶ See [CIE Position Statement on CRI and Colour Quality Metrics](#).

Parameter	What is it?	Why is it included?	Test Method
Colour maintenance ($\Delta u',v'$ at 6 000 h)	Colour maintenance quantifies the shift in the colour appearance of the light from an SSL product as it ages. This is mainly caused by the degrading of the phosphors.	This criterion ensures that as an SSL product ages, the colour appearance of light does not shift markedly from its original colour appearance. It may become noticeably warmer (yellow) or cooler (bluer) or develop an unnatural greenish or pinkish tint. If an individual SSL lamp or luminaire in a large installation is replaced, this criterion ensures that the new product's colour will not be noticeably dissimilar to those older installed products around it.	IES LM-80, and ISTMT or IES LM-84
Chromaticity tolerance	Chromaticity tolerance quantifies the allowable difference (or deviation) in the colour appearance of multiple units of the same SSL product.	This criterion is of high importance to ensure that the colour appearance of each SSL product within an installed group does not have a noticeable and unacceptable variation in its colour appearance compared to the collective group. This criterion attempts to ensure that all lamps and luminaires of the same claimed colour temperature have a similar colour appearance when installed.	CIE S 025/E CIE TN 001 ANSI C78.377-2017
Luminous intensity distribution	The luminous intensity distribution quantifies the angular distribution of light emitted by a lighting product and also provides data for the determining additional information such as beam angle and zonal light output (e.g. upward light, downward light).	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. A fit for purpose luminous intensity distribution of a product is critical to an optimal lighting design solution for particular applications.	CIE S 025/E
Dimmer compatibility	This criterion evaluates whether a SSL product will operate satisfactorily with the nominated models of dimmers	Dimmer compatibility is of high importance for the consumer as many SSL products are often not completely (satisfactorily) compatible with commonly available dimmers. The greatest issue is with legacy dimmers, those already installed for previously operating filament lamps. New IEC technical reports have been developed recommending the performance requirements for satisfactory interoperability of dimmable SSL products and nominated dimmers.	IEC TR 63036 (dimmers) IEC TR 63037 (lamps and control gear)

Parameter	What is it?	Why is it included?	Test Method
Displacement factor	Displacement Factor (or Fundamental Power Factor) quantifies the displacement (phase-shift) between the fundamental current and voltage waveforms by calculating the cosine of the phase-shift angle. Zero phase shift produces a displacement power factor of 1.	The displacement factor for the different low voltage feeders and substations in the grid are of concern to the electricity grid-operator. For each feeder in the grid, only the displacement factor for the added total loads is important. The added load depends on the size of the loads of the different devices, how the devices are used in time and the content of reactive loads (capacitive or inductive). For the domestic sector, the SSL load generally only constitutes a small part of the total mixed load. The capacitive SSL load compensates beneficially for a part of the dominant inductive load from other devices. For the domestic sector, the displacement factor is thus not an issue. For feeders dominated by street lighting and for some feeders supplying commercial or industrial customers, the SSL lighting is dominant, and the displacement factor is thus important. In these cases, where the displacement factor for the total load is below 0.9, the customers may be subject to a penalty payment.	IEC 62612 IEC 62717 IEC 60598.2.1 IEC 61000-3-2
Total 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, cause overheating in cables (lost energy) and electrical distribution devices and cause a loss of reliability of switch pulse information.	IEC 61000-4-7
Harmonic Components	The individual harmonic components are the more detailed measures to quantify the distortion of the mains current and its effect on the power supply network.	Particular harmonics have greater impact on the network than others either in terms of efficient transmission or interference with the transmission of control signals.	IEC 61000-4-7
Stroboscopic Effect Visibility Measure (SVM)	Stroboscopic Effect Visibility Measure quantifies the likelihood of perceived change in motion caused by cyclical variations in light output (both in total luminous flux or in chromatic characteristics) as viewed by a stationary observer of a non-static environment (i.e. moving object).	Under most lighting conditions, the stroboscopic effect is undesirable. It is a source of distraction and may modify task performance. Setting an upper limit on SVM is therefore necessary to avoid the negative impacts of this effect. Note that SVM is not applicable to the stroboscopic effects observed on moving machines and tools.	IEC TR 63158 CIE TN 006:2016 CIE TN 012:2021

Parameter	What is it?	Why is it included?	Test Method
Short-term Flicker (P_{st}^{LM})	Short term flicker quantifies the likelihood of perception of a visual unsteadiness caused by cyclical variations in light output (both in total luminous flux or in chromatic characteristics) as viewed fluctuating brightness and/or colour perception by a stationary observer of a static environment (i.e. no movement by either).	As well as being distracting and annoying flicker, TLM at the same frequency range can produce photosensitive seizures amongst susceptible people. Limiting exposure to these risks is important to people's health. Limitation on P_{st}^{LM} levels can assist in this endeavour.	IEC TR 61547-1 CIE TN 006:2016 CIE TN 012:2021
Photo-biological risk group (blue light and UV hazard)	Photobiological risk groups are defined in IEC 62471, with additional information given in IEC TR 62778. 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/ 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 62560 (lamps) IEC 62776 (linear lamps) IEC 60598 series (luminaires)
Warranty duration	This criterion specifies the duration in years from the date of installation of an SSL product.	It is very important that consumers have a guarantee that SSL products will perform as claimed.	
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: <ul style="list-style-type: none"> 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

Annex 2 Recommended methods for determining L₇₀B₅₀

Background

The life of a lamp is defined as the “total time for which a lamp has been operated before it becomes useless or is considered to be so according to specified criteria”. One of these criteria is the parametric failure mode of luminous flux output reaching an unacceptably low level (known as luminous flux maintenance). The threshold level of luminous flux output used for this criterion is typically 70% of the initial output, and is determined for the median lamp (*i.e.* 50th percentile) from a set of lamp samples. The designation for this metric is L₇₀B₅₀ (L = luminous flux, and B = parametric failures). With other lamp technologies, the reported value for this metric (or similar) was determined from a full test (*i.e.* until half the sample lamps have failed the criterion). With LED lamps the duration is impractical for full measurement and the only other option to determine this value is by prediction.

A review of available test method standards and associated predictive methods (Technical reports/memoranda) has determined that there is no internationally agreed approach to ascertaining the predicted L₇₀B₅₀ of an LED product. There is however, agreed international test method standards, which include approved use of referenced regional test method standards for measuring luminous flux maintenance after an operating duration of 25% of rated median lamp life that is capped at 6,000h. A widely-recognised predictive method for extrapolating such luminous flux maintenance measurements published by the Illuminating Engineering Society of North America (IESNA) uses the data acquired from these international test method standards.

The luminous flux measurement data used for both luminous flux maintenance and predictive lifetime methods may be acquired from actual product testing or from available test data that meets specific criteria for the light source components used in the construction of the product.

Limitation on Maximum Reported L₇₀B₅₀

In relation to predictive methods (IES TM-21 and IES TM-28), it should be noted that a maximum limit is set for the reported luminous flux maintenance life, L₇₀B₅₀, of the tested lamp. This limit is determined by the multiplication of the duration of on-time of the device under test and a multiplying factor which is based on the number of samples and type of device under test.

$$L_{70}B_{50}(\text{reported}) \leq (\text{test duration}) \times (\text{multiplying factor})$$

When applying IES TM-21 calculations to test data from LED packages or modules (*i.e.* IES LM-80 results) a greater number of samples is required to obtain a similar value for the multiplying factor achieved when applying IES TM-28 calculations to test data from LED lamps or luminaires (*i.e.* IES LM-84 results). The following table provides the details.

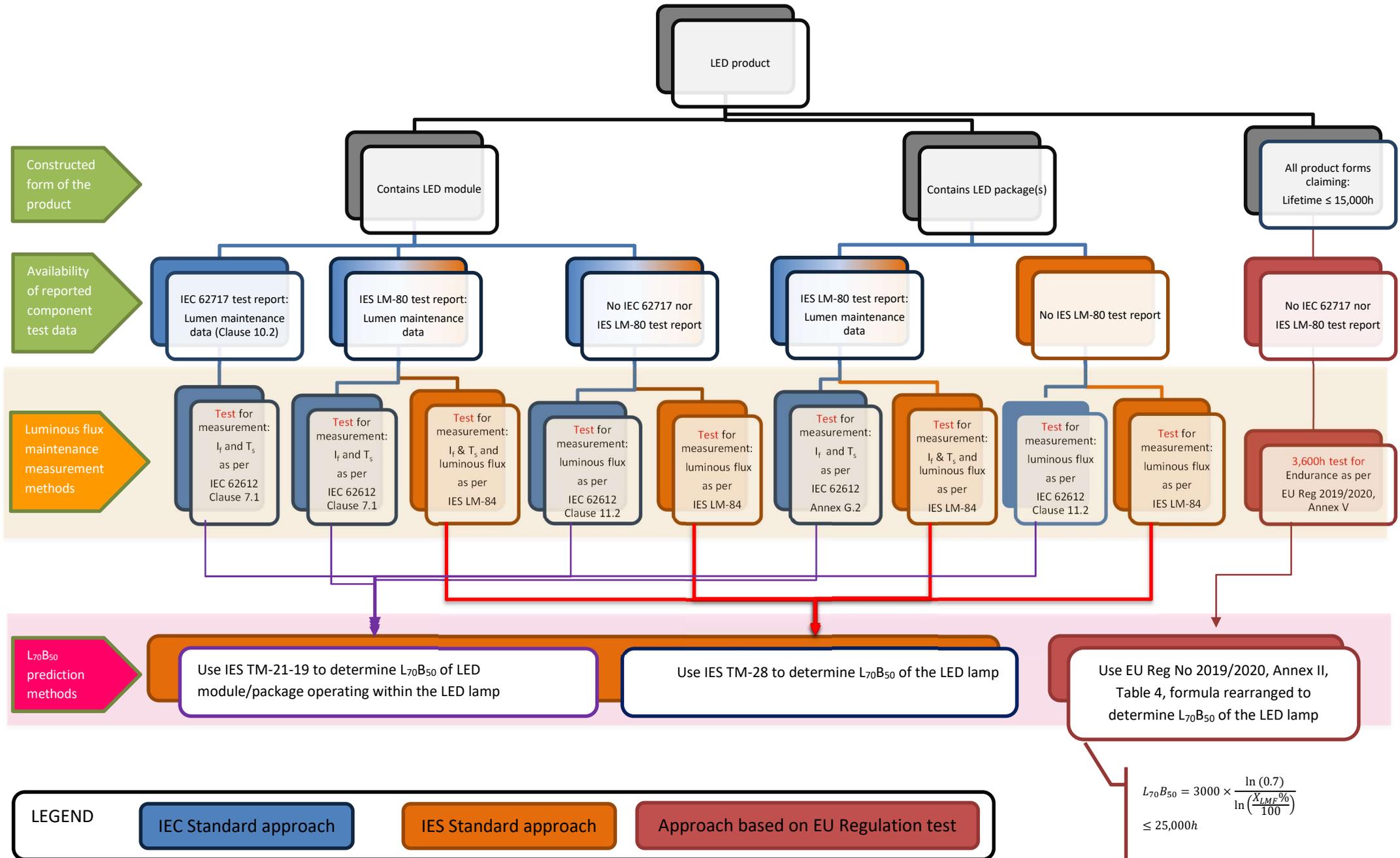
Table 3. Number of Samples Required for Multiplying Factor applying IES TM-28 Calculations to Test Data

Multiplying factor	Number of Samples	
	LED Packages/Modules (IES LM-80)	LED Lamps/Luminaires (IES LM-84)
3	Not permitted	3
4	Not permitted	4
5	Not permitted	5-6
5.5	10-19	7-9
6	≥ 20	≥ 10

As an example, 5 samples of an LED lamp which are tested for 6,000 hours of operation can only report an $L_{70}B_{50}$ of 30,000 hours ($6,000 \times 5$) if the calculated value exceeds this figure. A longer projection for $L_{70}B_{50}$ can be achieved by testing more samples and/or a longer test duration. (Note that some manufacturers of LED packages/modules have many products with reported luminous flux maintenance test results beyond 10,000 hours and even some >15,000 hours.)

Recommended Test and Prediction Methods

The following flowchart (published in AS/NZS 5341) provides the currently published pathways for the test and prediction methods recommended for determining a product's $L_{70}B_{50}$ based on the available component test data or the complete product test data. [Note: $X_{LMF\%}$ is the symbol used for luminous flux maintenance factor after 3,000 hours of operation]



Annex 3 Relevant Standards and References

Designation	Title
ISO 14021	Environmental labels and declarations – Self-declared environmental claims (Type II environmental labelling)
ISO 14025	Environmental labels and declarations – Type III environmental declarations – Principles and procedures
CIE S 009/IEC 62471	Photobiological safety of lamps and lamp systems
CIE S 025/E	Test Method for LED Lamps, LED Luminaires and LED Modules
CIE 13.3	Method of measuring and specifying colour rendering properties of light sources
CIE TN 001	Chromaticity Difference Specification for Light Sources
CIE TN 006	Visual Aspects of Time-Modulated Lighting Systems – Definitions and Measurement Models
CIE TN 008	Temporal Light Modulation Standards for Lighting Systems
CIE TN 012	Guidance on the Measurement of Temporal Light Modulation of Light Sources and Lighting Systems
IEC 60598.1	Luminaires - Part 1: General requirements and tests
IEC 60598.2.1	Luminaires. Part 2: Particular requirements. Section One: Fixed general purpose luminaires
IEC 61000-4-7	Electromagnetic compatibility (EMC) - Part 4-7: Testing and measurement techniques - General guide on harmonics and interharmonics measurements and instrumentation, for power supply systems and equipment connected thereto
IEC 62560	Self-ballasted LED-lamps for general lighting services by voltage > 50 V - Safety specifications
IEC 62612	Self-ballasted LED lamps for general lighting services with supply voltages > 50 V - Performance requirements
IEC 62717	LED modules for general lighting - Performance requirements
IEC 62776	Double-capped LED lamps designed to retrofit linear fluorescent lamps - Safety specifications
IEC 63103	Lighting equipment - Non-active mode power measurement
IEC TR 63036	Electrical interface specification for phase-cut dimmer in phase-cut dimmed lighting systems
IEC TR 63037	Electrical interface specifications for self ballasted lamps and control gear in phase-cut dimmed lighting systems
IEC TR 61547-1	Equipment for general lighting purposes - EMC immunity requirements - Part 1: An objective light flicker meter and voltage fluctuation immunity test method
IEC TR 62778	Application of IEC 62471 for the assessment of blue light hazard to light sources and luminaires
IEC TR 63158	Equipment for general lighting purposes - Objective test method for stroboscopic effects of lighting equipment
ANSI/IES LM-79	Approved Method: Optical and Electrical Measurements of Solid-State Lighting Products
ANSI/IES LM-80	Approved Method: Measuring Luminous Flux and Color Maintenance of LED Packages, Arrays, and Modules
IES LM-84	Measuring Luminous Flux and Color Maintenance of LED Lamps, Light Engines, and Luminaires
ANSI/IES TM-21	Technical Memorandum: Projecting Long-Term Lumen, Photon, and Radiant Flux Maintenance of LED Light Sources
IES TM-28	Projecting Long-Term Luminous Flux Maintenance of LED Lamps and Luminaries
ANSI/IES TM-30	IES Method for Evaluating Light Source Color Rendition
ANSI C78.377	American National Standard for Electric Lamps - Specifications for the Chromaticity of Solid State Lighting (SSL) Products
EU Reg No 2019/2020	Ecodesign requirements for light sources and separate control gears