

Solid State Lighting Annex: Quality and Performance Requirements

LED Lighting Products

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

DRAFT FOR STAKEHOLDER COMMENT
25 NOVEMBER 2020

Draft LED Quality and Performance Requirements Proposed by Governments Participating in the IEA 4E SSL Annex

ACTION REQUESTED: The IEA 4E SSL Annex is requesting that stakeholders review this document and submit written comments to ssl.annex@gmail.com before the **25 January 2021**. In the interests of transparency, the SSL Annex will post all comments on our website along with our responses and any revisions made to the quality and performance requirements, so these are visible to all interested parties.

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 lighting electricity consumption by 30%. While SSL technologies promised high performance, the experience at the time with compact fluorescent lamps demonstrated the need to prevent unwarranted claims or poor performance, which can seriously damage consumer confidence and slowdown market acceptance and transition to solid state lighting.

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 programs and priority needs from each country or region. Since the 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.

This approach is intended to assist governments and other organisations such as market transformation programme managers to develop consistent and evidence based requirements for voluntary 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 efficacy levels throughout the document are recommended for programs with commencement dates expected in the year 2023. This is an acknowledgement that programs, once initiated, take several years to implement including providing enough notification period for the market supply chain to prepare.

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 quality and performance requirements.

-- IEA 4E Solid State Lighting Annex

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)

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 worked as an expert member of the 4E SSL Annex. Canada joined in 2018. At the time of publication, member countries are: Australia, Canada, Denmark, France, the Republic of Korea, Sweden and the United Kingdom. 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. Thirteen 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 (completed)
- The Solid-State Lighting Annex (SSL)
- The Electronic Devices and Networks Annex (EDNA)
- The Power Electronic Conversion Technology Annex (PECTA)

Current members of 4E are Australia, Austria, Canada, China, 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 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, all of which will help to accelerate the market for SSL technology. The final decision to publish the quality and performance requirements 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.

Table of Contents

1	LED Quality and Performance Requirements - Intent of Performance Tiers.....	1
1.1	Tier 1: Minimum Acceptable Performance Level.....	1
1.2	Tier 2: Performance Level Required by Established Quality Programs	1
1.3	Tier 3: Current Highest Commercially Available Performance Level.....	1
2	Revision of Quality and Performance Requirements.....	2
2.1	Sources of product performance data.....	2
2.2	Method for establishing yearly trends for the performance requirements.....	3
2.3	Rationalised Product Categories.....	3
3	Updates and Clarifications (Note: this section will be moved to an Annex in the final version)....	5
3.1	Displacement Factor	5
3.2	Temporal Light Modulation	6
3.3	Colour - chromaticity coordinate system.....	7
3.4	Product lifetime	11
4	Product Classifications	15
4.1	Directional Lamp	15
4.2	Non-directional Lamp	15
4.3	Strip Light	15
4.4	Integrated LED Luminaire	15
4.5	Integrated Downlight.....	15
4.6	Planar (or Panel) LED Luminaire	15
4.7	Linear Batten LED Luminaire.....	15
4.8	Linear Troffer LED Luminaire	15
4.9	High bay/Low bay LED Luminaire	15
4.10	Outdoor (Floodlight) Integrated Luminaire	15
4.11	Roadway Integrated Luminaire.....	15
5	Scope of Coverage for Product Categories	16
5.1	CAT 1: Residential Lighting Products	16
5.2	CAT 2: Commercial and Industrial Lamps	17
5.3	CAT 3: Commercial and Industrial Indoor Luminaires	18
5.4	CAT 4: Outdoor Luminaires.....	20
6	Quality and Performance Requirements for 2023 Commencement.....	21
Annex 1	Explanation of Criteria and Required Test Methods.....	27
Annex 2	Predicted yearly efficacy trends.....	32
Annex 3	Recommended methods for determining $L_{70}B_{50}$	37
Annex 4	Relevant Standards and References	40

List of Figures

Figure 1: Fundamental currents for different Displacement Factors providing the same lamp power. 6

Figure 2: Lamp fundamental current vs Displacement Factor for different lamp technologies with equivalent light output: 12W LED, 23W Compact Fluorescent (CFL) and 100W Incandescent (INC). ... 6

Figure 3: Different light levels of adjacent peaks creating a 50 Hertz variation which is measurable in Short term flicker (P_{st}^{LM})..... 7

Figure 4: Light level varying at 100 Hz which is measurable in SVM 7

Figure 5: CIE 1931 (x,y) Chromaticity Diagram 7

Figure 6: CIE 1976 (u',v') Uniform Colour Scale Chromaticity Diagram 7

Figure 7: CIE 1976 (u',v') Uniform Colour Scale Chromaticity Diagram illustrating CCT isolines and D_{uv} directions away from Planckian curve 8

Figure 8: CIE 1976 (u',v') Uniform Colour Scale Chromaticity Diagram illustrating ANSI quadrangles, u'v' circles and MacAdam ellipses..... 10

Figure 9: CIE 1976 (u',v') Uniform Colour Scale Chromaticity Diagram illustrating chromaticity difference, $\Delta_{u',v'}$, between initial and maintained colour appearance..... 10

Figure 10: Poor product survival fraction profile..... 12

Figure 11: Good product survival fraction profile..... 12

Figure 12: Poor product failure probability profile..... 12

Figure 13: Good product failure probability profile..... 12

Figure 14: Effect on lamp operating temperature at the Temperature Measurement Point (TMP) of short and long switching cycles 13

Figure 15: Modelling of luminous flux depreciation and determination of the L_{70B50} 14

Figure 16: Efficacy Trend (in lm/W) projections for 20th, 80th and 95th percentiles based on US Lighting Facts data for non-directional LED lamps (n=1,381) 33

Figure 17: US Lighting Facts-derived efficacy projections (lm/W, shown with 95% confidence interval in grey) , overlaid with international test, market survey and efficient product registry data for non-directional LED lamps..... 34

Figure 18: Efficacy trend (in lm/W) projections for 20th, 80th and 95th percentiles based on US Lighting Facts data for Linear LED lamps, (n=4,966) 35

Figure 19: US Lighting Facts-derived efficacy projections (lm/W, shown with 95% confidence interval in grey) , overlaid with market survey and efficient product registry data for linear LED lamps..... 36

List of Tables

Table 1: Datasets accessed and included in Combined Product Database 3

Table 2. IEA 4E SSL Annex Quality and Performance Requirements for 2023..... 21

Table 3. Performance Criteria included in the IEA 4E SSL Annex Quality and performance requirements 27

Table 4. Number of Samples Required for Multiplying Factor applying IES TM-28 Calculations to Test Data..... 38

1 LED Quality and Performance Requirements - Intent of Performance Tiers

1.1 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 achievable by 2023 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 technologies they are replacing.

1.2 Tier 2: Performance Level Required by Established Quality Programs

This tier is intended to be similar to the performance requirements for established voluntary premium labelling, green procurement and incentive programmes that promote quality SSL products such as the Japanese Top Runner programme². In addition to the objectives set out in Tier 1, the SSL products in this tier have/are:

- Efficacy established at a level achievable by 2023 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.

1.3 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 2023. Products achieving these performance levels are intended to be equivalent to those participating in peak award programmes such as the SEAD³ global efficiency award programme.

² https://www.enecho.meti.go.jp/category/saving_and_new/saving/summary/

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

2 Revision of Quality and Performance Requirements

Two significant changes have been made as a result of the 2020 review.

Firstly, and most importantly, the ***efficacy levels throughout the document are recommended for programs with commencement dates expected in the year 2023***. This is an acknowledgement that programs, once initiated, take several years to implement including providing enough notification period for the market supply chain to prepare.

Secondly, ***there has been a re-structure of the product scopes*** in the Product Quality and Performance Requirements publications to reflect the advancement of energy efficiency across a broader range of product forms.

The revision of the performance requirements was a three-stage process.

1. Reputable sources of product performance data were identified, collected and incorporated into a combined product database (see Table 1) for detailed analysis.
2. Within the combined product database, yearly trends of specific percentiles that are used to define the performance tiers (20th Percentile for Tier 1, 80th percentile for Tier 2 and 95th percentile for Tier 3) for each product category within scope were examined. (See “Predicted yearly efficacy trends” for details)
3. A rationalisation of product categories was conducted by amalgamating appropriate product categories with similar trends or trend rates.

2.1 Sources of product performance data

As part of the review of the performance requirements of different categories of LED lighting, a combined product database has been developed so that a statistical analysis can be conducted to propose the efficacy thresholds for each tier based on percentiles. There are two main functional categories of product performance data. The first is market data, obtained from market surveys and public databases with no performance requirements, such as minimum efficacy, for listing. This category also includes laboratory data from market-available products tested for benchmarking purposes. The second is registration data, obtained from databases of registered products that have performance requirements, most notably efficacy, for listing. The datasets accessed for the combined product database along with number of products and the year of product listings are provided in Table 1. Only details for those categories of products within each database that are relevant to the product scopes of the performance requirements are included.

Table 1: Datasets accessed and included in Combined Product Database

Dataset Source	Number of lamps	Entry Years	Number of in-scope luminaires	Entry Years
Market Data				
US Lighting Facts database	12,868	2009 - 2016	57,326	2010 - 2019
Australian Market Survey	3,196	2017 - 2018		
Benchmarking test data (international)	342	2016-2019		
Register data				
Energy Star database	9,671	2009 - 2019	19,200	2009 - 2020
Japan energy-saving product database	433	2017		
Thailand Label No. 5 product database	284	2019		
Korea high-efficiency certification system database	3,487	2017 - 2019	29,255	2017 - 2019
Design Lights Consortium (DLC) Quality Product Listing	30,821	2016 - 2020	27,578	2016 - 2020
India Star Rating Register	355	2019		
Total listing	61,457	2009 - 2020	133,359	2009 - 2020

2.2 Method for establishing yearly trends for the performance requirements

The process of creating annual trends for each product category requires a large dataset, to minimise the influence of individual products, and a lengthy history to best establish the trend profile. The dataset also needs to have no limitation on product eligibility in terms of a minimum efficacy as this will arbitrarily inflate the efficacy value for the yearly percentiles.

Only the US Lighting Facts dataset best meets these criteria and is ultimately analysed to determine the efficacy yearly percentiles used for establishing trend projections to 2023. The remaining datasets listed in Table 1 were then superimposed as scatter plots over the percentile trend lines to validate or, if considered necessary, adjust/recalibrate the annual trend rates and the associated tier efficacy projected for 2023. “Annex 2, Predicted yearly efficacy trends”, provides the detailed analysis for (a) non-directional lamps and (b) linear lamps.

2.3 Rationalised Product Categories

The SSL Annex has published the 2020 edition of Recommended Quality and Performance Requirements grouping product types within the following four (4) overarching groups of LED lamps and luminaires for typical applications:

1. Residential Lighting Products (Version 1, 2020)
 - a. Non-directional Lamps (revision of Version 2, November 2016)
 - b. Directional Lamps (revision of Version 2, November 2016)
 - c. Linear strip light (New)
 - d. Downlight Luminaires (revision of Version 2, November 2016)
2. Commercial and Industrial lamps (Version 1, 2020)
 - a. Linear LED Lamps (revision of Version 1, November 2016)
 - b. Single capped high luminous flux lamps (New)

3. Commercial and Industrial Indoor Luminaires (Version 1, 2020)
 - a. Planar Luminaires (revision of Version 1, November 2016)
 - b. High/Low Bay LED Luminaires (revision of Version 1, November 2016)
 - c. Linear batten and troffer luminaires (New)
 - d. Commercial retrofit kits (New)

4. Outdoor Luminaires (Version 1, 2020)
 - a. Street Lighting (revision of Version 2, November 2016)
 - b. Outdoor Lighting (New)

These performance requirements are also provided on the website: <http://ssl.iea-4e.org/product-performance>

3 Updates and Clarifications (Note: this section will be moved to an Annex in the final version)

Since November 2016, several countries/regions have introduced, or are well progressed in developing, regulations for Minimum Energy Performance Standards (MEPS) for lighting products, mainly lamps intended for the domestic sector. Higher Efficiency Performance Standards (HEPS), some in conjunction with an Endorsement Label and subsidy programs, have also been developed for promoting higher quality lighting products in several countries. Procurement specifications for energy efficient streetlight luminaires have been adopted by local governments and other providers of public lighting (e.g. energy distribution businesses, energy service companies) for the purposes of reducing energy and service costs.

In relation to technical parameters, some of those used in previous versions of this document have been superseded. In addition, new metrics have been included in recently renewed fields of interest with links to health matters. The following sections document changes which endeavour to facilitate greater coverage and clarity of matters pertaining to the provision of good quality lighting service from energy efficient lighting products.

3.1 Displacement Factor

Historically, power factor has been the metric used in performance standards and regulations to describe the phase shift (i.e. alignment) between the current and voltage waveforms for the mains power supplied to the product. This metric incorporates two different electrical phenomena: the effects of harmonics on the shape of the current waveform (expressed as distortion factor) and the phase shift of the mains frequency (fundamental) component of the current waveform (expressed as displacement factor) caused by the reactive impedance (caused by the capacitive and inductive elements) of the LED driver.

The relationship between these three metrics is:

$$\lambda = K_{displacement} \times K_{distortion}$$

Where $\lambda = \text{power factor}$

$$K_{displacement} = \text{displacement factor}$$

$$K_{distortion} = \text{distortion factor}$$

Limits on the current harmonics are generally applied through other metrics so their inclusion, by using power factor, is unwarranted. Changing the metric to displacement factor is in line with current recommendations within relevant international standards. Displacement factor provides an indicator of any increased current requirements due to the fundamental current phase shift. The effects of changing displacement factor on the current required by a lamp is illustrated in Figure 1 and comparison of the effects for different lamp technologies is provided in Figure 2. It should be noted that the overall effect of displacement factor on the electricity transmission system is the collective result of all connected appliances and equipment to the system.

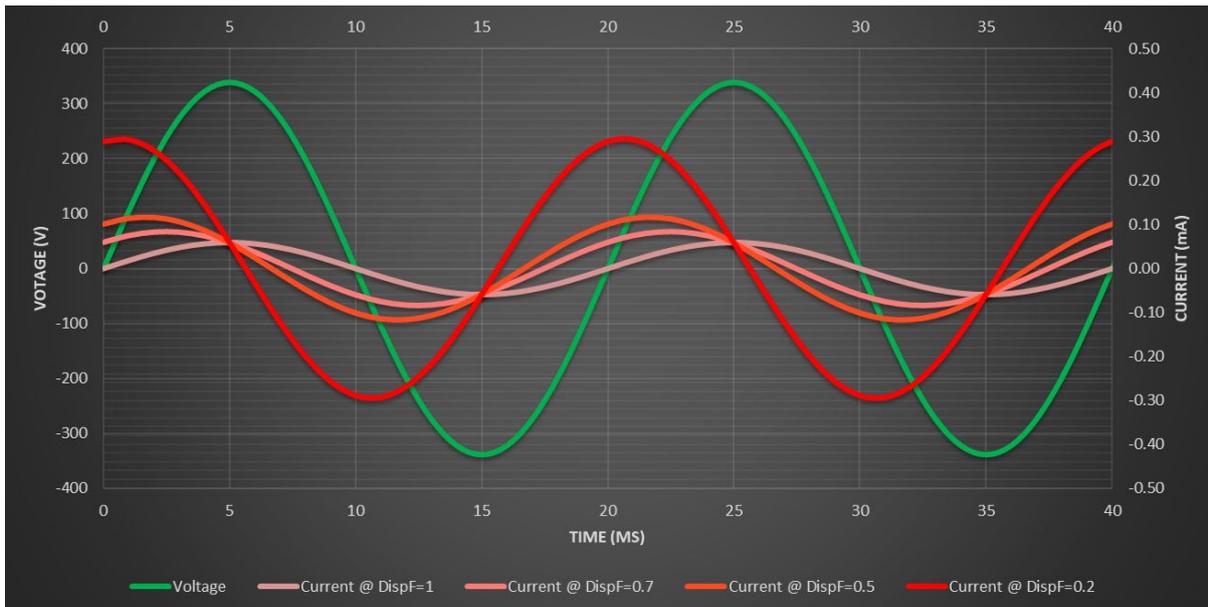


Figure 1: Fundamental currents for different Displacement Factors providing the same lamp power

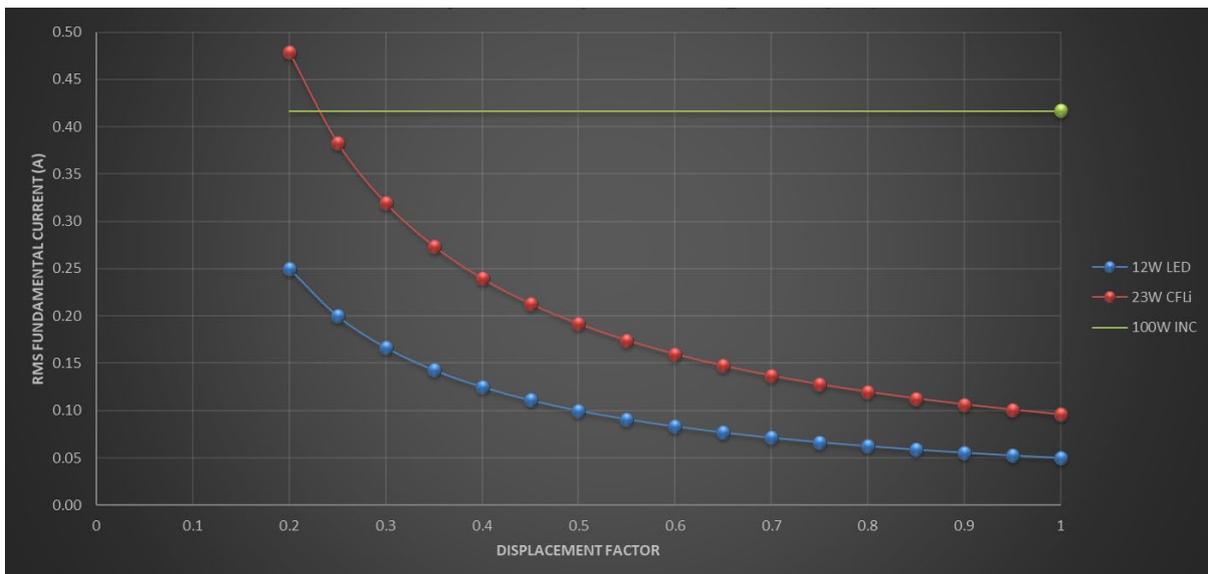


Figure 2: Lamp fundamental current vs Displacement Factor for different lamp technologies with equivalent light output: 12W LED, 23W Compact Fluorescent (CFL) and 100W Incandescent (INC).

3.2 Temporal Light Modulation

Light output from LED chips is super responsive to fluctuations in delivered electrical power in ways not experienced as dramatically with traditional light source technologies. This variation in light output with time is defined as temporal light modulation, TLM, and is known to produce unwanted changes in visual perception, known as temporal light artefacts, TLAs. This exposes a gap in lighting product performance standards and regulations that since 2016 has seen the defining of specific TLAs and their metrics by the CIE and the development of test methods by the IEC and proposed limits by regulators. Two TLA metrics are included in this current revision, Short term flicker, P_{st}^{LM} , for effects from lower frequencies, Figure 3, and stroboscopic visibility measure, SVM for effects from higher frequencies, Figure 4. More information on these TLAs is provided in CIE Technical Notes, TN 006-2016 and TN 008-2017.

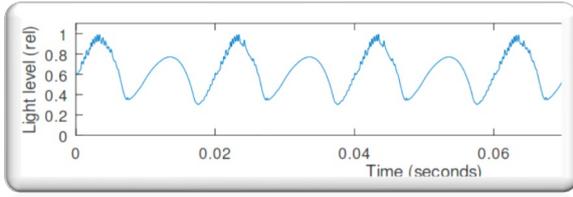


Figure 3: Different light levels of adjacent peaks creating a 50 Hertz variation which is measurable in Short term flicker (P_{st}^{LM})

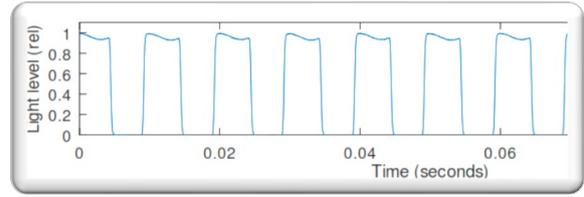


Figure 4: Light level varying at 100 Hz which is measurable in SVM

3.3 Colour - chromaticity coordinate system

Colour quality metrics are important for describing the colour of the light emitted by a light source as well as colour consistency between samples of the same product and the maintaining consistency of the colour of the light emitted over the useful life of the product. Reporting, and even visualising, colour appearance, colour difference or colour shift is best presented by a colour space which has a uniform scale of perceived colour change in any direction in the described colour space.

Historically, the x,y chromaticity coordinate system, developed in 1931 by the CIE, has been used in regulatory programs. This is a non-uniform colour space evidenced by the significant region of shades of green compared to other primary colours, Figure 5. The Uniform Colour Scale chromaticity coordinate system developed by the CIE in 1976 however provides a more balanced colour space, providing opportunity for colour variation metrics (u',v') where measured values throughout the space represent consistent change in colour appearance, Figure 6.

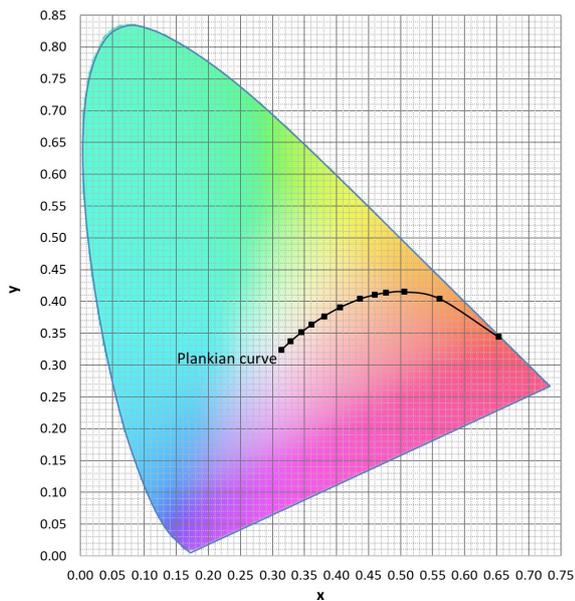


Figure 5: CIE 1931 (x,y) Chromaticity Diagram

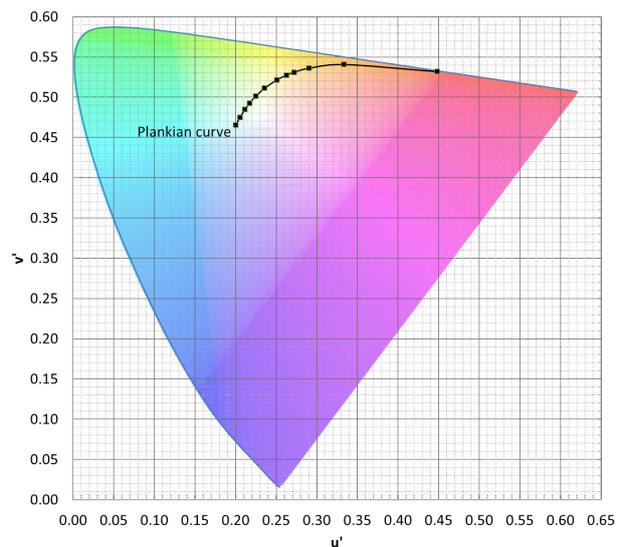


Figure 6: CIE 1976 (u',v') Uniform Colour Scale Chromaticity Diagram

In terms of white light colour appearance, Correlated Colour Temperature (CCT), is accepted and well recognised as a descriptor of the colour appearance of a light source. CCT is fundamentally based on the similarity (correlation) of the perceived colour of a light source, to the colour of the optical radiation emitted by the process of incandescence from a blackbody radiator of a particular temperature (in Kelvin, K).

The curve plotted on a chromaticity chart representing the change in colour appearance with the heating of a blackbody radiator is known as the Planckian curve, Figure 7. With increasing temperature, the colour appearance of the emitted light shifts from a reddish white to a bluish white.

Light sources with colour appearances that are deemed to be similar to a particular colour temperature on the Planckian curve are represented by the CCT isolines that cut across the Planckian curve, illustrated in Figure 7. A more precise designation of the appearance of light sources that have the same CCT but are located away from the Planckian curve is expressed by the metric Duv. This indicates the distance along the CCT isoline and whether above (+ sign) with a slightly greenish appearance or below (- sign) with a more pinkish appearance than the reference colour temperature on the Planckian curve, also illustrated in Figure 7.

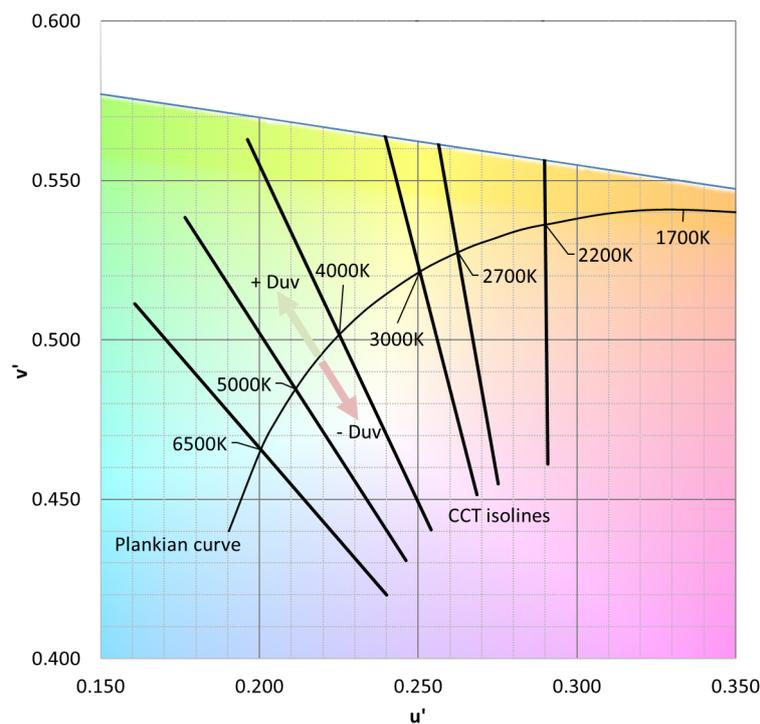


Figure 7: CIE 1976 (u',v') Uniform Colour Scale Chromaticity Diagram illustrating CCT isolines and D_{uv} directions away from Planckian curve

In terms of lit environments, it is important that products (of the same or different model) which are intended to provide the same CCT should be close enough in colour appearance to provide that intended experience. This can be achieved by restricting the distance between the light sources' colour appearances when depicted on a chromaticity diagram.

Previously, different sized ellipses (based on number of unit steps, where lower number indicates smaller size, e.g. 7-step ellipse) around the target colour for a limited set of reference colour temperatures⁴ have been used, Figure 8. These are defined within IEC 60081 and are based on ellipses defined by MacAdam⁵. However, in a uniform colour space (i.e. u',v' chromaticity diagram), the shape of the restriction boundary, centred on the target reference colour, should be a circle due to perceived change in colour appearance being equal in all directions. This is not the situation with the MacAdam ellipses.

Additional to this, IEC 60081 only defines six target reference colours, effectively limiting the range of colour appearances of light sources within lighting products. Ultimately, this forces a rejection of LED packages with colour appearances outside of the MacAdam ellipses but still adjacent to the Planckian curve, from use in general lighting products, Figure 8.

From both commercial and sustainability perspectives, it is reasonable to expect manufactured LED packages with colour appearances near the Planckian curve to be able to be utilised in general lighting products. This philosophy is supported by the defining of ANSI⁶ quadrangles⁷ centred on ten target reference colours which encompass the region adjacent to the Planckian curve from approximately 2100 K to 7000 K, Figure 8.

For situations where colour appearance is required to be very uniform (from multiple light sources) or precise (from a single light source), a more restrictive requirement can be specified based on a set of small circles (with the radius stated as a number of unit steps) inside the ANSI quadrangles. The circles are known as n-step u',v' circles (e.g. 4-step u',v' circle). The smaller the number of steps, the smaller the circle.

⁴ See IEC 60081:2002 Double-capped fluorescent lamps- Performance specifications

⁵ D.L. MacAdam, JOSA, 1, 18-26 (1943)

⁶ American National Standards Institute

⁷ ANSI/NEMA C78.377-2017

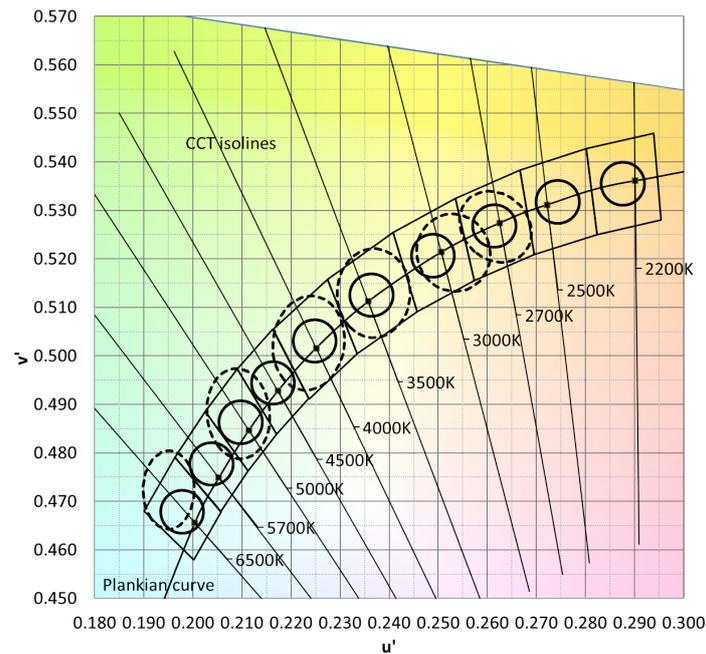


Figure 8: CIE 1976 (u',v') Uniform Colour Scale Chromaticity Diagram illustrating ANSI quadrangles, u',v' circles and MacAdam ellipses

Another colour performance quality is for a product to maintain an acceptable shift in colour appearance over its life. It can be readily determined within the uniform colour space (i.e. u',v' chromaticity diagram) using the chromaticity difference, $\Delta_{u',v'}$, between the colour appearance at the beginning and the end of an operating period. This is represented by a move from an initial position on the chromaticity diagram (i.e. the initial colour appearance, u'_1, v'_1) to a position after the designated operating period (i.e. the maintained colour appearance, u'_2, v'_2). An example is provided in Figure 9.

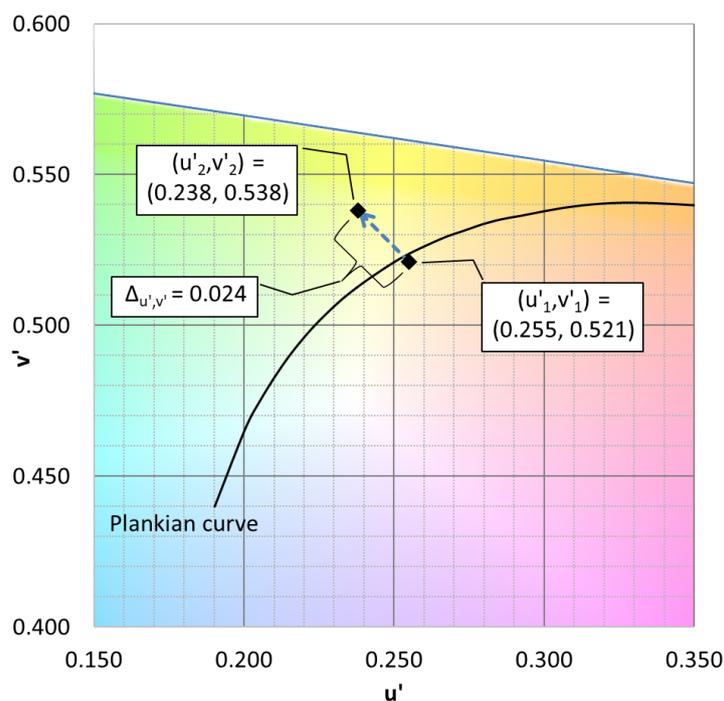


Figure 9: CIE 1976 (u',v') Uniform Colour Scale Chromaticity Diagram illustrating chromaticity difference, $\Delta_{u',v'}$, between initial and maintained colour appearance

The metrics described above:

- u',v' for chromaticity coordinates
- CCT and D_{uv} for colour appearance
- n-step u',v' circles for colour consistency
- $\Delta_{u',v'}$ for colour shift

are used for the recommended colour performance requirements in this document. They have been selected as the most appropriate for assisting and understanding the designation of colour appearance and appreciating quantitative differences. Further details see CIE Technical Note, TN 001-2014 and ANSI/NEMA C78.377-2017.

3.4 Product lifetime

The life of a product is determined by the time until it cannot provide a useful amount of light for its intended purpose. This may be either by (a) catastrophic failure, that is the inability to produce any light by the lamp, or (b) parametric failure, wherein some light is still produced by the lamp but is unsatisfactory for the intended purpose. Typical causes of catastrophic failure are electronic component or electrical connection failures, while typical parametric failures are deterioration of the LED die (manifested as colour shift and light loss) and LED driver performances (manifested as flicker and light loss). The rated lifetime of a product is generally intended to represent the median lifetime of multiple units of the same product. This means, by definition, that half the units will have a lifetime shorter than this rated value and the remainder will exceed it. As well as the typical lifetime of a product complying with the rated lifetime, the spread of the lifetimes of samples of the product (around the rated value) is important in appreciating the likelihood of the consumer purchasing a sample of a product and ultimately receiving a service near to the rated lifetime.

This is clearly illustrated for two products which have the same lifetime of 15,000 hours but one is a poor quality product, Figure 10, with many early failures (nearly 30% of samples at 6,000 hours operation) whereas the good quality product, Figure 11, has virtually no failures (3%) at 6,000 hours. Appropriate test methods need to be able to expose the relatively high probability of early failure of poor products, Figure 12, while having a low probability of causing failures of the good products, Figure 13.

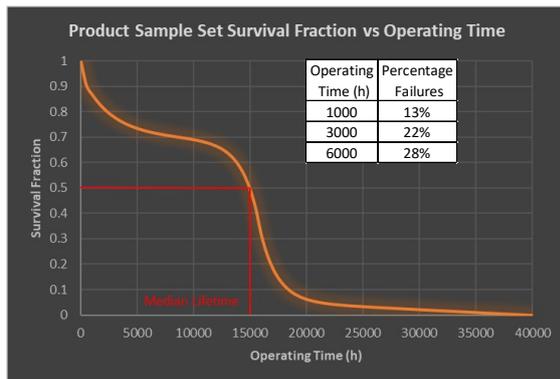


Figure 10: Poor product survival fraction profile

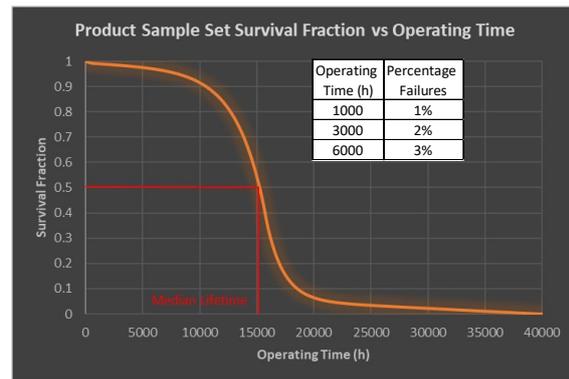


Figure 11: Good product survival fraction profile

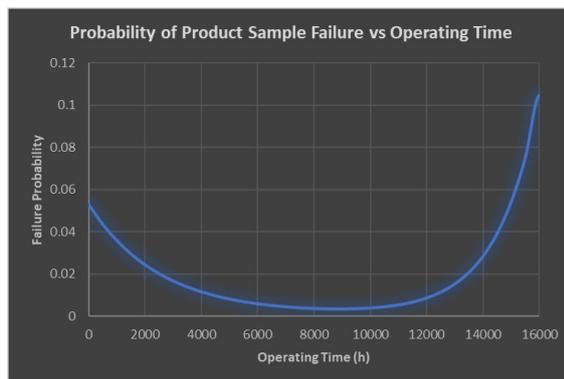


Figure 12: Poor product failure probability profile

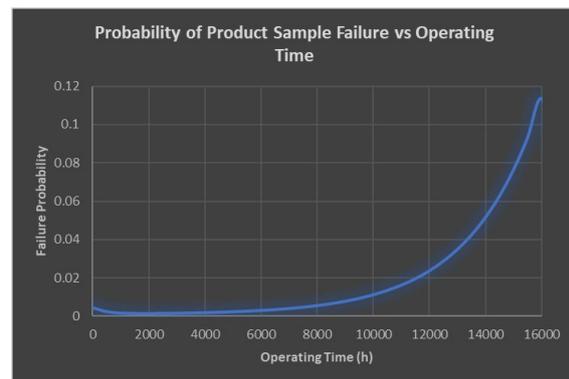


Figure 13: Good product failure probability profile

To protect consumers, metrics that guard against very early (i.e. premature) failure are required. There are typically two reasons for premature failure, both of catastrophic nature:

1. failure of components under the operating electrical and/or thermal conditions, and
2. mechanical failure of electrical connections due to stresses created from the impact of different thermal expansion rates between materials when subjected to large variations in temperature.

This requires subjecting product samples to conditions that would either be reasonably expected to be encountered in typical installations (e.g. switch cycling at typical ambient temperature), or extreme conditions that may accelerate the same failure mechanisms that can then be identified after relatively short test durations (e.g. exposure to temperature extremes in unpowered or cycling switched states). The impact of operating time and switching cycle on lamp component temperatures is illustrated in Figure 14. With the ambient temperature remaining near 20°C, the temperature variation at the lamp's Temperature Measurement Point (TMP) changes significantly from approximately:

- 5°C for switch cycling of 1 minute on and 1 minute off, (as shown in Figure 14 in the region of the Relative Time scale from approximately 15-60 minutes), to
- 45°C for switch cycling of 2.5 hours on and 0.5 hours off, (as shown in Figure 14 in the region of the Relative Time scale from approximately 100-450 minutes).

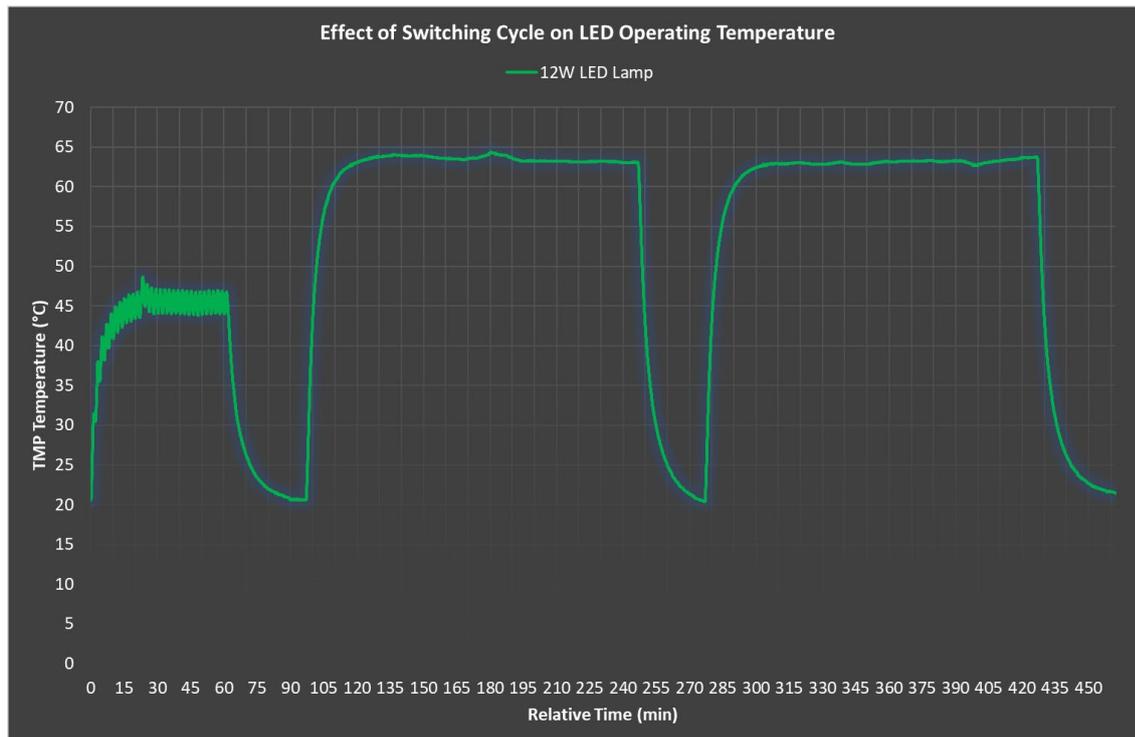


Figure 14: Effect on lamp operating temperature at the Temperature Measurement Point (TMP) of short and long switching cycles

These are known as endurance tests and they identify a product’s early failure rate and generally do not include any early indication of reduction in luminous flux output, although there are ongoing research activities in this area.

Checking that the typical lifetime (which accounts for catastrophic and parametric failures) of the samples of a product comply with the rated lifetime is a more complex process given the extremely long operating life of LED products and the lack of an accepted theoretical model and associated test method for long-term catastrophic failure prediction rates. There is however a generally accepted theoretical model for the long-term parametric failure mode of luminous flux depreciation. This requires use of a performance testing method able to be conducted over a duration considerably shorter than the product’s lifetime and then combining these test results with an accepted algorithm, which models the depreciation in luminous flux output of LED products, to confirm the rated lifetime of the product. The calculations within this type of test only ascertain the predicted median lifetime due to the luminous flux depreciation of the samples and not from any operational failures. The commonly used defined metric for the value that is determined from this test is the median time for the luminous flux maintenance of samples of a product to drop to 70%, $L_{70}B_{50}$. An illustration of the test and prediction process is provided in Figure 15.

Metrics and testing are required to provide indicative lifetime information on

- Endurance
- Lumen maintenance

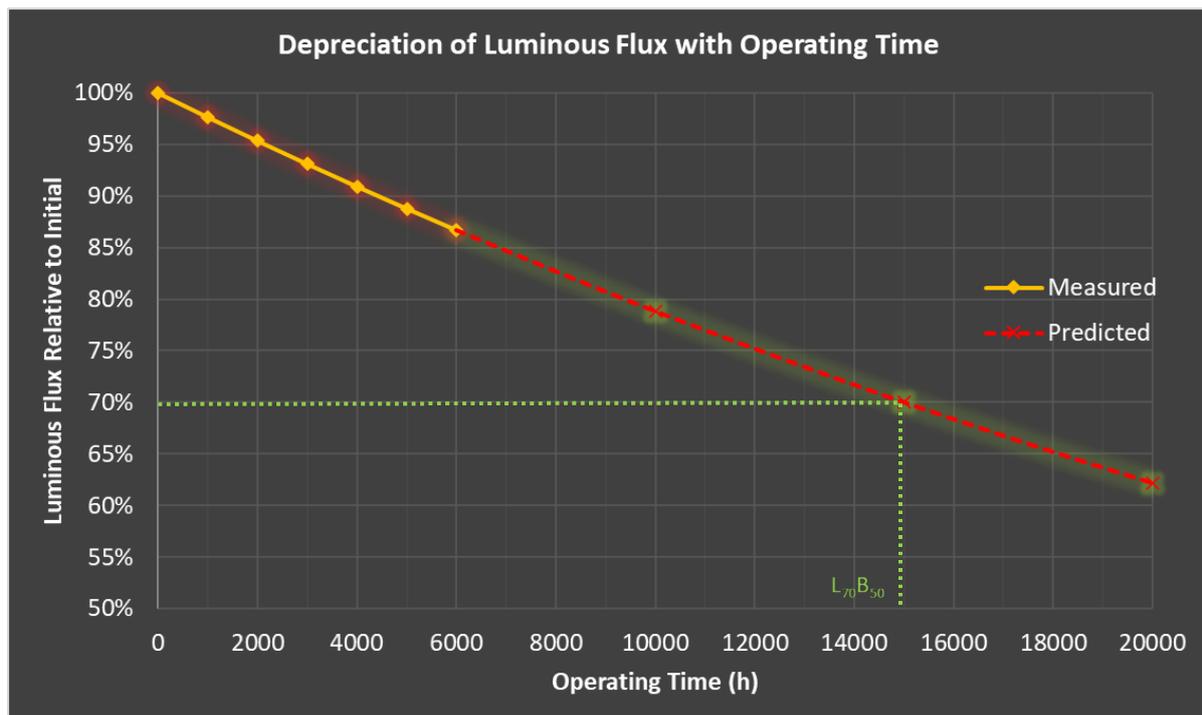


Figure 15: Modelling of luminous flux depreciation and determination of the $L_{70}B_{50}$

In 2020, the SSL Annex continued investigations into lifetime testing of LED products, by commissioning a study to review the latest literature and research on the topic. The study will provide, based on the evidence, recommendations on the perceived best approach(es) to lifetime testing for LEDs and LED products, which may then facilitate further targeted research verifying and refining the relationship and test methodology.

This body of work may ultimately contribute to redefining metrics and test procedures for product lifetime; but until then, existing published metrics and test procedures continue to be recommended by the SSL Annex and are presented in Annex 3.

4 Product Classifications

4.1 Directional Lamp

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

4.2 Non-directional Lamp

A lamp which not a directional lamp.

4.3 Strip Light

A narrow, flexible or rigid, circuit board containing onboard control unit circuitry and surface mounted LEDs. It is energised by an independent power supply.

4.4 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.

4.5 Integrated Downlight

1. Satisfies definition of an Integrated LED luminaire, and
2. small luminaire concentrating the light, usually recessed in the ceiling [IEC IEV Ref 845-10-15].

4.6 Planar (or Panel) LED Luminaire

1. Satisfies definition of an Integrated LED luminaire, and
2. consists primarily of a frosted waveguide material as the emitting surface.
3. Has a predominant thickness (product height) ≤ 30 mm.

4.7 Linear Batten LED Luminaire

1. Satisfies definition of an Integrated LED luminaire, and
2. long luminaire usually installed surface mounted.
3. Has a predominant thickness (product height) > 30 mm.

4.8 Linear Troffer LED Luminaire

1. Satisfies definition of an Integrated LED luminaire, and
2. long luminaire usually installed with the opening flush with the ceiling [IEC IEV Ref 845-10-13].
3. Has a predominant thickness (product height) > 30 mm.

4.9 High bay/Low bay LED Luminaire

1. Satisfies definition of an Integrated LED luminaire, and
2. indoor luminaire intended for mounting at heights ≥ 6 m.

4.10 Outdoor (Floodlight) Integrated Luminaire

1. Satisfies definition of an Integrated LED luminaire, and
2. designed for floodlighting, usually capable of being pointed in any direction [IEC IEV Ref 845-10-28]

4.11 Roadway Integrated Luminaire

1. Satisfies definition of an Integrated LED luminaire, and
2. designed for street and road lighting, for the purposes of pedestrians and drivers.

5 Scope of Coverage for Product Categories

5.1 CAT 1: Residential Lighting Products

1. Non-directional and directional LED lamps intended for general lighting service (general service lighting)

- a. Operating at voltages of 100 to 347 Vac, or 12 to 50 Vac or Vdc.
- b. Initial luminous flux ≥ 60 lm and $< 2,600$ lm
- c. Base types (Note on what the number is)

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 Vac, or 12 to 50 Vac or Vdc.
- 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 Vac, or 12 to 50 Vac or Vdc.
- b. Initial luminous flux of ≥ 60 lm and $< 2,600$ lm
- c. A small direct lighting unit where the light emitting elements are integrated (viz may take the form of LED packages, LED modules or LED Light Engines BUT not LED lamps)
- d. Directs the light downward. It may be recessed, surface mounted, or suspended
- e. Operated with either:

- i. an integrated driver



- ii. a separate Extra Low Voltage converter (ELVC)

- iii. a separate LED driver



- f. Excluding those not intended for general lighting service

5.2 CAT 2: Commercial and Industrial Lamps

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

1. Double-capped Linear LED Lamps

- a. Operating at voltages of 100 to 347 Vac, or 12 to 50 Vac or Vdc.
- b. With tube lengths from 550 mm - 2400 mm inclusive
- c. With caps:
 - i. intended for replacing fluorescent lamps (as defined in IEC 60081) with the same caps (as defined in IEC 60081), or



G5, G13



FA6, FA8



- 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"

d. Excluding those not intended for general lighting service

- 2. Single-capped High Luminous Flux LED Lamps
 - a. Operating at voltages of 100 to 347 Vac
 - a. With caps E26, E27, E39, E40
 - b. Initial luminous flux ≥ 2600 lm
 - c. Intended as replacement lamps for:

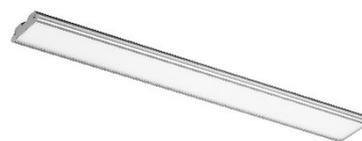
- i. high intensity discharge lamps



5.3 CAT 3: Commercial and Industrial Indoor Luminaires

- 1. Integrated LED Luminaires
 - a. Operating at voltages of 100 to 347 Vac, or 12 to 50 Vac or Vdc.
 - 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 Vac, or 12 to 50 Vac or Vdc.
- 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 Vac
- b. Initial luminous flux of ≥ 5000 lm
- c. Integrated LED fixtures intended as an alternative to lamp based:

- i. High bay and low bay luminaires



5.4 CAT 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 based outdoor luminaires).

1. Roadway Integrated LED Luminaires

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



2. Outdoor Integrated LED Luminaires

- a. Operating at voltages of 100 to 347 Vac
- b. Initial luminous flux of ≥ 3000 lm
- c. Integrated LED fixtures intended as an alternative to lamp based:
Floodlight



6 Quality and Performance Requirements for 2023 Commencement

Table 2. IEA 4E SSL Annex Quality and Performance Requirements for 2023

	Product & Parameter	Tier 1	Tier 2	Tier 3
Energy-Efficiency				
Minimum luminous efficacy, η				
CAT 1: Residential Lighting Products	Non-directional lamp <i>Default level</i>	105 lm/W	140 lm/W	155 lm/W
	<i>Concessions (additive):</i> Lumens < 400 lm CCT < 2500 K CRI \geq 90	subtract 10 lm/W subtract 10 lm/W subtract 10 lm/W		
	Directional lamp <i>Default level</i>	80 lm/W	115 lm/W	130 lm/W
	<i>Concessions (additive):</i> Beam Angle < 20° CCT < 2500 K CRI \geq 90	subtract 10 lm/W subtract 10 lm/W subtract 10 lm/W		
	Downlight and downlight retrofit kits <i>Default level</i>	90 lm/W	115 lm/W	130 lm/W
	<i>Concession:</i> Retrofit kits	subtract 10 lm/W		
	Strip light <i>Default level</i>	80 lm/W	90 lm/W	100 lm/W
	<i>Concession:</i> CCT < 2500 K	subtract 10 lm/W		
CAT 2: Commercial & Industrial Lamps	Double-capped linear lamp <i>Default level</i>	125 lm/W	180 lm/W	205 lm/W
	<i>Concession:</i> CCT < 2500 K	subtract 15 lm/W		
	Single-capped high luminous flux lamp <i>Default level</i>	105 lm/W	140 lm/W	155 lm/W
	<i>Concession:</i> CCT < 2500 K	subtract 15 lm/W		
CAT 3: Commercial & Industrial Luminaires	Linear, Troffer, and commercial retrofit kits <i>Default level</i>	110 lm/W	150 lm/W	170 lm/W
	Panel (planar) <i>Default level</i>	90 lm/W	130 lm/W	150 lm/W
	High bay, Low bay, and industrial retrofit kits <i>Default level</i>	125 lm/W	155 lm/W	185 lm/W
CAT 4: Outdoor Luminaires	Roadway and outdoor <i>Default level</i>	110 lm/W	150 lm/W	170 lm/W
Maximum non-networked standby power mode power consumption				
All	All	0.5 W	0.3 W	0.2 W
Maximum networked standby power mode power consumption				
All	All	0.5 W	0.3 W	0.2 W

	Product & Parameter	Tier 1	Tier 2	Tier 3
Life				
Minimum rated lifetime (F₅₀)				
CAT 1	Lamp	15 000 h	20 000 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, outdoor	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%	
	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, outdoor	95.8%	96.5%	97.2%
Maximum Early Failure Rate (F_x @ 3 000 h)				
All	All	10%		
ALTERNATE: Minimum Luminous Flux Maintenance when Combined Test with Maximum Early Failure Rate (L_x @ 3 000 h)				
CAT 1	Lamp with rated lifetime < 15 000 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 < 15 000 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 R ₉ : 0	R _a : 85 R ₉ : 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 R ₉ : 0	R _a : 85 R ₉ : 50																																																																											
	High bay, Low bay, & retrofit kits	R _a : 80	R _a : 80 R ₉ : 0																																																																												
CAT 4	Roadway, outdoor	R _a : 70																																																																													
Maximum chromaticity tolerance limits																																																																															
CAT 1	Lamp Downlight & retrofit kits Strip Light	<table border="1"> <thead> <tr> <th>Nominal CCT (K)</th> <th>Target CCT and Tolerance (K)</th> <th>Target Duv</th> <th>Duv Tolerance Range</th> </tr> </thead> <tbody> <tr> <td>2200</td> <td>2238 ± 102</td> <td>0.0000</td> <td rowspan="3">T_x: CCT of the source</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> <td rowspan="2">For T_x < 2870K 0.000 ± 0.0060</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> <td rowspan="2">For T_x ≥ 2870K</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> <td rowspan="4">D_w(T_x) ± 0.0060 where D_w(T_x) = 57700 × (1/T_x)² - 44.6 × (1/T_x) + 0.00854</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> <tr> <td></td> <td></td> <td></td> </tr> </tbody> </table>	Nominal CCT (K)	Target CCT and Tolerance (K)	Target Duv	Duv Tolerance Range	2200	2238 ± 102	0.0000	T _x : CCT of the source	2500	2460 ± 120	0.0000	2700	2725 ± 145	0.0000	3000	3045 ± 175	0.0001	For T _x < 2870K 0.000 ± 0.0060	3500	3465 ± 245	0.0005	4000	3985 ± 275	0.0010	For T _x ≥ 2870K	4500	4503 ± 243	0.0015	5000	5029 ± 283	0.0020	D _w (T _x) ± 0.0060 where D _w (T _x) = 57700 × (1/T _x) ² - 44.6 × (1/T _x) + 0.00854	5700	5667 ± 355	0.0025	6500	6532 ± 510	0.0031				<table border="1"> <thead> <tr> <th>Nominal CCT (K)</th> <th>Centre Point of Circle CCT (K)</th> <th>Duv</th> <th>Radius of Circle</th> </tr> </thead> <tbody> <tr> <td>2200</td> <td>2238</td> <td>0.0000</td> <td rowspan="10">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> <tr> <td>5000</td> <td>5029</td> <td>0.0020</td> </tr> <tr> <td>5700</td> <td>5667</td> <td>0.0025</td> </tr> <tr> <td>6500</td> <td>6532</td> <td>0.0031</td> </tr> </tbody> </table>	Nominal CCT (K)	Centre Point of Circle CCT (K)	Duv	Radius of Circle	2200	2238	0.0000	0.0044 in (u',v') diagram	2500	2460	0.0000	2700	2725	0.0000	3000	3045	0.0001	3500	3465	0.0005	4000	3985	0.0010	4500	4503	0.0015	5000	5029	0.0020	5700	5667	0.0025	6500	6532	0.0031
Nominal CCT (K)	Target CCT and Tolerance (K)		Target Duv	Duv Tolerance Range																																																																											
2200	2238 ± 102		0.0000	T _x : CCT of the source																																																																											
2500	2460 ± 120		0.0000																																																																												
2700	2725 ± 145		0.0000																																																																												
3000	3045 ± 175		0.0001	For T _x < 2870K 0.000 ± 0.0060																																																																											
3500	3465 ± 245		0.0005																																																																												
4000	3985 ± 275		0.0010	For T _x ≥ 2870K																																																																											
4500	4503 ± 243		0.0015																																																																												
5000	5029 ± 283		0.0020	D _w (T _x) ± 0.0060 where D _w (T _x) = 57700 × (1/T _x) ² - 44.6 × (1/T _x) + 0.00854																																																																											
5700	5667 ± 355	0.0025																																																																													
6500	6532 ± 510	0.0031																																																																													
Nominal CCT (K)	Centre Point of Circle CCT (K)	Duv	Radius of Circle																																																																												
2200	2238	0.0000	0.0044 in (u',v') diagram																																																																												
2500	2460	0.0000																																																																													
2700	2725	0.0000																																																																													
3000	3045	0.0001																																																																													
3500	3465	0.0005																																																																													
4000	3985	0.0010																																																																													
4500	4503	0.0015																																																																													
5000	5029	0.0020																																																																													
5700	5667	0.0025																																																																													
6500	6532	0.0031																																																																													
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, outdoor																																																																														
CAT 1	Lamp Downlight Strip Light	N/A	N/A	0.004																																																																											
CAT 2	Double-capped linear lamp Single-capped high luminous flux lamp																																																																														
CAT 3	Linear, Troffer, Planar, retrofit kit High bay, Low bay, retrofit kit																																																																														
CAT 4	Roadway, outdoor																																																																														
Maximum colour maintenance shift (Δu',v' at 6000 h)																																																																															
CAT 1	Lamp Downlight Strip Light	N/A	N/A	0.007																																																																											
CAT 2	Double-capped linear lamp Single-capped high luminous flux lamp																																																																														
CAT 3	Linear, Troffer, Planar, retrofit kit High bay, Low bay, retrofit kit																																																																														
CAT 4	Roadway, outdoor																																																																														

	Parameter	Tier 1	Tier 2	Tier 3
Operation				
Minimum initial luminous flux - Equivalent incandescent wattage claim only				
CAT 1	Non-directional lamp		Equivalent Incandescent Lamp Wattage (W)	LED Lamp, Minimum Luminous Flux (lm)
			15	135
			25	250
			40	470
			60	800
			75	1000
			100	1500
			150	2450
200	3450			
Luminous intensity distribution - Omni-directional claim only				
CAT 1	Non-directional lamp	N/A	<p>No less than 5% of total flux (zonal lumens) shall be emitted in the 130° to 180° γ-angle zone.</p> <p>No less than 35% of total flux (zonal lumens) shall be emitted in the 90° to 180° γ-angle zone.</p>	<p>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.</p> <p>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.</p> <p>No less than 5% of total flux (zonal lumens) shall be emitted in the 130° to 180° zone.</p>
CAT 2	Non-directional lamp Single-capped high luminous flux lamp			
Luminous intensity distribution – Beam Angle				
CAT 1	Directional lamp	N/A	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 (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 shall meet requirements of IEC 63037 and new phase-cut dimmers shall meet requirements of IEC 63036</p>		
Minimum Displacement factor ($K_{displacement}$)				
ALL	All	<p>Power < 25W: $K_{displacement} > 0.50$</p> <p>Power \geq 25W: $K_{displacement} > 0.90$</p>		
Harmonics				
ALL	All	As per IEC 61000-3-2 Clause 7.4		
Health				
Maximum intrinsic Short-term flicker, P_{st}^{LM}, at full load				
ALL	All	1.0		
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 kit High bay, Low bay, retrofit kit			
CAT 4	Roadway, outdoor	N/A*		
Maximum Photobiological risk group				
ALL	All	Blue light: RG1		UV: RG1
Safety Requirements				
ALL	All	Must meet regional requirements for material safety, and mechanical and electrical appliance safety laws, including electromagnetic compatibility (EMC) requirements, and requirements for labelling / marking.		

* The 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.

	Parameter	Tier 1	Tier 2	Tier 3
Environment				
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	
RoHS requirements				
ALL	All	Compliant, 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				
ALL	All	Must meet Zhaga specifications for luminaires		

Annex 1 Explanation of Criteria and Required Test Methods

Table 3. Performance Criteria included in the IEA 4E SSL Annex Quality and performance requirements

Criterion	What is it?	Why is it included?	Test Method
Luminous efficacy (lm/watt)	The ratio of the total light output of a light source 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 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 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. 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 3 for options

Criterion	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-80 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 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	<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 ⁸ . 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

⁸ See [CIE Position Statement on CRI and Colour Quality Metrics](#).

Criterion	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 too markedly from its original colour appearance. It may become noticeably warmer (yellower) 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 standards have been developed for stipulating the performance requirements for satisfactory interoperability of dimmable SSL products and nominated dimmers.	IEC 63036 (dimmers) IEC 63037 (lamps and control gear)

Criterion	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.	This is important to electricity distributors and generators as a product with a low displacement factor requires that more than the minimum amperes must be available to supply the real power. This increases generation and transmission infrastructure capacity requirements and increases power line losses. The level of importance in part depends upon the nature (transmission distance and existing capacity) of the generation network. For street lighting and commercial or industrial lighting; customers may be subject to a penalty charge if power factor is below 0.9.	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, 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
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).	Effects of temporal light modulation (TLM) include physiological and psychological manifestations including migraine, eyestrain, seizures, vertigo, anxiety, autistic behaviour and reduction in task performance. Limiting exposure to these risks is important to people's health. Limitation on SVM levels can assist in this endeavour.	IEC TR 63158 CIE TN 006:2016
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

Criterion	What is it?	Why is it included?	Test Method
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. 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 Predicted yearly efficacy trends

Luminous efficacy trends over time were obtained based on the US Lighting Facts database for lamps and luminaires in relevant product categories. These trends were extrapolated using a linear trendline to obtain estimates of projected tier efficacy targets for 2023 (with 95% confidence interval illustrating upper and lower estimates).

N.B. The US Lighting Facts Database is used for the analyses as it, in comparison to other data sources:

- 1. contains a large volume of data and can be considered representative of the general market as a voluntary product register with no minimum luminous efficacy requirements.*
- 2. lists the initial date products are registered – unlike many other data sources where the date is associated with the year available for sale, or the year data was accessed (which may be several years after the product entered the market), and,*
- 3. is sufficiently detailed to enable the LED products to be cohesively grouped by type, size and application.*

The US Lighting Facts Database is therefore the most suitable choice for observing and extrapolating LED product efficacy trends over time.

The extrapolated luminous efficacy trends for each of the product categories were then compared with recent data from a range of other data sources (mostly international LED product registers) in order to observe the fit of these actual product efficacy data with projected efficacy trends.

An example of this data analysis is shown here in Figure 16 for non-directional lamps. This figure shows the US Lighting Facts data for this lamp category in the years the lamp database was active. Highlighted are the trends for a total of 1,381 lamps from 2010 to 2016:

- Tier 1 – 20th percentile of data
- Tier 2 – 80th percentile of data
- Tier 3 – 95th percentile of data

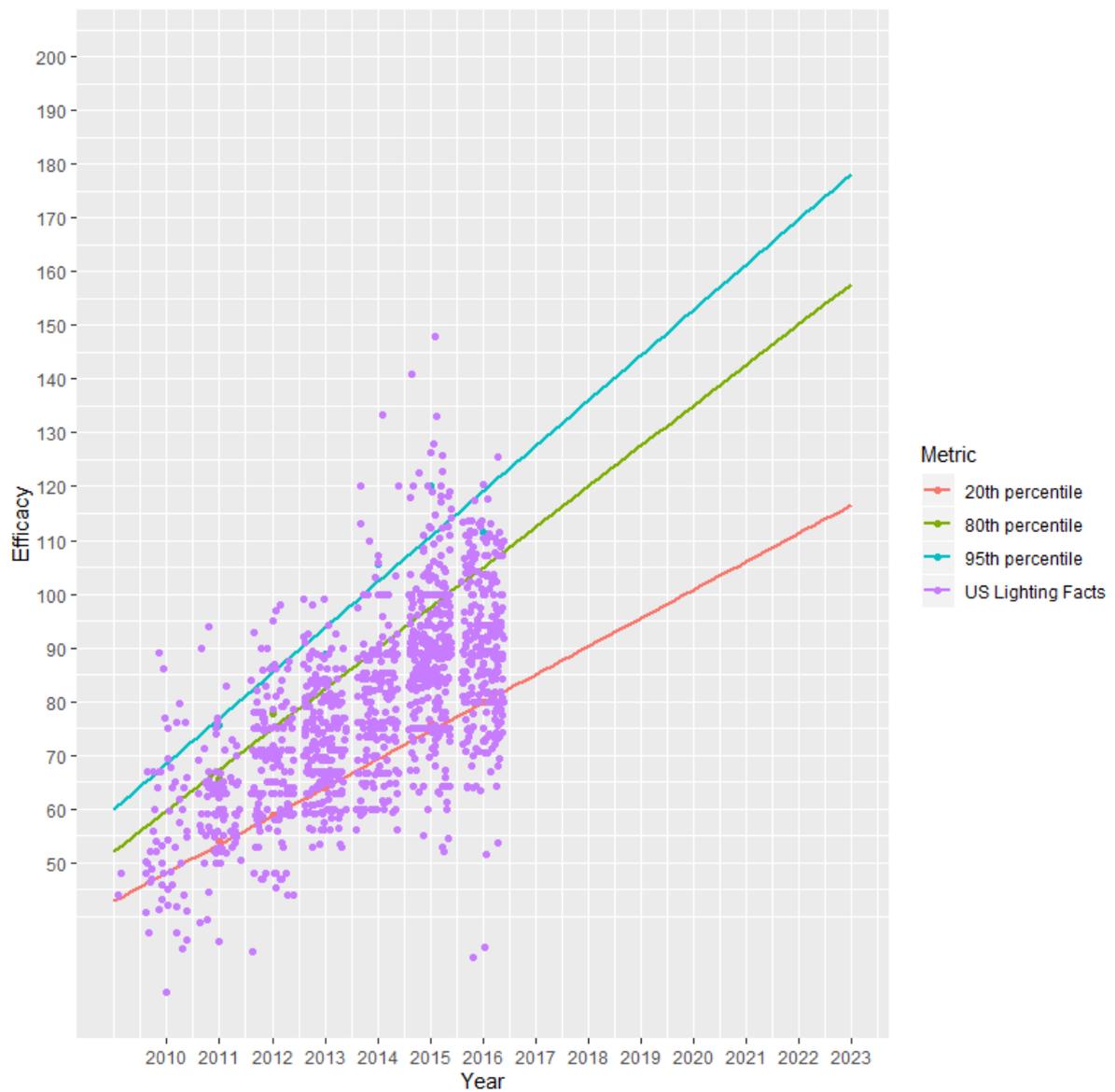


Figure 16: Efficacy Trend (in lm/W) projections for 20th, 80th and 95th percentiles based on US Lighting Facts data for non-directional LED lamps (n=1,381)

In order to validate the projected trends, a comparison was conducted with the most recent available data from other international sources. Figure 17 shows again the three trend lines, derived from the US Lighting Facts data, but now overlaid only with a scatterplot consisting of data from:

- Test data from 236 non-directional lamps available for sale in SE Asia in 2016.
- Australian Market data obtained from a 2017/18 survey of LED lamps available for sale online and in-store – lists 2141 non-directional lamps.
- US/Canada’s Energy Star database – lists 3486 non-directional LED lamps (active at July 2019). This register has a minimum efficacy requirement implemented in 2017.
- India’s Star Rating Register – lists 355 GLS equivalent LED lamps (listed as registered in 2019). This registration has tiered efficacy requirements for 1-5 star ratings.
- Japan’s Top Runner Program register – lists 433 ‘GLS-shaped’ LED lamps (listed registration year 2017). This register has a minimum efficacy of 100 lm/W.

- Thailand’s Label No.5 product database – lists 95 A-shape LED lamps (data download year 2019).

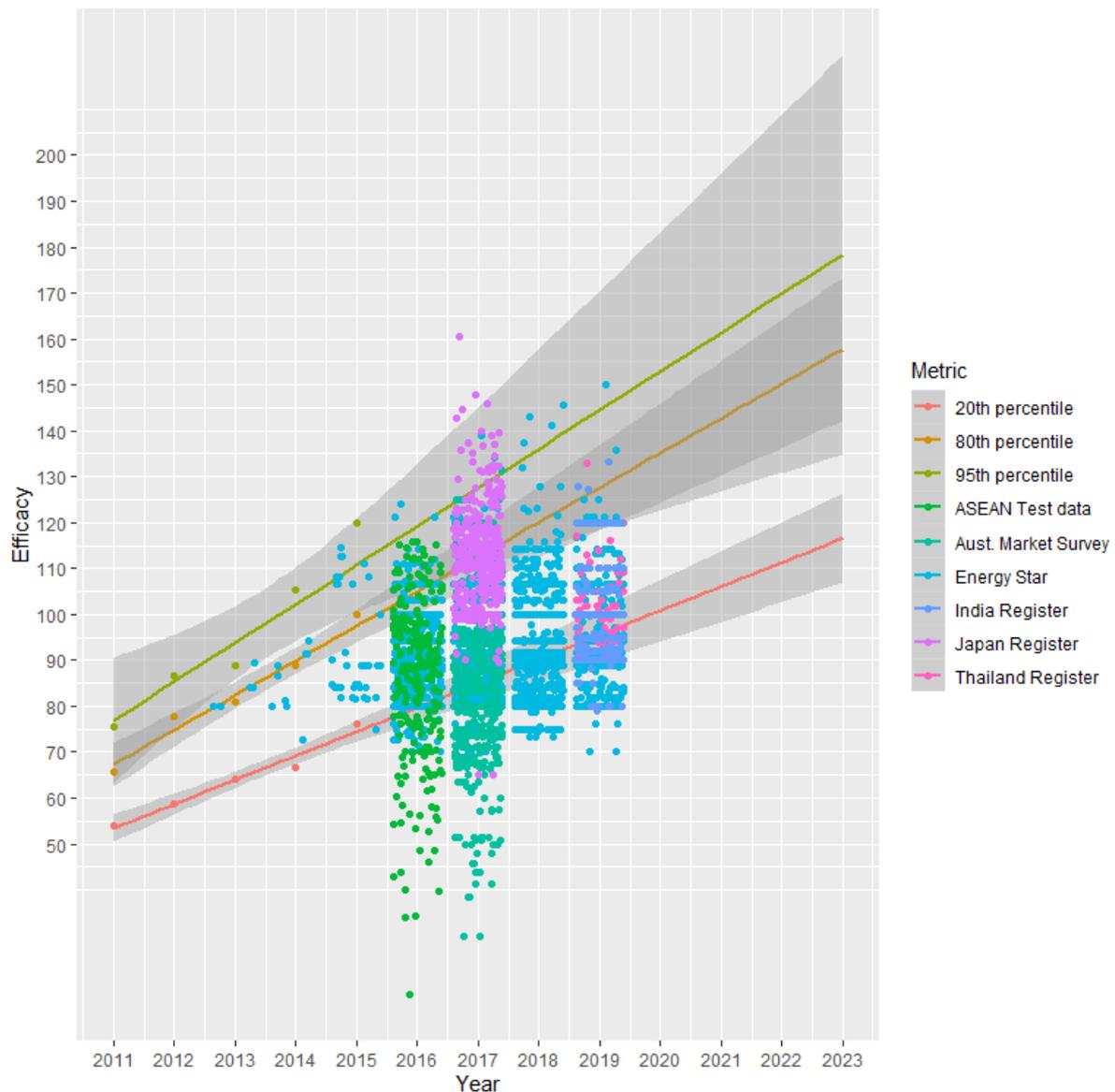


Figure 17: US Lighting Facts-derived efficacy projections (lm/W, shown with 95% confidence interval in grey) , overlaid with international test, market survey and efficient product registry data for non-directional LED lamps

Figure 17 shows that the Tier 1 projection is consistent with register data from Energy Star and the Japanese, Indian and Thai energy efficient product databases (note that the Energy Star set its efficacy requirement in 2017, for Tier 1 reference).

Tier 2 and 3 projections beyond 2016 (where the US Lighting Facts data on LED lamps ends) show that there are products achieving these levels in quantities consistent with the expected performance level.

The data also shows that in the absence of minimum efficacy requirements (market survey and test data), the spread of data ranges from well below the Tier 1 projection to in line with and above the Tier 3 projection. It must be noted that the market and tested product data incorporates products which entered the market in years prior to their data entry date.

A second example of this efficacy trend analysis is provided for linear LED lamps. Highlighted for this lamp category in Figure 18 below are the trends for US Lighting Facts data for a total of 4,966 lamps from 2013 to 2016:

- Tier 1 – 20th percentile of data
- Tier 2 – 80th percentile of data
- Tier 3 – 95th percentile of data

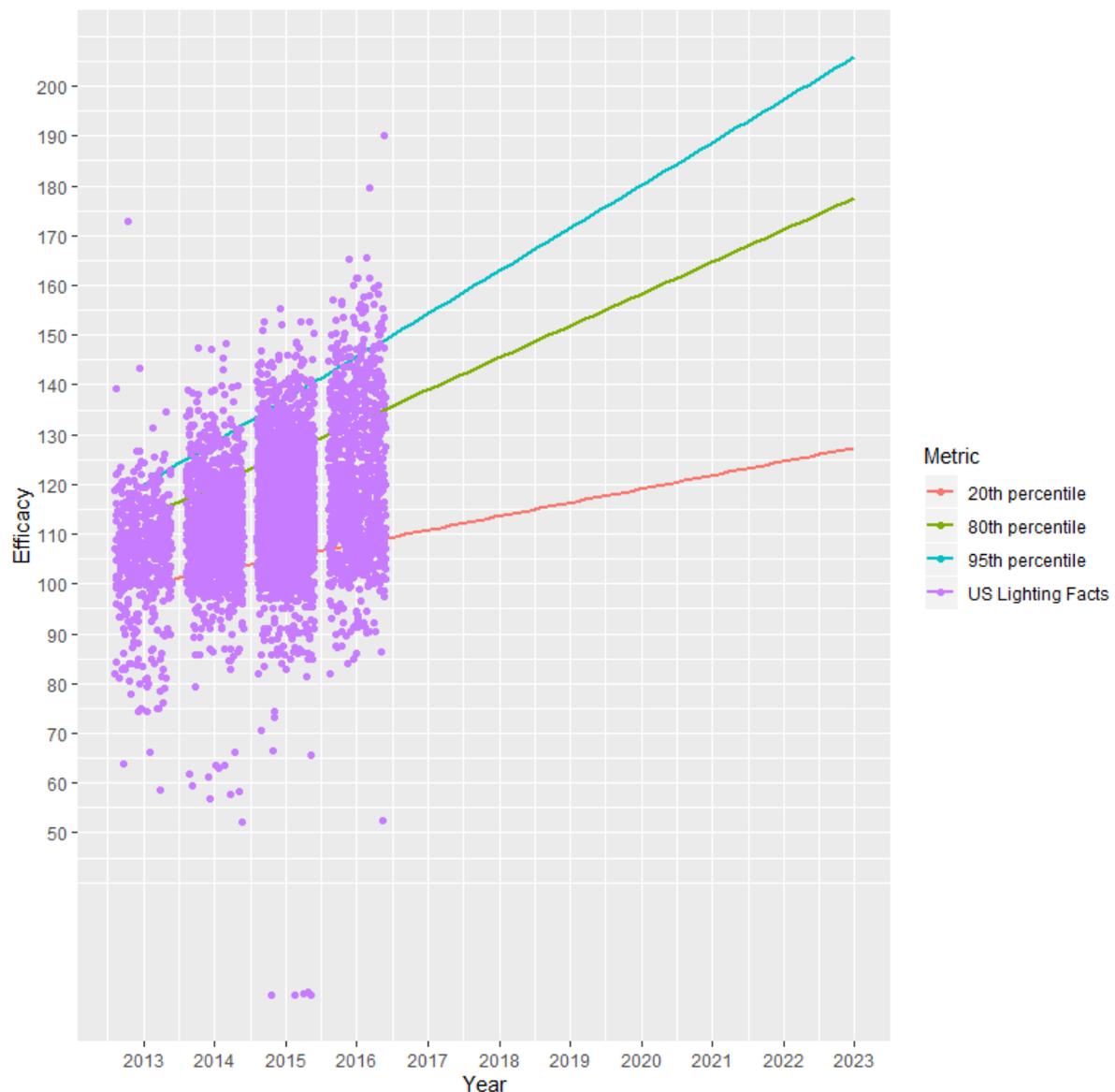


Figure 18: Efficacy trend (in lm/W) projections for 20th, 80th and 95th percentiles based on US Lighting Facts data for Linear LED lamps, (n=4,966)

Again, to validate the projected trends, a comparison was conducted with the most recent available data from other international sources, Figure 19 shows comparison (scatter) data from:

- Australian Market data obtained from a 2017/18 survey of LED lamps available for sale online and in-store – lists 372 linear lamps.
- Design Lights Consortium (DLC) Standard register – lists 30,821 linear LED lamps (active at April 2020). This register has a minimum efficacy requirement.

- Thailand’s Label no.5 Program product register – lists 101 LED tubes (linear lamps), (data download year 2019).

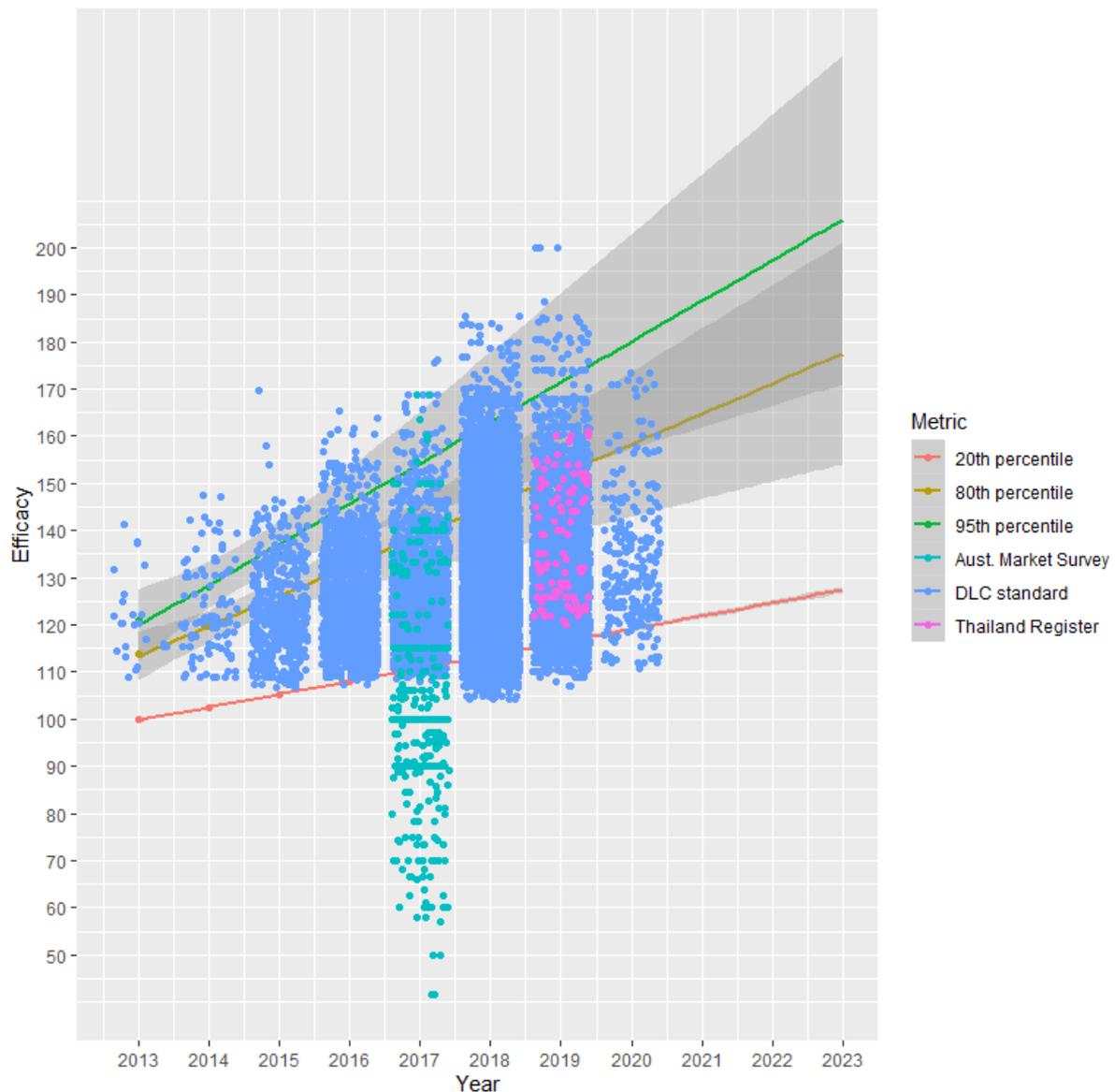


Figure 19: US Lighting Facts-derived efficacy projections (lm/W, shown with 95% confidence interval in grey) , overlaid with market survey and efficient product registry data for linear LED lamps.

In this comparison, we see the DLC standard and Thai Label No.5 register data is consistent with all efficacy projections. The market survey data displays a spread of efficacy, ranging from well below the Tier 1 projection to in-line with and above the Tier 3 projection – again it is noted that this survey would include products which entered the market in years prior to the survey date.

Annex 3 Recommended methods for determining $L_{70}B_{50}$

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 $L_{70}B_{50}$ (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 $L_{70}B_{50}$ 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 $L_{70}B_{50}$

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, $L_{70}B_{50}$, 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.

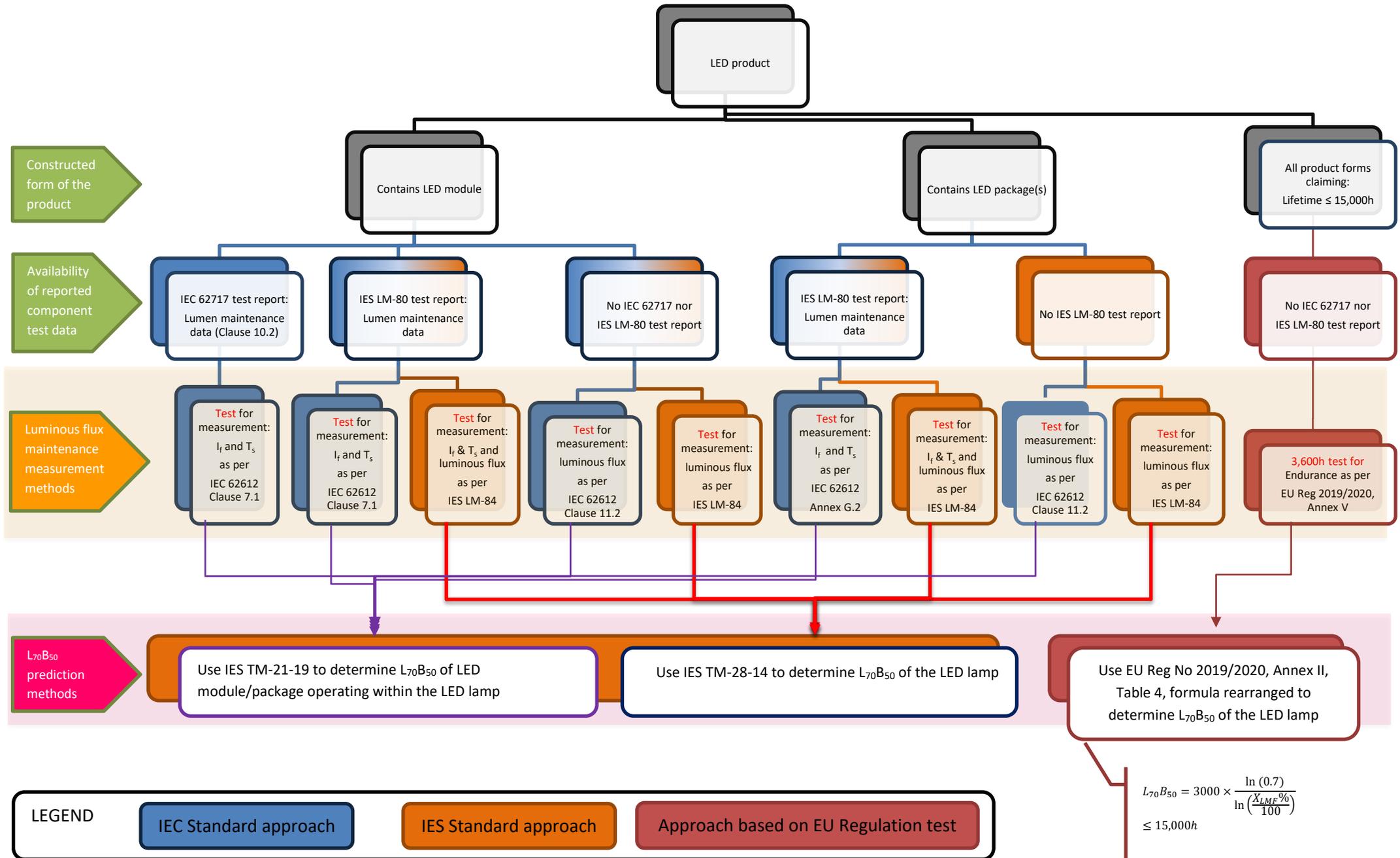
Table 4. Number of Samples Required for Multiplying Factor applying IES TM-28 Calculations to Test Data

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 symbol used for luminous flux maintenance factor after 3,000 hours of operation]



Annex 4 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 025E	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
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 controlgear in phase-cut dimmed lighting systems
IEC/TR 61547-1	Equipment for general lighting purposes - EMC immunity requirements - Part 1: An objective light flickermeter 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-30-18	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