SUSTAINABLE PUBLIC PROCUREMENT

GREEN PUBLIC PROCUREMENT TECHNICAL GUIDELINES AND SPECIFICATIONS FOR ENERGY-EFFICIENT LIGHTING

United Nations Environment Programme – One Planet – Global Environmental Facility | United for Efficiency (U4E)

Green Public Procurement Technical Guidelines and Specifications for Energy-Efficient Lighting

STREET/OUTDOOR LIGHTING AND OFFICE/LARGE BUILDING INDOOR LIGHTING

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACRONYMS AND ABBREVIATIONS

AM	Air mass
CaaS	Cooling as a Service
CCT	Correlated Colour Temperature
CIE	Commission Internationale de l'Éclairage
CRI	Colour Rendering Index
EMC	Electromagnetic compatibility
EPR	Extended producer responsibility
ESM	Environmental Sound Management
GEF	Global Environment Facility
IEC	International Electrotechnical Commission
IES	Illuminating Engineering Society
IK	Impact resistance index
IP	Ingress protection index
ISMT	In-situ temperature measurement test
LaaS	Lighting as a Service
LCC	Life Cycle Cost
LED	Light Emitting Diode
$LiFePO_4$	Lithium iron phosphate (batteries)
LOR	Light Output Ratio
MEPS	Minimum Energy Performance Standards
NDC	Nationally Determined Contributions
NiMH	Nickel-metal hydride (batteries)
PC	Polycarbonate
Pst^{LM}	Short term flicker perceptibility of light
PV	Photovoltaic
SPP	Sustainable Public Procurement
SVM	Stroboscopic Visibility Measure
ULOR	Upper Light Output Ratio
ULR	Upward Light Ratio
UNEP	United Nations Environment Programme
U4E	United for Efficiency
ERP	Extended Producer Responsibility
WEEE	Waste Electrical and Electronic Equipment
WHO	World Health Organization

1 INTRODUCTION

The Public Sector stands out in its capacity to exert enormous purchasing power, representing 12% of GDP in OECD countries and up to 30% in developing countries. This demonstrates the considerable potential for public procurement to be leveraged as a means to drive a Nation's economy towards a greener and more sustainable one.

Public procurement refers to the purchase made by governments, state and semi-state-owned enterprises for goods, services and works. As public procurement accounts for a substantial portion of the taxpayers' money, governments are expected to carry it out efficiently and with high standards of conduct in order to ensure high quality service delivery and to safeguard the public interest[1]. Furthermore, Sustainable Public Procurement (SPP), or Green Public Procurement as it is often also called, allows governments to serve as an exemplary model and send strong market signals so as to achieve multiple benefits such as the reduction of greenhouse gas (GHG) emissions, improved energy security and economic competitiveness, resource efficiency or circularity.

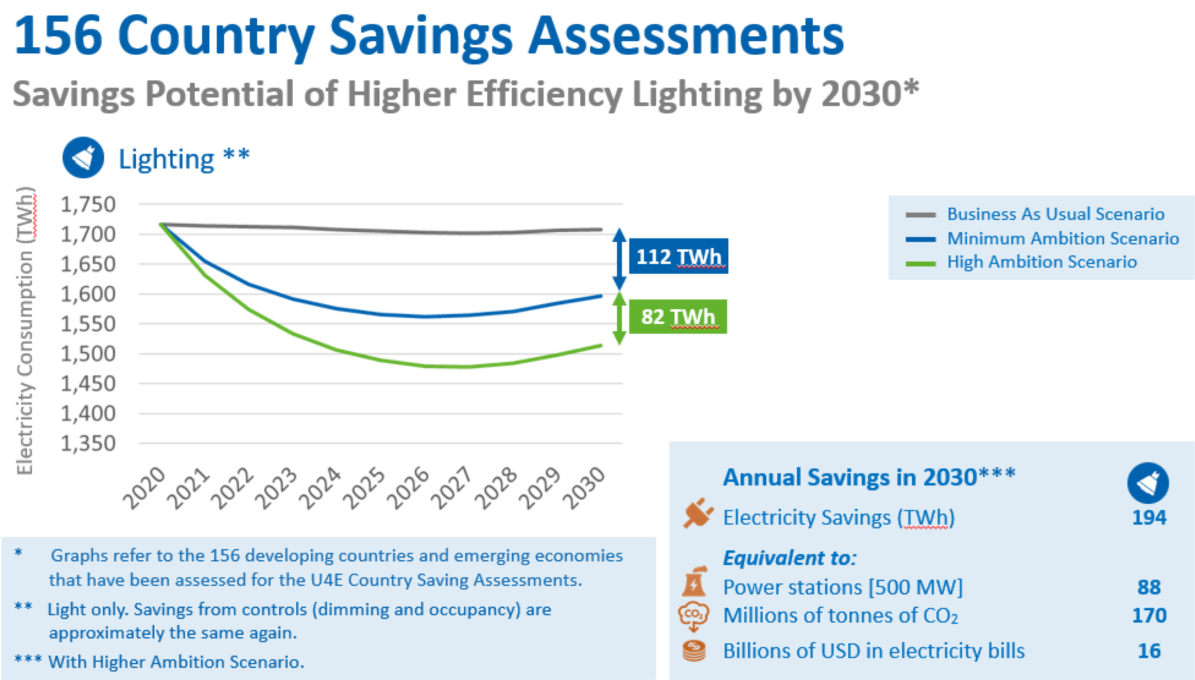
SPP practices have the ability to transform markets by leveraging the power of public purchases to drive markets towards sustainability, reducing governments' environmental footprint and contributing significantly therefore to the achievement of considerable GHG emissions reduction while at the same leading to significant financial savings for state and semi-state entities due to much lower energy consumption.

Stimulating SPP can help gear government spending towards sustainability but also can foster private sector and consumer behaviour change, enabling the overall transition to a green, sustainable economy. By sustainably procuring energy efficient lighting, appliances and electrical equipment, governments and public authorities in general can also impact their countries´ Nationally Determined Contributions (NDC´s) in different ways and intensity, as well as contributing towards achieving the following SDGs: n°7 "Affordable and Clean Energy", n°12 "Responsible Consumption and Production" and n°13 "Climate Action".

Therefore, as a side effect of SPP, markets can be ready to implement more stringent Minimum Energy Performance Standards (MEPS) and eco-design requirements for all lighting and appliances entering the market, leading to more energy savings and reducing the environmental impact. Figure 1 shows the energy consumption and potential energy saving across 156 nations for energy efficient lighting, considering minimum and higher ambition scenarios for minimum energy performance standards (MEPS). Considering only the light source itself (excluding controls), if higher ambition MEPS are implemented, the expected annual energy savings by 2030 are 194 TWh compared to the base case scenario, equivalent to 88 large power plants of 500 MW each and more than USD $16 billion in annual savings. The benefits from modern street light dimming controls and building lighting occupancy controls can further provide the same again in savings.

[1] *https://www.oecd.org/gov/public-procurement/*

Figure 1: Energy consumption and potential energy saving across 156 nations for efficient LED lighting considering minimum and higher ambition scenarios for minimum energy performance standards



(Source: U4E country assessment)

Currently, SPP is not sufficiently embedded in sectoral policies and overarching sustainable development strategies, resulting in a lack of market readiness and response capacity from governments to purchase sustainable and green products and service alternatives. The relatively poor performance of SPP leads in turn to the insufficient leveraging of public procurement which results in:

- Limited market transformation,
- High environmental and social footprints of state actors, and
- Insufficient mitigation of climate change and limited impact on other sustainability objectives.

Against this background, the United Nations Environment Programme (UNEP) United for Efficiency (U4E) initiative, has developed a series of Green Public Procurement Guidelines to provide a set of technical specifications for countries to develop their requirements for procuring higher energy efficient products and thus, complement and strengthen their market transformation processes to more energy efficiency lighting, appliances and equipment. If countries focus on the main electrical products, which are usually procured in large numbers by state and semi-state entities, they can instigate and accelerate the market penetration of high impact electrical products such as lighting, appliances (refrigerators and room air conditioners) and equipment (electric motors and power distribution transformers), products that together represent more than one third of global energy consumption.

This guide includes a step-by-step approach on how to apply sustainability and current best technical criteria for the selected products in accordance with best international regulatory, social and environmental practices and introduces the rationale to be adopted by procurement practitioners when selecting among a set of products.

U4E Green Public Procurement Guidelines are a key strategic instrument intended for public procurers, technical personnel and related officers in the expectation that these recommendations are integrated in their day-to-day procurement activities. They are also intended to address policymaker decisions related to Public Procurement Policy development to support their SPP implementation in the many relevant public institutions, as well as to address those interested in raising awareness of the significant opportunities with Climate Friendly and Energy Efficient purchases.

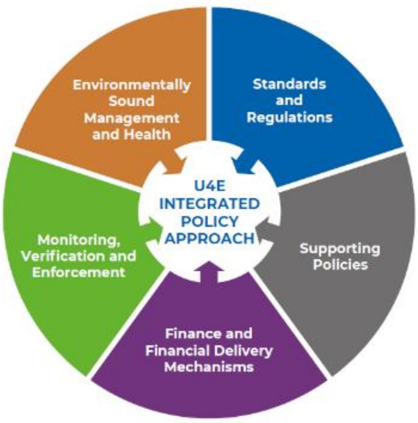
This Green Public Procurement Guideline is a supplement to the U4E Model Regulation Guideline and other already available international tools, standards and reports from the U4E portfolio.

ABOUT UNITED FOR EFFICIENCY

U4E (united4efficiency.org/) is a global initiative led by UNEP, supported by leading companies and organizations with a shared interest in transforming markets for lighting, appliances and equipment, by encouraging countries to implement an integrated policy approach to energy-efficient products so as to bring about a lasting, sustainable and cost-effective market transformation.

The approach focuses on the end-user market and targets the five main components of the value chain for an energy-efficient market:

1. Standards and regulations.
2. Supporting policies, including education, information, and training.
3. Market monitoring, verification and enforcement.
4. Finance and financial delivery mechanisms, including incentives and public procurement.
5. Environmentally sound management and health.



U4E provides countries with tailored technical support through their in-house international experts and specialized partners, to get the most out of countries´ electricity by accelerating the widespread adoption of energy-efficient products, allowing monetary savings on consumer electricity bills, helping businesses to thrive through greater productivity, enabling power utilities to meet growing demands for electricity and assisting governments in reaching their economic and environmental ambitions. Currently the initiative is present in more than 30 countries worldwide. Based on each country's circumstances, U4E works with any of the following products: Lighting, Refrigerators, Room Air Conditioners, Electric Motors and Distribution Power Transformers – the five products that together consume over half of the world's electricity. Such support is available at three levels: Global, Regional and National; providing tools and resources and supporting multiple stakeholders on international best practices, regional policy roadmaps and harmonization process recommendations through guidelines and publications, such as energy efficiency Policy Guides, Global Model Regulations Guidelines, Model Public Procurement Specifications and Financing Guidelines. In addition, the initiative provides capacity building and education, policy tools and technical resources which include Country Savings Assessments completed for more than 155 countries showing the significant available financial, environmental, energy, and societal benefits that are possible with a full transition to more energy-efficient electrical products. This growing suite of tools and resources equips policymakers to understand the significant opportunities and the steps needed to start transforming their markets to eco-efficient appliances and equipment.

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2 SCOPE OF THESE GUIDELINES

This guideline applies to LED lighting technology. LED lighting products that comply with these guidelines are widely available on the world market at reasonable prices and surpass traditional lighting technologies in efficiency, lifetime and reliability.

The scope of lighting product categories includes all office lighting luminaires or sources including LED luminaires and LED tubes and all street lighting luminaires ranging from highway lighting to small street lighting with the exception of 'aesthetic/beautification' and 'artistic/place' lighting.

The recommendations proposed in the following document are based on the following considerations:

- Requirements for all higher performance lighting products should be higher than the Minimum Energy Performance Standards contained in the U4E Model Regulation Guidelines for Lighting[2] as relevant. SPP energy requirements should target products that are above the average efficiency in the market in order to incentivise industry and the market to accelerate the transition to more sustainable technologies. It is recommended that tenders set the energy limits to target around the 20% most efficient lighting in the market.
- Efficiency requirements should be based on the relevant energy label for the products if it exists. The simplest way to set the green procurement efficiency requirement is to use the energy label by targeting the energy efficiency classes with the most efficient products. Some countries use endorsement labels, which can only be used by the most efficient products in the market, e.g. energy star in USA, or PROCEL in Brazil. Endorsement labels are also an easy way to identify the efficient products in the market. Nevertheless, it is recommended that the requirements of the endorsement label are checked to verify they are not obsolete and still target the most efficient products in the market (around the 20% most energy efficient). Otherwise, the labelling system needs to be updated before it could be used in the SPP process.
- Products must be available at a reasonable price for public agencies.

[2] *U4E's Model Regulation Guidelines for Lighting, published in February 2021.*

- *For General Service Lamps: https://united4efficiency.org/resources/model-regulation-guidelines-for-energy-efficiency-and-functional-performance-requirements-for-general-service-lamps/*
- *For Linear Lighting: https://united4efficiency.org/resources/model-regulation-guidelines-for-energy-efficiency-and-functional-performance-requirements-for-linear-lighting/*

These guidelines give a simple set of recommendations on the technical requirements to be considered during the SPP process, to ensure that the overall product and the system installation are efficient.

They address the following technical requirements for LED office/large building lighting and LED street/outdoor lighting (on-grid and off-grid):

- Performance criteria of the luminaire (efficacy, lifetime, photometry).
- Light quality (colour rendering index, correlated colour temperature, flicker, stroboscopic effect).
- Electrical features (operational voltage range, fundamental power factor, standby power, surge protection, harmonic distortion).
- Light control and performance.
- General safety.

These green procurement technical guidelines and specifications aim to facilitate the preparation of tender documents issued by governments, state and semi-state-owned enterprises and also, for Lighting as a Service (LaaS) contracts. LaaS is a service-based business model in which light service is charged on a subscription basis. The consumer (building owner or municipality) doesn't need to invest in the luminaires upfront. Instead, a lighting subscription fee is charged by the provider which covers the implementation, operation and maintenance of the lights for the duration of the contract. The subscription fee may be characterized in terms of illumination level, quality of the light and other parameters. The technical criteria and values recommended in these guidelines are also applicable for LaaS models.

All relevant specified product criteria are already subject to routine test reporting to address the regulatory requirements in the major international markets [such as the European Union and the US markets]. If any of the relevant criteria are not specified in local supplier technical documentation, buyers can also request the details from the manufacturer directly without an additional testing cost implication. The performance values recommended in these guidelines are based on commonly available products in the international lighting market at a reasonable cost. The standards that should be used for testing procedures are also referenced in these guidelines and all standards quoted must be the latest versions available.

Various Minimum Energy Performance Standards criteria, such as those recommended in the U4E Model Regulation Guidelines, are also applicable to the higher performance products under the scope of these guidelines. For example, for LED tubes, the minimum flux level still applies to higher performance level lighting as well as the requirement for compatibility with existing control gear where appropriate.

3 SUMMARY OF PERFORMANCE CRITERIA

3.1 STREET/OUTDOOR LIGHTING

<table>
<tr><th>Performance criteria</th><th>Standard public procurement requirements</th></tr>
<tr><td>Efficacy of the luminaire</td><td><table><tr><th>Power</th><th>< 50 Watt</th><th>≥ 50 Watt</th></tr><tr><td>2023</td><td>130</td><td>150</td></tr><tr><td>2025</td><td>145</td><td>165</td></tr><tr><td>2027</td><td>160</td><td>180</td></tr></table></td></tr>
<tr><td>Lifetime</td><td>30,000 hours for L90B50 (corresponding to 100,000 hours for L70B50)</td></tr>
<tr><td>General safety</td><td>Compliance with IEC 60598-2-3</td></tr>
<tr><td>Photometry distribution</td><td>ULR ≤ 1% or ULOR = 0% for a tilt angle of 0°</td></tr>
<tr><td>Colour rendering index (CRI)</td><td>CRI ≥ 70</td></tr>
<tr><td>Corelated colour temperature (CCT)</td><td>CCT ≤ 5,000 Kelvin</td></tr>
<tr><td>Colour consistency</td><td>Variation of the chromaticity coordinates within a six-step McAdam ellipse</td></tr>
<tr><td>Flicker</td><td>Pst^{LM} ≤ 1.0 at full load and a sinusoidal input voltage</td></tr>
<tr><td>Operational voltage range</td><td>160 VAC to 250 VAC at 50Hz or 60 Hz</td></tr>
<tr><td>Fundamental power factor</td><td>≥ 0.9</td></tr>
<tr><td>Standby power and connected control devices</td><td>≤ 0.15W standby power
≤ 0.15W for connected control devices measured independently</td></tr>
<tr><td>Surge protection</td><td>IEC 61547 standard recommendations</td></tr>
<tr><td>Harmonic distortion</td><td>IEC 61000-3-2: standard</td></tr>
<tr><td>Protection against electrical shock</td><td>Compliance with IEC 60598-2-3</td></tr>
<tr><td>Class of ingress protection</td><td>IP66 (or IP65 where no heavy rain is expected)</td></tr>
<tr><td>Class of impact resistance</td><td>Minimum IK08</td></tr>
<tr><td>Humidity and corrosion</td><td>All luminaires shall be humidity-proof where humid conditions may occur in normal use following the IEC 60598-1 humidity test. ("Luminaires – Part 1: General requirements and tests")</td></tr>
<tr><td>Dimming</td><td>LED lighting should be dimmed by 30% of its nominal flux for at least 4 hours per night (for example from 1 AM to 5 AM). This requirement should be considered in relation to the typical traffic flow for the particular carriageway. Not applicable if the nominal illuminance level is below 1 lux</td></tr>
<tr><td>Installed Illumination Power Density</td><td>≤3 Watts per linear meter per road lane</td></tr>
<tr><td>Warranty</td><td>At least 5 years.
The availability of spare parts should be made mandatory by contract for a 10 year period after the purchase of the street lighting pole</td></tr>
<tr><td>Maintenance</td><td>Luminaire should be maintainable and designed for serviceability, particularly with replaceable control gear and preferably with replaceable LED module</td></tr>
<tr><td>Environmentally Sound Management</td><td>It is recommended that the disbursement of the final contract payment be dependent upon receiving all of the necessary ESM documentation</td></tr>
</table>

3.2 PV SOLAR STREET LIGHTING

Performance criteria	Standard public procurement requirements
Efficacy of the luminaire	2023: ≥ 160 lm/W 2025: ≥ 180 lm/W 2027: ≥ 200 lm/W
Lifetime	30,000 hours for L90B50 (corresponding to 100,000 hours for L70B50)
Lifetime of the photovoltaic module	≥ 25 years at 80% of the rated capacity
Lifetime of the battery	≥ 10 years at 80% of the rated capacity (equivalent to 3,650 charge and discharge cycles or more)
General safety of the luminaire	Compliance with IEC 60598
Battery technology	No lead-based battery
PV peak power	**Peak PV power ≥ 1.2 x P_{lum} x T100% / Irradiance** Peak power: Peak power of the PV in Watt peak (Wp) Plum: Rated power of the luminaire in Watt (W) T100%: time equivalent when luminaire is operating at its rated power in hours
Battery Capacity	**Capacity ≥ 1.85 x P_{lum} x T100%** Capacity: Capacity of the battery in Watt hour (Wh) Plum: Rated power of the luminaire in Watt (W) T100%: time equivalent when luminaire is operating at its rated power in hours (h)
Photometry distribution	ULR ≤ 1% or ULOR = 0% for a tilt angle of 0°
Colour rendering index (CRI)	CRI ≥ 70
Corelated colour temperature (CCT)	CCT ≤ 5,000 Kelvin
Colour consistency	Variation of the chromaticity coordinates within a six-step McAdam ellipse
Flicker	Only if AC operated: PstLM ≤ 1 at full load and a sinusoidal input voltage
Standby power and connected control devices	≤ 0.15W standby power ≤ 0.15W for connected control devices measured independently
Class of ingress protection	IP66 (or IP65 where no heavy rain is expected)
Class of impact resistance	Minimum IK08
Humidity and corrosion	All luminaires shall be humidity-proof where humid conditions may occur in normal use following the IEC 60598-1 humidity test. ("Luminaires – Part 1: General requirements and tests"). The outside metal envelope components of the luminaire should be made of stainless steel or aluminium (sheet, extruded or cast) or die-cast zinc. Iron coated with zinc can be acceptable with special characteristics
Dimming	LED lighting should be dimmed by 30% of its nominal flux for at least 4 hours per night (for example from 1 AM to 5 AM). Not applicable if the nominal illuminance level is below 1 lux
Installed Illumination Power Density	≤3 Watts per linear meter per road lane
Warranty	Minimum of 5 years, including the LED driver, LED module, battery, PV panel and all electronics The availability of spare parts should be made mandatory by contract for a 10 year period after the purchase of the street lighting pole

Performance criteria	Standard public procurement requirements
Maintenance	All technical documentation should contain comprehensive instructions to replace the LED driver, the battery, the battery management system, the solar panel. The appropriate tool(s) must be provided with the street lighting pole. Luminaire should be maintainable and designed for serviceability. The PV panel should be cleaned at least once a year (unless it's sufficiently cleaned by the rain itself) and after every significant sand or wind storm or other relevant metrological event
Theft protection	Battery at the top of the pole in a secured box inside the pole, making it invisible. Fixation of the PV panel to the pole with special anti-theft screws/locks as appropriate
Environmentally Sound Management	It is recommended that the disbursement of the final contract payment be dependent upon receiving all of the necessary ESM documentation

3.3 OFFICES/LARGE BUILDINGS

<table>
<tr><th>Performance criteria</th><th>Standard public procurement requirements</th></tr>
<tr><td>Luminaires:
Minimum efficacy lm/W
by implementation year
(Flux range in Lumen)</td><td><table><tr><th>Flux range</th><th>60≤ Φ< 600</th><th>600 ≤ Φ< 1200</th><th>1200 ≤ Φ</th></tr><tr><td>2023</td><td>110</td><td>120</td><td>130</td></tr><tr><td>2025</td><td>130</td><td>140</td><td>150</td></tr><tr><td>2027</td><td>150</td><td>160</td><td>170</td></tr></table></td></tr>
<tr><td>Retrofit tubes:
Minimum efficacy lm/W
by implementation year</td><td><table><tr><td>2023</td><td>130</td></tr><tr><td>2025</td><td>150</td></tr><tr><td>2027</td><td>170</td></tr></table></td></tr>
<tr><td>Lifetime</td><td>20,000 hours for an L70B50 according to IEC 62717</td></tr>
<tr><td>General safety</td><td>Compliance with IEC 60598</td></tr>
<tr><td>Colour rendering index (CRI)</td><td>CRI ≥ 80</td></tr>
<tr><td>Corelated colour temperature (CCT)</td><td>CCT ≤6,500 Kelvin (maximum)</td></tr>
<tr><td>Colour consistency</td><td>Variation of the chromaticity coordinates within a six-step McAdam ellipse</td></tr>
<tr><td>Flicker</td><td>Pst^{LM} ≤ 1 at full load and a sinusoidal input voltage</td></tr>
<tr><td>Stroboscopic effect</td><td>SVM ≤ 0.4 at full load</td></tr>
<tr><td>Operational voltage range</td><td>160 VAC to 250 VAC at 50Hz or 60 Hz</td></tr>
<tr><td>Fundamental power factor
or displacement factor
(Varies with wattage)</td><td><table><tr><td>P ≤ 5 W</td><td>No limit</td></tr><tr><td>5 W < P ≤ 10 W</td><td>≥ 0.5</td></tr><tr><td>10 W < P ≤ 25 W</td><td>≥ 0.7</td></tr><tr><td>P > 25W</td><td>≥ 0.9</td></tr></table></td></tr>
<tr><td>Standby power and connected control devices</td><td>≤ 0.15W standby power
≤ 0.15W for connected control devices measured independently</td></tr>
<tr><td>Surge protection</td><td>IEC 61547 standard recommendations</td></tr>
<tr><td>Harmonic distortion</td><td>IEC 61000-3-2 standard</td></tr>
<tr><td>Protection against electrical shock</td><td>Compliance with IEC 60598</td></tr>
<tr><td>Class of ingress protection</td><td>IP20 or IP54 in industrial environment</td></tr>
<tr><td>Class of impact resistance</td><td>Minimum IK05 (IK08 for luminaire fixed on the wall)</td></tr>
<tr><td>Humidity and corrosion</td><td>All luminaires shall be humidity-proof where humid conditions may occur in normal use following the IEC 60598-1 humidity test. (“Luminaires – Part 1: General requirements and tests”). The outside metal envelope components of the luminaire should be made of stainless steel or aluminium (sheet, extruded or cast) or die-cast zinc. Iron coated with zinc can be acceptable with special characteristics.</td></tr>
<tr><td>Dimming and occupancy control</td><td>LED lighting should have the capability to be dimmed when daylight is sufficient
LED luminaires should incorporate automatic on/standby occupancy control/presence detection</td></tr>
<tr><td>Installed illumination power density</td><td>< 6 W/m2 of floor area</td></tr>
<tr><td>Warranty</td><td>At least 4 years.
The availability of spare parts should be made mandatory by contract for a 10-year period after the purchase.</td></tr>
<tr><td>Maintenance</td><td>Luminaire should be maintainable and designed for serviceability, particularly with replaceable control gear and preferably with replaceable module</td></tr>
<tr><td>Environmentally Sound Management</td><td>It is recommended that the disbursement of the final contract payment be dependent upon receiving all of the necessary ESM documentation</td></tr>
</table>

4 STREET LIGHTING PROCUREMENT CRITERIA

The main objective for street lighting is to ensure the safety at night for vehicles, cyclists and pedestrians in the streets and roads. Safety for vehicle drivers in this context means the ability to perceive and to take the appropriate action when an object, other vehicle, person or animal will possibly encounter their vehicle. This perception is driven by sight and hearing. Street lighting must maintain the appropriate ability of the driver to see at night. Light sources must provide the correct amount of light on the street or pavement so that the surroundings are clearly visible for safety. For pedestrians, there is an additional requirement which is important for safety perception: the ability to recognize a face at night.

Street lighting is often the responsibility of public local authorities. The standard public procurement technical criteria included here for grid connected lighting as well as autonomous photovoltaic (PV) street lighting will help guide them in fulfilling their responsibilities while consuming the least amount of energy as possible. In the case of PV Street Lighting systems, these include, along with the luminaire, a solar panel to collect the energy of the sun during the day and a battery to store it during the day and restore it to the luminaire at night, when artificial light is needed. The recommended approach is to periodically update SPP energy efficiency requirements, so that only the higher efficiency lighting products and systems are targeted for purchase during the sustainable public procurement processes. SPP energy requirements should target products that are above the average efficiency in the market if they want to incentivize industry and the market to accelerate the transition to more sustainable technologies. It is recommended that tenders set the energy limits to target around the 20% most efficient lighting products and systems in the market.

More efficient products can also be targeted and justified with a life cycle cost analysis (LCC) method, which will account in detail for the initial costs, operational costs and external costs due to CO_2 emissions and other indirect cost savings, hence the higher the energy consumption, the higher the operational costs and emissions. LED technology has proven to be the most efficient technology readily available in the market at reasonable prices. More information on life cycle costs, emissions and examples of technology comparison is given in Annex 3.

The green public procurement energy efficiency and quality requirement parameters proposed for grid connected and photovoltaic solar street/outdoor lighting are outlined in Sections 4.1 and 4.2 respectively. Full definitions of each parameter are given in Annex 1 and a list of the relevant testing standards is given in Annex 2. The environmentally sound management considerations for both forms of street lighting are discussed in Section 4.3.

4.1 GRID CONNECTED STREET LIGHTING

This section describes the energy efficiency and quality requirements for grid connected street lighting.

4.1.1 General safety

This is the requirement for a luminaire to be safe in use or to fail safely if subjected to abnormal conditions. Practically, this means it is required to pass tests that make sure there is no risk of electric shock or fire. This includes mechanical strength and water ingress where specified. Construction details such as spacing between live parts, electrical insulation and thermal limits are all checked and have specific requirements.

IEC 60598 defines both general and particular requirements to ensure safety of a luminaire in use. All luminaires must comply with IEC 60598.

Additionally, the procurement specification must state the required operating temperature in use (ta). This must then be declared and shown on the luminaire.

4.1.2 Efficacy of the luminaire

This efficacy is defined as the lumen output divided by the input power of the luminaire. It takes into account the Light Output Ratio (LOR) of the luminaire, the luminous efficacy of the LED and the electronic control gear efficacy. It is recommended that tenders set the efficacy limits to target around the 20% most efficient lighting products and systems in the market.

Depending on local characteristics, the energy efficiency requirements can be set using one of two options.

Option 1: Energy efficiency labels currently in place – setting the efficiency requirements based on the energy efficiency labels and supported by local market data

The simplest way to set the efficiency requirement is to use the energy efficiency label by targeting the energy efficiency classes with the most efficient products.

If the share of products within the Class is known, one should use the Class to promote the top 20% of the product in the market.

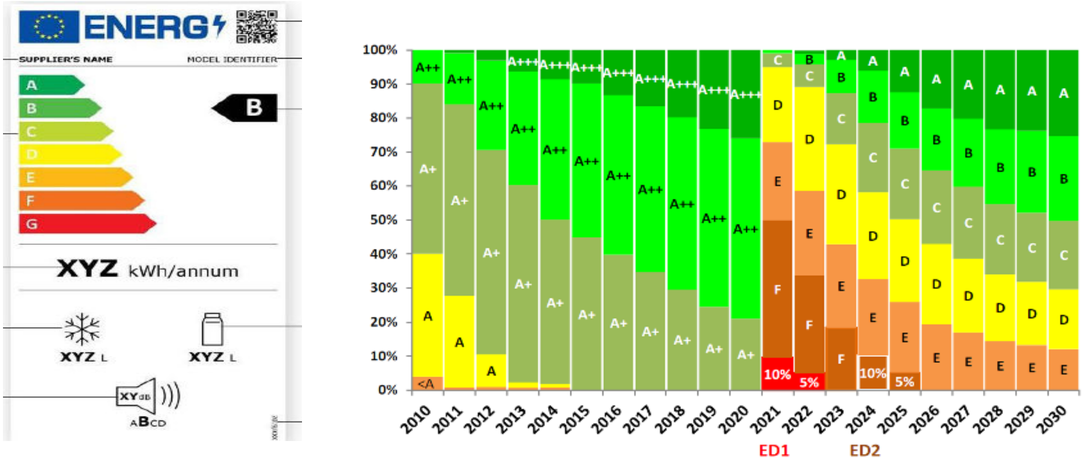
For example, in Figure 2 the models in the Classes A to C are expected to represent around 30% of the market in 2023. Therefore, the requirement could be increased to Class C or higher in 2023. Then, the requirement can be updated again to Class B or higher in 2025 and to Class A in 2028.

Therefore, the energy efficiency requirements for SPP should be updated periodically. This must be considered when setting the legal basis to avoid administrative barriers when updating the minimum efficiency requirements in the future. Otherwise, the requirements might become obsolete in a few years.

Option 2 No energy efficiency labels are available, or they are outdated – setting the efficiency requirements based on energy efficiency international benchmarks

In some countries, an energy efficiency label for street/outdoor lighting is not available, or it is not working effectively (e.g., when the top efficiency class contains more than 30% of the products in the market) or it is outdated (for

Figure 2: Energy efficiency label in Europe (from 2021) and market distribution projected until 2030



(Source: Draft new labelling EU regulation[3])

example, more than 5 years old), making it difficult to use as a reference to distinguish between the most efficient lighting in the market. In this case, the luminaire efficacy requirements for SPP can be set with the help of market data and/or with international best practices efficiency levels (benchmarks). In this case, the local label (if any) cannot be used as a reference and thus, high efficiency levels from other economies can be used as a benchmark to set the SPP requirements. One should note that, in a lower energy efficiency market (or one with relatively higher initial purchase costs for energy-efficient equipment), taking the high efficiency level from other economies as a minimum SPP requirement might be too ambitious. Therefore, the benchmark used should be supported by data gathered directly from the market for the target product, so the requirements are set with an ambitious but realistic limit. In order to fairly compare between international standard levels and the local label if there is one, both should be expressed for the same reference parameters such as type of luminaire and test method (or adjusted for discrepancies).

To clearly reference the maximum luminaire energy consumption requirement for street/outdoor lighting SPP, the minimum benchmark luminaire efficacy recommended is shown in Table 1.

Note that luminaires with power levels higher than 50 Watts are mostly used for roadway lighting. Those with a power lower than 50 Watts are mostly used for amenity lighting with more decorative effects, as well as glare control, which reduces efficacy.

[3] *Draft new EU regulation: COMMISSION DELEGATED REGULATION supplementing Regulation (EU) 2017/1369 of the European Parliament and of the Council with regard to energy labelling of refrigerating appliances and repealing Commission Delegated Regulation (EU) No 1060/2010*

Table 1: Minimum energy efficiency for street/outdoor lighting

Power of the luminaire	Year of implementation		
	2023	2025	2027
< 50 Watts	130 lm/W	145 lm/W	160 lm/W
≥ 50 Watts	150 lm/W	165 lm/W	180 lm/W

4.1.4 Lifetime

The definition of lifetime is crucial to the design of the installation and its maintenance. For street lighting, people can tolerate a gradual decrease of 30% in the light level without noticing. However, when the luminaire emits less than 70% of its initial light level, it should be replaced to maintain a sufficient level of light in the street or road in accordance with the installation design values. Hence, the minimum recommended lifetime required is:

Minimum 100,000 hours for an L70 and B50[4]

The current norms are not made for such lifetime claim. The norm allows measurement up to 6,000 hours with a limit of 6 times for extrapolations (maximum 36,000 hours). Hence a claim verified at 30,000 hours for L90B50 is equivalent.

4.1.5 Photometry distribution

The photometry distribution parameter upward light output ratio (ULOR), is the ratio of the upward luminous flux of the luminaire, measured under specified conditions with its own lamp(s) and equipment, to the sum of the individual luminous fluxes of the same lamp(s) when operated outside the luminaire with the same equipment, under specified practical conditions[5]. Additionally, the ratio known as the upward light ratio (ULR) is simply the proportion of light emitted from the luminaire upwards without reference to flux losses within the luminaire.

The upward luminous flux of the luminaire is not useful for lighting the road or the pavement. It is a direct loss of light and of the energy used to produce that light. It also contributes to light pollution. It should therefore be strictly limited.

The direction of the luminous flux from a luminaire also depends on the tilt angle of the luminaire relative to horizontal. The luminaire technical datasheets usually provide information on the ULOR or ULR of the luminaire for different tilt angles, and at least for a tilt angle = 0° (horizontal mounting). The recommended criteria requirement is:

ULR ≤ 1% for a tilt angle of 0° or
ULOR = 0% for a tilt angle of 0°

4.1.6 Colour rendering index (CRI)

For street lighting the distinction of colours or colour contrast is not as critical as it is for interior environments. The recommended value is aligned with international practices:

CRI ≥ 70

[4] Following IEC 62722-2-1 and IEC 62717 definitions

[5] International Commission of Illumination definition

4.1.7 Correlated colour temperature (CCT)

Light has a different impact on fauna and the flora depending on its colour. Because blue light brightens the night sky more than warmer colours of light, it's important to minimize the amount of blue light emitted. Exposure to blue light at night has also been shown to harm human health and endanger wildlife under certain conditions. The simplest way to limit the blue part of the light emitted by a light source, is to limit its colour temperature. However, low colour temperature can also mean a less efficient light source. A good compromise requirement for street lighting is:

CCT ≤ 5,000 Kelvin

Note: Whenever possible, the **CCT should not exceed 4,000 Kelvin** in order to limit light pollution and its negative impact on fauna and flora.

4.1.8 Colour consistency

Different requirements are used in European regulations for colour consistency (variation of chromaticity coordinates within a six-step MacAdam ellipse or less).

The variation of the chromaticity coordinates of the product shall be within a six-step McAdam ellipse

4.1.9 Flicker

Research on flicker is ongoing and more stringent international values could be set within a few years, however the current international standard requirements recommended are:

Pst^{LM} ≤ 1.0 at full load and a sinusoidal input voltage

4.1.10 Operational voltage range

Due to voltage fluctuations on the electricity grid in developing countries and emerging economies, the operational voltage range of the luminaire should be specified as:

160 VAC to 250 VAC

4.1.11 Fundamental power factor or displacement factor

Street lighting networks can be subject to high voltage fluctuations. Increasing the fundamental power factor can limit the stress on the power supply network. The suggested minimum applicable power factor value is:

≥ 0.9

4.1.12 Standby power and connected control devices (quiescent power consumption)

Street lighting poles are often on the same distribution line. The quiescent power of individual luminaires should be limited to avoid unnecessarily high non-illumination power consumption. The recommended requirement for the quiescent power of individual luminaires is:

Maximum 0.15 Watts allowed for standby power and maximum 0.15 Watts allowed for Connected control devices measured independently

4.1.13 Surge protection

Surge protection is an important parameter to protect the LED equipment, especially for outdoor lighting. It should be noted that the new version of the IEC 61547 standard (2020) includes significant technical changes with respect to the previous edition, notably increased electrostatic discharge and surge test levels for road and street lighting equipment. Luminaires should then comply with the requirements of:

IEC 61547 standard for surge protection.

4.1.14 Harmonic distortion

Harmonic distortions should be limited to avoid unnecessary consumption and disturbance of neighbouring luminaires.

The acceptable limits for harmonic current emissions are as per the IEC 61000-3-2 standard

4.1.15 Protection against electric shock

Street lighting luminaires should be **Class II luminaires according to the definitions in IEC 60598-1**. These are luminaires in which protection against electric shock does not rely on basic insulation only, but in which additional safety precautions such as double insulation or reinforced insulation are provided, there being no provision for protective earthing or reliance upon installation conditions.

4.1.16 Class of ingress protection

For street lighting, a good level of ingress protection for the luminaire is:

IP66

- **Dust-tight (first characteristic IP numeral 6)**
- **Powerful water jet-proof luminaires (second characteristic IP numeral 6)**

No ingress of dust enters the enclosure. Water from heavy seas or water projected in powerful jets shall not enter the enclosure in harmful quantities.

IP65 where no heavy rain is expected

When the gear compartment and the optical system are separated, IP66 should apply to the sealed optic whereas IP54 or higher is sufficient for the gear compartment.

Note: Under certain circumstances, specifying the second characteristic IP numeral at a lower level 5 "jet-proof luminaire" could be sufficient. For testing purposes, this relates to a luminaire subjected to a water flow rate of 12.5 l/min for 15 minutes, which can be sufficient in some places whereas for IP numeral level 6 the luminaire is subjected to a water flow rate of 100 l/min for 3 minutes.

4.1.17 Class of impact resistance

The recommended impact resistance value for street/outdoor lighting is:

Minimum IK08

IK08 is equivalent to the impact of 1.7 kg dropped from a height of 300 mm (equivalent to an impact of 5 joules), which can be sufficient in normal conditions for luminaires placed at a minimum height of 6 meters. IK10 is four times more resistant.

4.1.18 Humidity and corrosion

Humidity

Luminaires should comply with the humidity testing requirements in IEC 60598:1 with the following conditions:

The luminaire is brought to a temperature of 34°C and then directly placed for a continuous period of 48 hours in a cabinet containing air with a relative humidity maintained between 91 % and 95 % and a temperature of 30°C +/-1°C.

After this treatment, the sample shall show no damage affecting compliance with the requirements of this document.

Corrosion

The exposed metallic envelope components of the luminaire should be made of stainless steel or aluminium (sheet, extruded or cast) or die-cast zinc. Cast iron or malleable iron at least 3.2 mm thick can also be used provided it is coated with a minimum of 0.05 mm of zinc on the outside surfaces and with a visible coating of such material on the inside envelope surfaces.

Note: When exposed to an atmosphere containing aggressive chemicals, the optics made from polycarbonate (PC) or acrylic can lose their optical characteristics and mechanical performance.

4.1.19 Dimming

It should be noted that, and according to MEPS in many countries, street lighting luminaires must be dimmable. The following dimming recommendations are proposed:

LED street lighting should be dimmed by 30% of its nominal flux for at least 4 hours per night (as an example from 1 am to 5 am)

Note 1: When the illuminance level is already relatively low, around 1 lux, dimming is not appropriate.

Note 2: Dimming can be enabled for a group of luminaires using just one sensor.

4.1.20 Performance criteria

It is important to have efficient luminaires, but it is also important to have an overall efficient lighting installation. If too many luminaires are installed, unnecessary levels of light are produced with a corresponding unnecessary expenditure on energy. The levels recommended for street lighting are well known and based on standards like the European standard EN 13201[6] and CIE 180 "Road transport lighting for developing countries". The overall light levels can be expressed in terms of illumination (unit: lux) together with the uniformity of the light on the road.

Four types of representative roads were considered for procurement specification analysis:

- Expressways that have a width of 12 meters and four road lanes.
- Provincial and territorial roads with a width of 8 meters and an average 2.7 road lanes.
- Municipal roads of width 6 meters and 2 road lanes.
- Streets of width 4 meters and an average 1.3 road lanes.

For each of these roads, the typical height of the luminaire, spacing and power to obtain the desired illumination and uniformity levels were considered, resulting in:

- *Expressways*: 20 lux, uniformity 0.4.
- *Provincial and territorial roads*: 30 lux, uniformity 0.4.
- *Municipal roads*: 20 lux, uniformity 0.4.
- *Streets*: 15 lux, uniformity 0.4.

The power installed for lighting per linear meter and per road lane along those roads' ranges from 1.7 Watts per meter for provincial and territorial roads to 2.4 Watts per meter for municipal roads.

[6] *Applied in Germany, Austria, England, Ireland, France, Netherlands among others.*

Based on this analysis, a recommended performance requirement limiting the power that can be installed for street lighting to:

A maximum of 3 Watts per linear meter per road lane is proposed

Note 1: When the illumination level is lower than that used for the calculation here, a pro-rata lower limit value can be used.

Note 2: This criterion is key in comparing tenders even if the absolute values cannot be reached.

4.1.21 Warranty

The lifetime of the luminaire is set to at least 50,000 hours in accordance with the parameters and test methods defined in Annex 1.D.

Night is longer during the winter and shorter during the summer. However, as a first approximation we can consider that the total duration of the night-time in one year is equal to 4,380 hours (= 12 x 365).

The minimum lifetime of the luminaire at 50,000 hours (L70B50) is therefore 11.4 years (= 50,000 / 4,380).

A warranty period of 5 years could be reasonably required

The abrupt failure rate at the warranty lifetime (5 years or 22,000 hours) should not exceed 3%. The parameter is then C3 at 22,000 hours.

This warranty should cover all the components of the luminaire, including the control gear and the light source

4.1.22 Maintenance

If available on the market, products with a replaceable module should be preferred along with a guarantee to have spare parts (at least the module, control gears and relevant connectors) available for 10 years or more. Buyers should be able to separately replace the light source and/or the control gear without having to replace the whole luminaire. Luminaires should be maintainable and designed for serviceability.

When the maintenance of the street lighting installation is carried out internally (i.e., by the municipality itself), buyers should also ensure that they get all the necessary technical documentation for maintaining the luminaire and its components. Maintenance should be planned according to the expected lifetime of the luminaire with financial provision made every year to anticipate the requirement to fully replace the luminaires at the end of their useful lifetime.

When the maintenance work is partially or fully externalized (or contracted), buyers should clearly define the verification parameters to be checked to ascertain whether the service provided is satisfactory or not. Measurement of the illuminance on the street and its uniformity are quite simple to check. Their **values should not vary by more than 30% compared to the initial values**. Measurements can be carried out on a periodic base, every two years for example, and contract penalties could be reasonably applied in the case of non-compliance with the maintenance requirements.

4.2 PHOTOVOLTAIC SOLAR STREET LIGHTING

This section describes the energy efficiency and quality requirements for photovoltaic solar street lighting.

4.2.1 General safety

Luminaire

This requirement refers to the safety of the luminaire in normal operational use or for it to fail safely if subjected to abnormal conditions. Practically, it means that the luminaire shall pass test procedures that make sure there is no risk of electric shock or fire, which includes passing mechanical strength and water ingress test requirements where specified. Construction details such as the spacing between live parts, electrical insulation and thermal limits are all to be test checked to meet specific safety requirements. IEC 60598 defines both general and particular requirements to ensure the safety of a luminaire in use.

All luminaires must comply with IEC 60598

Photovoltaic module

For photovoltaic modules (PV modules), general safety requirements refer to the fundamental construction requirements for PV modules in order to provide for safe electrical and mechanical operation. In the relevant norm(s) that need to be complied with for safety, specific parameters are provided for the assessment of the prevention of electrical shock, fire hazards and personal injury due to mechanical and environmental stresses.

Photovoltaic modules should comply with IEC 61730

Battery

For batteries, norm **IEC 63056** specifies the requirements and related tests for the product safety of secondary lithium cells and batteries used in electrical energy storage systems. **IEC 62485-2** provides requirements on the safety aspects associated with the erection, use, inspection, maintenance and disposal of lead-acid and NiCd/NiMH batteries.

4.2.2 Efficacy of the luminaire

This efficacy is defined as the lumen output divided by the input power of the luminaire. It takes into account the Light Output Ratio (LOR) of the luminaire, the luminous efficacy of the LED and the electronic control gear efficacy.

The LED module is supplied with DC current. As the current provided by the battery is also DC, the LED driver used in solar street lighting systems does not have to convert the input current from AC to DC as required in mains grid connected systems. Hence, the minimum efficacy of LED luminaire (module and driver) in solar systems is superior to that of traditional mains powered luminaires with the minimum energy efficiency levels recommended as per Table 2.

Table 2: Minimum energy efficiency for street/outdoor photovoltaic lighting

Year	Efficacy
2023	≥ 160 lm/W
2025	≥ 180 lm/W
2027	≥ 200 lm/W

4.2.3 Lifetime

Luminaire

The definition of lifetime is crucial in the design of the installation and its maintenance. For street lighting, people can tolerate a gradual decrease of 30% in the light level without noticing. However, when the luminaire emits less than 70% of its initial light level, it should be replaced to maintain a sufficient level of light in the street or road in accordance with the installation design values. Hence, the minimum recommended lifetime required for the luminaire is:

Minimum 100,000 hours for an L70 and B50

The current norms are not made for such lifetime claim. The norm allows measurement up to 6,000 hours with a limit of 6 times for extrapolations (maximum 36,000 hours). Hence a claim verified at 30,000 hours for L90B50 is equivalent.

Photovoltaic module

Photovoltaic modules can decrease in efficacy with time. This means that for a same irradiation, less electricity is produced and stored in the battery to supply the luminaire over time.

Lifetime of the photovoltaic module at 80% of the rated capacity should be at least 25 years

Battery

Lifetime of the battery depends on many parameters, such as the depth of discharge, temperature and speed of charging/ discharging.

Lifetime of the battery at 80% of its rated capacity must be 10 years or more (equivalent to 3,650 charge and discharge cycles or more)

4.2.4 Battery technology

The main types of batteries used for solar street lighting applications are lead acid, nickel-metal hydride (NiMH) and lithium iron phosphate ($LiFePO_4$). Of these three types, lead batteries should be prohibited. They are inefficient and bulky, requiring a large volume due to low energy density and small allowed depth of discharge for a minimum lifetime.

Even if lead batteries are usually recycled, lead recycling is an important cause of environmental contamination and human exposure, which is a concern given the long-lasting impacts on human health. Lead is a cumulative toxicant that affects multiple body systems including the neurological, haematological, gastrointestinal, cardiovascular, reproductive and renal systems. Infants and young children are particularly vulnerable to lead exposure and toxicity[7].

Therefore, the battery type must be either nickel-metal hydride (NiMH) or lithium iron phosphate ($LiFePO_4$)

4.2.5 Battery capacity

The battery must have the capacity to store the electricity needed for the luminaire to produce the light required during a certain time at night. Three main parameters must be considered when choosing the battery capacity requirement to meet these electricity needs.

The battery supplies the energy stored with a certain efficacy to the luminaire, typically 90%. It means that 10% of the energy stored is lost in the transfer.

To maintain its operational integrity, the battery must not be discharged to its maximum level. The maximum allowed depth of discharge is around 90%.

The street light must produce light at night even if the battery is not reloaded during the day, due to adverse weather for example. The full autonomy (without any reload) should be a minimum of 1.5 days, meaning the battery fully loaded should have the capacity to provide sufficient electricity during 1.5 days to the luminaire.

$$\textbf{Capacity} \geq 1.85 \times P_{lum} \times T_{100\%}$$

Capacity: Capacity of the battery in Watt hour (Wh).
P_{lum}: Rated power of the luminaire in Watt
$T_{100\%}$: time equivalent when luminaire is operating at its rated power in hours.

4.2.6 Battery C-rate

The battery is designed to be loaded and discharged at a certain speed. It is designed to provide a defined power intensity during a determinate period of time. For solar street lighting applications, the battery must be able to provide the desired power for a duration of 10 hours.

The C-rate must be C10

4.2.7 Peak power of the photovoltaic panel

The photovoltaic panel must be able to provide sufficient power to the battery to meet operational needs, which are defined based on battery capacity and characteristics. The solar PV panel's ability to produce electrical power depends mainly on the irradiance level of the sunlight received, the panels efficacy and size.

In real applications, photovoltaic panels are exposed to dust, moisture or other elements which, when they stay on the PV surface, decrease efficiency. To take account of this decrease and any natural decrease of efficiency over time, the peak PV power specified should be 20% more than the nominal power level required.

Peak power of a solar PV panel is the power produced for standard test condition[8]. Such conditions are an irradiance of 1,000 W/m^2 (1 kW/m^2) of full solar noon sunshine when the panel and cells are at a standard ambient temperature of 25°C with a sea level Air Mass (AM) of 1.5.

$$\textbf{Peak PV power} \geq 1.2 \times P_{lum} \times T_{100\%} / \textbf{Irradiance}$$

[7] Recycling used lead-acid batteries: Brief information for the health sector, World Health Organization (WHO)

[8] Norm IEC 60904-3 Photovoltaic devices – Part 3: Measurement principles for terrestrial photovoltaic (PV) solar devices with reference spectral irradiance data

Peak power: Peak power of the PV in Watt peak (W_p)
P_{lum}: Rated power of the luminaire in Watt (W).
$T_{100\%}$: time equivalent when luminaire is operating at its rated power in hours (h).
Irradiance: mean daily horizontal irradiation (kWh/m^2/day) of the place where it is installed during the worst month.

The average daily horizontal irradiance over one year is an easily available data from different websites[9].

The optimum calculation should be made for a daily average irradiance considering the month with the minimum irradiation, with the solar panel tilted at the best angle to collect direct irradiance during that month. However, as this data is usually not readily available, in the above formula, we consider the average, horizontally and over one year as reasonable for this sizing calculation.

4.2.8 Orientation of the photovoltaic panel

The photovoltaic panel must collect the maximum amount of energy when the need is at its maximum, for example, when night time is at its longest. This occurs during the winter, usually December/January in the northern hemisphere and June/July in the southern hemisphere.

The photovoltaic panel should be oriented south in the northern hemisphere and north in the southern hemisphere, tilted at an angle so that the daylight beam coming from the sun is perpendicular to the photovoltaic panel, so as to optimise daily energy capture.

4.2.9 Maintenance of the PV

The solar PV panel´s ability to collect energy (photons) is dependent on the level of light reaching its conversion surface, so that the panel's PV cells can absorb and convert the available energy from the sunlight. However, this property can be diminished by dust and moisture deposition as the available solar radiation has to pass through the dust layer before reaching the cell. Under certain circumstances such as after a sand/dust/wind/rainstorm, the solar PV panel can lose ca. 10% of its capacity to collect the available solar radiation. To avoid deposition and accumulation of dust and moisture, the PV panel should be cleaned at least once a year (unless it's sufficiently cleaned by the rain itself) and after every significant sand or wind storm or other relevant metrological event. There are many products in the market for cleaning the PV panel surface, but it can be done with just a tissue/cloth and water.

4.2.10 Theft protection

For PV solar street lighting, the photovoltaic panel and the battery can be two elements of interest to criminals. In order to help prevent the battery from being stolen, it is recommended to either:

- Place the battery at the top of the pole (e.g.; just under the PV panel), in a secured box.
- Place the battery inside the pole, making it invisible. This requires a special form factor of the battery in order to fit the shape of the pole.

[9] *https://re.jrc.ec.europa.eu/pvg_tools/en/ or https://natural-resources.canada.ca/maps-tools-and-publications/tools/modelling-tools/retscreen/7465*

Likewise, to help prevent the photovoltaic panel from being stolen, it is recommended that the PV panel be secured with mechanical fixation to a plate that is part of the pole. The fixation of the panel should be made with special anti-theft screws/locks as appropriate.

4.2.11 Warranty and serviceability

The solar lighting pole should have a minimum installation warranty of 5 years. The warranty should cover all components of the street lighting pole, including the LED driver, LED module, battery, PV panel and all electronics.

A warranty period of 5 years could be reasonably required

The street lighting pole must be easily maintained. For that purpose, all technical documentation should contain comprehensive instructions to replace:

- The LED driver
- The battery
- The battery management system,
- The solar panel

All the above parts should be replaceable with standard tools. For the anti-theft fixation kit of the solar panel, the appropriate tool(s) must be provided with the street lighting pole.

Replacement work should be carried out in the event of a defective component or when the battery lifetime has been reached.

The availability of spare parts should be made mandatory by contract for a 10-year period after the purchase of the street lighting pole.

4.3 ENVIRONMENTALLY SOUND MANAGEMENT

The generation of waste originating when purchasing new lighting units to replace old ones must be taken into account during any procurement process. This waste includes:

- The old luminaires that are replaced.
- The new luminaires, which will become waste at the end of their useful life.
- The shipment containers and packaging in which the new luminaires are sent.
- Other accessory products that are part of the lighting system (e.g., lamps, batteries, solar panels, electronic components, etc).

Old luminaires must be managed correctly and, if there is a suitable recycling facility locally available, it should be prioritized as the first preferred disposal option. Environmental considerations for PV solar lighting elements also apply (i.e., PV panels, batteries, etc). At the time of development of the procurement documentation, current relevant environmental legislation, and type of luminaire to be replaced should be main factors to be considered.

The responsibility for the management of used luminaires, PV panels and batteries can be very diverse. If the current applicable legislation provides for an extended producer responsibility (EPR) regime that includes the types of luminaires that are replaced and other elements from the installation, the procurer should require that the seller/supplier be part of an appropriate environmentally sound management system and that they guarantee the correct disposal management of the replaced lamps. If the lamps, PV panel and batteries and any other elements from the street lighting installation are not included in any EPR scheme, the buyer can request as part of the tender criteria, that the seller/supplier take responsibility for the collection and environmentally sound management of the replaced units. Otherwise, the buyer can choose to manage it themselves.

If the buyer chooses to have the disposal management carried out by the seller/supplier of the products as an additional condition of contract, some aspects must be included in the procurement specification to the selling/suppling companies, mainly:

- A reasonable estimate of the number of luminaires by each type to be discarded from the building or street.
- The solutions for recycling/treatment of the various components of the replaced equipment: lamps, luminaires, batteries, photovoltaic panels, other elements from the installation.
- The minimum requirements for the withdrawal of the spent products from service/storage and their subsequent management.
- Verifiable/proven documentation from the seller that shows that the removed luminaires, as well as the mercury they may contain (if applicable) are being managed correctly and that the company in charge of the used/waste product management is an authorized operator.
- Authorized waste manager takes the responsibility of the management of the wastes – a copy of the official permits of the waste manager and the full traceability of the different components to be replaced must be requested.

The minimum proven documents that should be requested, to assess the tracking of the discarded luminaires, lamps and related components/materials, are the certificates of the recycling plants that have received the material and the certificate of the facility in charge of managing the mercury (if applicable). **It is recommended that the disbursement of the final contract payment be dependent upon receiving all the necessary ESM documentation**.

Depending on the type of luminaire, collection and management of used luminaires differs and can be expensive and complex. For instance, incandescent lamps are not dangerous and can be managed within the municipal solid waste system. LED lamps are not dangerous either. The composition of LED lamps is very diverse and resembles that of some other electronic equipment, such as mobile phones. The most important materials, by weight, that make up these luminaires are glass, plastics, ceramics, metals (such as copper), organic compounds, adhesives and electronic components. However, the lamps contain small amounts of valuable products, such as chemical elements (lutetium, cerium or europium), technological metals (gallium and indium) and precious metals (gold and silver). Although the processes to recover these products at an industrial level are under development, it is recommended that they are sent to recycling facilities if these are locally available.

Discharge luminaires, which includes various types of luminaires (e.g., linear fluorescent lamps, compact fluorescent lamps, sodium vapor lamps and discharge lamps that work at high pressure), contain mercury (with the exception of low-pressure sodium vapor lamps), so when discarded they become a hazardous waste.

All luminaires are fragile, so they must be handled carefully to avoid breakage. This contract requirement should be emphasized for lamps that contain mercury, as it is toxic (in order to prevent the mercury from being released into the atmosphere).

For other components, such as batteries and solar panels, a few environmental considerations should be followed. Given that the types of batteries most used in solar public lighting are lead acid, NiMH and $LiFePO_4$ batteries, it is important that, when treating them at their end of life, there is a balance between their technical characteristics and their treatment. Thus, it is important to evaluate whether the battery will be considered hazardous waste or not at the end of its life based the current or planned country legislation. The real challenge is collecting and sorting all the batteries so that recycling facilities, if any, only receive the batteries they can treat. To overcome this problem, it is necessary to separate the batteries according to their chemical composition, which can be achieved by proper sorting at recycling facilities or specialized intermediate warehouses.

Typical solar panel life spans range between 20 and 35 years, and it is recommended to install PV panels with high durability of more than 25 years and to specify those that do not have dangerous/hazardous components or that where any potentially so are minimised. At present, when PVs panels are dismantled, recovery of cabling, aluminium frames and glass is typical. This represents slightly more than 70% by weight of the materials, but the most valuable materials are still far from being recovered. The remaining material can be incinerated, although currently it typically contains silver, copper and silicon, which together account for some two-thirds of the economic value of the most common panel types. Recycling processes can only be paid for if there is funding external to the process itself, such as through an EPR scheme. The possible danger from PV solar panel materials depends on the definition of hazardous waste in the country. Unless there is already specific legislation in place, it is advisable to require the supplier to provide information on the potential danger of the panels offered in the final disposal and handling, specifying the legal framework that is used. Examples of common legal frameworks for the sustainable and sound final disposal of PV products include those applied in the European Union, Japan or United States (e.g., California).

The used luminaires must be collected in specific containers, separating any linear fluorescent lamps from the rest of the lamps to avoid any breakages, including from compact fluorescent lamps. This means collecting them in separate or at least compartmentalized containers. Depending on the specific case, such containers can be requested from the seller/supplier as an additional requirement in the procurement specification. If the number of luminaires justifies it, it is recommended that the luminaire be separated at the source by type, separating those that contain mercury from those that do not. This way, the cost of transportation and treatment of the set of luminaires can be significantly reduced. These collection containers should be installed in a ventilated place to vent any mercury from a broken luminaire.

Regarding the shipment containers and packaging for the new lighting, these must be separated and delivered to a recycler. If an EPR system is in place for these packing materials, the most appropriate option is to deliver the packaging waste directly to the local waste management facility.

Changing to newer lighting technology usually involves changing lamps and/or other accessory products. The used luminaires should be managed without the lamp whenever possible. However, for some luminaires it is very difficult to remove the lamps. If there is any doubt that the lamps are dangerous and/or cannot be removed on-site, the luminaire-lamps fitting should be treated as hazardous waste and must be sent to an appropriate recycler. If an EPR system is in place for the lamps, the most appropriate option is to deliver this waste to the local waste management facility.

Summary of ESM considerations to take into account

1. The entity that acquires the luminaires and rest of elements for the street lighting system must know, before calling the tender, if the relevant waste management legislation incorporates an EPR scheme for the type of waste generated at the time of the acquisition, specifically if the seller/supplier of the luminaire has an obligation to take responsibility for the management and recycling of:

    - The old luminaires.
    - The packaging generated.
    - The lamps.
    - Batteries and solar panels

    If this is the case, the management system to which the seller/supplier is attached for the these products, is responsible for the collection and recycling/treatment. However, the buyer must verify that there are no exceptions in relation to equipment installed before the entry into force of the legislation.

2. If the EPR scheme has not been locally implemented, or does not affect the products, the responsibility for the collection and recycling/management of said products lies with the buyer, as the final holder of the waste. However, the buyer can request appropriate agreement(s) with the manufacturer/seller/supplier for the management of the waste, but the conditions of this agreement must be included in the bidding rules for the acquisition of the new luminaires/related elements.

3. It should be noted that the environmentally appropriate treatment of used luminaires, batteries, PV panels and electronic components can be expensive, and the procurer must take this into account in considering their disposal cost in the offers.

4. For lighting replacement projects, if the luminaires to be replaced are of different types, it is recommended to separate them at source. This can lead to significant savings, particularly if there is a significant percentage of incandescent lamps. Nonetheless, it is not always easy to differentiate between incandescent lamps, LEDs and discharge lamps, in which case all lamps must be treated as if they were discharge lamps. This waste sorting process also applies to batteries and solar panels if applicable to the replacement project.

5. During the tendering process, it is recommended to include provision for the submission and verification of bidder certificates on appropriate EPR scheme membership and separate additional certification stating the destination of the mercury to guarantee its correct disposal (where mercury is relevant).

5 INDOOR LIGHTING PROCUREMENT CRITERIA

Lighting in buildings should complement natural lighting with the aim of providing the appropriate level of visibility of the particular surrounding environment when required. The level of light required for proper visual perception inside a building can be several tens of times higher than that required for outdoor visual perception at night. For example, the desk illuminance level recommended by European standard EN 12464 is 500 lux whereas 10 lux can be sufficient for street lighting.

Indoor lighting in the context of these guidelines encompasses the performance criteria recommended for general lighting in government office buildings and public institutions, such as schools, universities, hospitals or similar. The main objective for the target building group is to provide an adequate and efficient level of general lighting for the people using and working in these types of buildings, including their circulation areas. It does not include specialised task lighting such as surgery lighting.

The recommended approach is to periodically update SPP energy efficiency requirements, so that only higher efficiency lighting products and systems are targeted for purchase during the SPP process. SPP energy requirements should target products that are above the average efficiency in the market if they want to incentivize industry and the market to accelerate the transition to more sustainable technologies. It is recommended that tenders set the energy limits to target around the 20% most efficient lighting products and systems in the market.

More efficient products can also be targeted and justified with a life cycle cost analysis (LCC) method, which will account in detail for the initial costs, operational costs and external costs due to CO_2 emissions and other indirect cost savings, hence the higher the energy consumption, the higher the operational costs and emissions. LED technology has proven to be the most efficient technology readily available in the market with reasonable prices. More information on life cycle costs, emissions and examples of technology comparison is given in Annex 3.

The general performance criteria recommended for indoor lighting are quite similar to those for street/outdoor lighting. However, some of the street/outdoor lighting criteria do not apply, such as the upward lumen output ratio which is not relevant for indoor lighting. Some additional criteria should be included for indoor lighting, such as the stroboscopic visibility measure (SVM), which will be further explained later in this section.

The green public procurement parameters proposed for indoor lighting are outlined in the following sections. Full definitions of each parameter are given in Annex 1 and a list of the relevant testing standards is given in Annex 2.

5.1 ENERGY EFFICIENCY AND QUALITY REQUIREMENTS

5.1.1 General safety

This is the requirement for a luminaire to be safe in use or to fail safely if subjected to abnormal conditions. Practically, this means it is required to pass tests that make sure there is no risk of electric shock or fire. This includes mechanical strength and water ingress where specified. Construction details such as spacing between live parts, electrical insulation and thermal limits are all checked and have specific requirements.

IEC 60598 defines both general and particular requirements to ensure the safety of a luminaire in use. All luminaires must comply with IEC 60598

5.1.2 Efficacy of the luminaire

The efficacy of the luminaire or light source in lumen (measures the amount of light) per Watt (measures the electrical power) increases with the input power. Therefore, higher efficacies are expected with higher power or flux. It is recommended that tenders set the efficacy limits to target around the 20% most efficient lighting products and systems in the market.

Depending on local characteristics, the energy efficiency requirements can be set using one of two options.

Option 1: Energy efficiency labels currently in place – setting the efficiency requirements based on the energy efficiency labels and supported by local market data

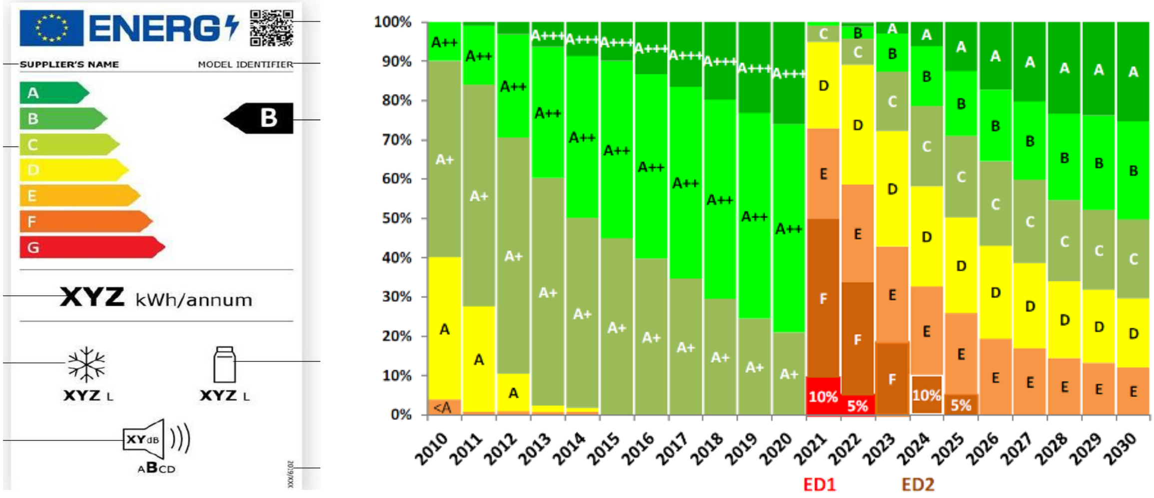
The simplest way to set the efficiency requirement is to use the energy efficiency label by targeting the energy efficiency classes with the most efficient products.

For example, Figure 3 shows the evolution of the energy efficiency classes distribution in Europe with the actual label and with the new label projected from 2021 until 2030. In this case, for the new label, the efficiency Class D or higher are expected to share around 30% of the market in 2021, while C or higher will share around 5% of the market. Therefore, targeting the D efficiency class or higher (Class A, Class B and Class C) would be the SPP requirement for 2021. Taking a minimum efficiency Class of C or higher as a mandatory requirement could be too ambitious, leaving the tender without any bid, or with higher life cycle cost.

However, the number of energy-efficient models is expected to increase in the future. For example, the models in the Classes A to C are expected to represent around 30% of the market in 2023. Therefore, the requirement could be increased to Class C or higher in 2023. Then to Class B or higher in 2025; and to Class A in 2028.

Therefore, the energy efficiency requirements for SPP should be updated periodically. This must be considered when setting the legal basis to avoid administrative barriers when updating the minimum efficiency requirements in the future. Otherwise, the requirements might become obsolete in a few years.

Figure 3: Energy efficiency label in Europe (from 2021) and market distribution projected until 2030



Source: Draft new labelling EU regulation[10]

The same logic used in the previous example to set the SPP efficiency requirement on the European label (A to G) can be applied with any other type of comparative label. For instance, the 5-star label in India, or the percentage of savings label in Mexico. The most important aspect is to know the energy efficiency level in the market so as to set an ambitious, but realistic target for sustainable public procurement.

Some countries use endorsement labels, which can only be used by the most efficient products in the market, e.g., energy star in USA, or PROCEL in Brazil. Endorsement labels are also an easy way to identify the efficient products in the market. Nevertheless, it is recommended to check that the requirements of the endorsement label are not obsolete and to target the most efficient products in the market (around 20%). Otherwise, the label needs to be updated before it could be used in the SPP process. **For new LED luminaires, embedded controls are recommended as mandatory**.

Option 2: No energy efficiency labels are available, or they are outdated – setting the efficiency requirements based on energy efficiency international benchmarks

In some countries, an energy efficiency label for indoor lighting is not available, or it is not working effectively (e.g., when the top efficiency class contains more than 30% of the products in the market) or it is outdated (e.g., more than 5 years old), making it difficult to use as a reference to distinguish between the most efficient lighting in the market. In this case, the luminaire efficacy requirements for SPP can be set with the help of market data and/or with international best practices efficiency levels (benchmarks). In this case, the first option above is that the local label (if any) cannot be used as a reference for SPP and thus, high efficiency levels from other

[10] *Draft new EU regulation: COMMISSION DELEGATED REGULATION supplementing Regulation (EU) 2017/1369 of the European Parliament and of the Council with regard to energy labelling of refrigerating appliances and repealing Commission Delegated Regulation (EU) No 1060/2010*

economies can be used as a benchmark to set the SPP requirements. One should note that, in a lower energy efficiency market (or one with a relatively higher initial purchase costs for energy efficiency equipment), taking the high efficiency level from other economies as a minimum SPP requirement might be too ambitious. Therefore, the benchmark used should be supported by data gathered directly from the market for the target product, so the requirements are set with an ambitious, but realistic, limit.

To fairly compare between international benchmark levels and the local label if one, both should be expressed for the same reference parameters such as type of luminaire and test method (or adjusted for discrepancies). **To clearly reference the maximum luminaire energy consumption requirement for indoor lighting SPP, the current minimum benchmark luminaire efficacy is recommended in Table 3.**

Table 3: Minimum energy efficiency for indoor lighting

Flux bandwidth	Year of implementation		
	2023	2025	2027
60 lm ≤ Φ < 600 lm	110 lm/W	130 lm/W	150 lm/W
600 lm ≤ Φ < 1200 lm	120 lm/W	140 lm/W	160 lm/W
1200 lm ≤ Φ	130 lm/W	150 lm/W	170 lm/W

For reference, Φ is the flux in lumen (lm) of the lamp or luminaire and power is expressed in Watts (W). **For new LED luminaires, embedded controls are recommended as mandatory**.

Note: The U4E 2021 Lighting Model Regulation Guideline[11] for T8 LED luminaires recommends 100 lm/W as the minimum luminous efficacy allowed in the national market [MEPS].

In order to clearly reference the maximum lamp/tube-only energy consumption requirement for indoor lighting SPP (e.g., for retrofit), the minimum benchmark lamp/tube efficacy recommended is in Table 4.

Table 4: Minimum energy efficiency for indoor retrofit lighting

Year of implementation		
2023	2025	2027
130 lm/W	150 lm/W	170 lm/W

[11] *Available at: https://united4efficiency.org/resources/model-regulation-guidelines/*

5.1.3 Lifetime

The definition of lifetime is crucial to the design of the installation and its maintenance. For indoor lighting, people can tolerate a gradual decrease of 30% in the light level without noticing. However, when the luminaire emits less than 70% of its initial light level, it should be replaced in order to maintain a sufficient level of light in accordance with the installation design values. Hence, the minimum recommended lifetime required for indoor lighting is:

Minimum 20,000 hours for an L70 and B50[12]

5.1.4 Colour rendering index (CRI)

For indoor lighting, the distinction of colour is important. International standards usually set the suitable CRI for indoor lighting as:

CRI ≥ 80

Note: In some situations, this requirement can be higher, for example, in industry or technical departments where colour identification is critical.

5.1.5 Correlated colour temperature (CCT)

Colour temperature indoors is less critical for light pollution effect limitation on fauna and flora than for outdoor lighting. However blue light can also damage human health. The simplest way to limit blue light emission by artificial sources is through the colour temperature. Recent studies show that high CCT results in eye fatigue for office lighting[13]. However, low colour temperature can also mean a less efficient light source. The proposed recommended value to adopt as the maximum allowable is the following CCT value or less:

CCT ≤ 6,500 Kelvin

5.1.6 Colour consistency

Different requirements are used in European regulations for colour consistency (variation of chromaticity coordinates within a six-step MacAdam ellipse or less).

The variation of the chromaticity coordinates of the product shall be within a six-step McAdam ellipse

5.1.7 Flicker

Research on flicker is ongoing and more stringent international values could be set within a few years, but the current international standard requirements recommended are:

Pst^{LM} ≤ 1.0 at full load and a sinusoidal input voltage

5.1.8 Stroboscopic effect

Stroboscopic effect is critical for indoor lighting, especially for buildings that host applications with moving parts, which can appear motionless. Therefore, an SVM lower than 1 should be respected. However, products have to be easily available on the market and the recommended requirements for indoor lighting are:

SVM ≤ 0.4 at full load

[12] *Following IEC 62722-2-1 and IEC 62717 definitions*

[13] *"Office Lighting Design in Consideration of eye fatigue and task performance" Lin, C.W. CIE 2018 Conference on Smart Lighting.*

5.1.9 Operational voltage range

Due to voltage fluctuations on the electricity grid in developing countries and emerging economies, the operational voltage range of the luminaire should be specified as:

160 VAC to 250 VAC

5.1.10 Fundamental power factor or displacement factor

Indoor luminaires usually operate at lower power than, for example, the ones for outdoor lighting. Their potential contribution to power factor disturbances on the network will then be lower and therefore, a lower displacement factor can be tolerated. The suggested minimum applicable power factor values are in Table 5.

Table 5: Fundamental power factor for indoor lighting

Rated Input Power P in W	Fundamental Power Factor
P ≤ 5 W	No limit
5 W < P ≤ 10 W	≥ 0.5
10 W < P ≤ 25 W	≥ 0.7
P > 25W	≥ 0.9

5.1.11 Standby power and connected control devices (quiescent power consumption)

The quiescent power of the luminaire when no light is emitted should be limited to:

Maximum 0.15 Watts allowed for standby power and maximum 0.15 Watts allowed for connected control devices measured independently

5.1.12 Surge protection

Surge protection is an important parameter to protect the LED equipment, both for indoor as well as for outdoor lighting. The luminaire should comply with the requirements of the:

IEC 61547 standard

5.1.13 Harmonic distortion

Harmonic distortions should be limited to avoid unnecessary consumption and electrical disturbances. The luminaire should comply with the requirements of the:

IEC 61000-3-2 standard

5.1.14 Protection against electric shock

Indoor luminaires should be **Class I luminaires according to the definitions in IEC 60598-1**. These are luminaires in which protection against electric shock does not rely on basic insulation only, but in which additional safety precautions such as double insulation or reinforced insulation are provided, there being no provision for protective earthing or reliance upon installation conditions.

5.1.15 Class of ingress protection

For indoor luminaires, a good protection level for the office/large building environment is:

IP20

This enclosure class provides protection against fingers or similar objects not exceeding 80 mm in length and solid objects exceeding 12 mm in diameter. There is no special protection against water.

Note: For technical departments in municipalities for example, IP54 should be specified to provide protection against dust and splashing water.

5.1.16 Class of impact resistance

The recommended impact resistance value for most indoor applications is:

Minimum IK05

IK05 is equivalent to the impact of 0.2 kg dropped from a height of 350 mm (equivalent to an impact of 0.7 joules), which is sufficient in normal conditions for luminaires in office buildings.

Note: **For luminaires fixed on the wall or similar, IK08 should be specified** in order to provide adequate protection against impact (tested for 5 joules).

5.1.17 Humidity and corrosion

Humidity

Luminaires should comply with the IEC 60598:1 standard for humidity testing with the following conditions:

The luminaire is brought to a temperature of 34°C and then directly placed for a continuous period of 48 hours in a cabinet containing air with a relative humidity maintained between 91 % and 95 % and at a temperature of 30°C+/-1°C.

After this treatment, the sample shall show no damage affecting compliance with the requirements of the IEC 60598:1 standard.

Corrosion

The exposed metallic envelope components of the luminaire should be made of stainless steel or aluminium (sheet, extruded or cast) or die-cast zinc. Cast iron or malleable iron at least 3.2 mm thick can also be used coated with a minimum of 0.05 mm zinc on the outside surfaces and a visible coating of such material on the inside surface.

Note: The recommendations are similar to outdoor lighting as humidity and temperature can be the same inside a building as outside.

5.1.18 Dimming and occupancy controls

Daylight sensors

Natural lighting is sometimes sufficient during daytime for some particular tasks. When it is not sufficient, artificial light can complement it to reach the appropriate level of light. Some LED luminaires can be dimmed according to the level of natural light. Some even have a daylight sensor embedded.

LED lighting should be dimmed when daylight is sufficient.

The daylight sensor has a given viewing angle. For a traditional ceiling height of 2.8 meters, the area within the viewing angle is about 35 square meters. If not embedded in the luminaire, the sensor must collect the light coming from the area to be lit. Indeed, if the sensor is too close to the window, the sensor will detect a relatively high level of natural light and any dimmed artificial lighting may not compensate for the lighting needed at the back of the space when the natural light there is not sufficient. The opposite occurs if the detector is too far away from any source of natural light and the artificial light will remain switched on fully or at too high a dimmed level. The optimum solution depends a lot on the geometry of the room but as a rule of thumb:

If the building floor space area (in which the natural light level determines the level of artificial lighting) is larger than 30 square meters, more than one daylight sensor should be used to appropriately control the level of artificial light (whether embedded in the luminaire or not).

Occupancy controls

Occupancy controls, which are used to detect the presence of a person so as to automatically turn the lighting on and off, can lead to more than a 50 % energy savings in some spaces such as corridors, restrooms, meeting rooms, storage areas and garages.

Indeed, these detectors can significantly reduce energy consumption and should be considered for inclusion in the specifications wherever possible and relevant. Presence detection is achieved through infrared detection or motion detection. Some detectors are now embedded in the luminaire as standard or can be as an option, especially in LED luminaires.

The advantage of modern LED luminaires with built-in occupancy control, is their ability to employ presence and daylight sensing to easily save energy by using artificial light only when and where it is needed, and without the need to have to carefully place separate detectors and to design the wiring system to control the right group of luminaires.

Note: Placement of sensors is a complex topic and it is recommended that further information and guidance be requested from manufacturers/suppliers to help ensure appropriate operation for the task/environment.

5.1.19 Performance criteria

It is important to have efficient luminaires, but it is also important to have an overall efficient lighting installation. If too many luminaires are installed, unnecessary levels of light are produced with the corresponding unnecessary expenditure on energy. This can be limited in order to promote an efficient total number of luminaires by restraining the maximum power installed by the floor area (square metres, m2) of the room. The recommended overall performance requirement for the installation or project, limiting the power that can be installed for indoor lighting, is:

< 6 Watts/m^2 of floor area for each place

Note 1: That is equivalent to a maximum power density of 2 Watts/m^2/100 lux for an illuminance of 300 lux.

Note 2: This criterion is key in comparing tenders even if the absolute value cannot be reached.

5.1.20 Warranty

The lifetime of the luminaire is set to at least 20,000 hours in accordance with the parameters and test methods in Appendix 1.B.

Standard EN 15193 specifies the annual operating time of lighting in offices to be taken as 2,543 hours.

The minimum lifetime of the luminaire at 20,000 hours (L70B50) is therefore 7.9 years (= 20,000/2,543).

A warranty period of 4 years could be reasonably required.

The abrupt failure rate at the warranty lifetime (4 years or 10,000 hours) should not exceed 3%. The parameter is then C3 at 10,000 hours.

This warranty should cover all the components of the luminaire, including the control gear and the light source.

5.1.21 Maintenance

If available on the market, **products with a replaceable module should be preferred along with a guarantee to have spare parts (at least the module, control gears and relevant connectors) available for 10 years**. Buyers should be able to replace the light source and/or the control gear only without having to replace the whole luminaire. Luminaires should be maintainable and designed for serviceability. When the maintenance of the lighting installation is carried out internally (i.e., by the municipality or by the building owner themselves), buyers should also ensure that they get all the necessary technical documentation for maintaining the luminaire and its components. Maintenance should be planned according to the expected lifetime of the luminaire with financial provision made every year to anticipate the requirement to fully replace the luminaires at the end of their useful lifetime.

When the maintenance work is partially or fully externalized (or contracted), buyers should clearly define the verification parameters to be checked to ascertain whether the service provided is satisfactory or not. Measurement of the illuminance on the desk or on the floor and its uniformity are quite simple to check. Their values should not vary by more than 30% compared to the initial values. Measurements can be carried out on a periodic base, every two years for example, and contract penalties could be reasonably applied in the case of non-compliance with the maintenance requirements.

5.2 ENVIRONMENTALLY SOUND MANAGEMENT

The generation of waste that originates when purchasing new lighting units to replace old ones must be taken into account during any procurement process. This includes:

- The old luminaires that are replaced.
- The new luminaires, which will become a waste at the end of their useful life.
- The shipment containers and packaging in which the new luminaires are sent.
- Other accessory products that are part of the luminaires (e.g., lamps).

Old luminaires must be managed correctly and, if there is a suitable recycling facility locally available, it should be prioritized as the first preferred disposal option. At the time of development of the procurement documentation, current relevant environmental legislation and type of luminaire to be replaced should be main factors to be considered.

The responsibility for the management of used luminaires can be very diverse. If the current applicable legislation provides for an extended producer responsibility (EPR) regime that includes the types of luminaires that are replaced, the procurer should require that the seller/supplier be part of an appropriate environmentally sound management system and that they guarantee the correct disposal management of the replaced lamps. If the lamps are not included in any EPR scheme, the buyer of the lamps can request, as part of the tender criteria, that the selling/suppling company take responsibility for the collection and environmentally sound management of the replaced units. Otherwise, the buyer can choose to manage it themselves.

If the buyer chooses to have the disposal management of the used luminaire carried out by the seller/supplier of the products as an additional condition of contract, some aspects must be included in the request for offers to the selling/suppling companies, mainly:

- A reasonable estimate of the number of luminaires by each type to be discarded from the building or street.
- The minimum requirements for the withdrawal of the spent products from service/storage and their subsequent management.
- Verifiable/proven documentation from the seller that shows that the removed luminaires, as well as the mercury they may contain (if applicable) are being managed correctly and that the company in charge of the used/waste product management is an authorized operator.

The minimum proven documents that should be requested, in order to assess the tracking of the discarded luminaires, lamps and related components/materials, are the certificates of the recycling plants that have received the material and the certificate of the facility in charge of managing the mercury (if applicable). **It is recommended that the disbursement of the final contract payment be dependent upon receiving all of the necessary ESM documentation**.

Depending on the type of luminaire, collection and management of used luminaires differs and can be expensive and complex. For instance, incandescent lamps are not dangerous and can be managed within the municipal solid waste system. LED lamps are not dangerous either. The composition of LED lamps is very diverse and resembles that of some other electronic equipment, such as mobile phones. The most important materials, by weight, that make up these luminaires are glass, plastics, ceramics, metals (such as copper), organic compounds, adhesives and electronic components. However, the lamps contain small amounts of valuable products, such as chemical elements (lutetium, cerium or europium), technological metals (gallium and indium) and precious metals (gold and silver). Although the processes to recover these products at an industrial level are under development, it is recommended to send them to recycling facilities if these are locally available.

Discharge luminaires, which includes various types of luminaires (e.g., linear fluorescent lamps, compact fluorescent lamps, sodium vapor lamps and discharge lamps that work at high pressure), contain mercury (with the exception of low-pressure sodium vapor lamps), so when discarded they become a hazardous waste.

All luminaires are fragile, so they must be handled carefully to avoid breakage. This contract requirement should be emphasized for lamps that contain mercury, as it is toxic (in order to prevent the mercury from being released into the atmosphere).

The used luminaires must be collected in specific containers, separating the linear fluorescent lamps from the rest of the lamps to avoid any breakages, including from compact fluorescent lamps. This means collecting them in separate or at least compartmentalized containers. Depending on the specific case, such containers can be requested from the seller/supplier as an additional requirement in the procurement specification. If the number of luminaires justifies it, it is recommended that the luminaire be separated at the source by type, separating those that contain mercury from those that do not. This way, the cost of transportation and treatment of the set of luminaires can be significantly reduced. These collection containers should be installed in a ventilated place to vent any mercury from a broken luminaire.

Regarding the new lighting shipment containers and packaging, these must be separated and delivered to a recycler. If an Extended Producer Responsibility system is in place for these packing materials, the most appropriate option is to deliver the packaging waste directly to the local waste management facility.

Changing to newer lighting technology usually involves changing lamps and/or other accessory products. The used luminaires should be managed without the lamp whenever possible. However, for some luminaires it is very difficult to remove the lamps. If there is any doubt that the lamps are dangerous and/or cannot be removed on-site, the luminaire-lamps fitting should be treated as hazardous waste and must be sent to an appropriate recycler. If an EPR system is in place for the lamps, the most appropriate option is to deliver this waste to the local waste management facility.

Summary of ESM considerations to take into account

1. The entity that acquires the luminaires must know, before calling the tender, if the relevant waste management legislation incorporates an EPR scheme for the type of waste generated at the time of the acquisition of the new luminaires, specifically, if the seller/supplier of the luminaire has an obligation to take responsibility for the management and recycling of:

    - The management and recycling of the old luminaires.
    - The packaging generated.
    - The lamps.

    If this is the case, it will be the management system to which the seller/supplier is attached for the aforementioned products, which is responsible for the collection and recycling/treatment. However, the buyer must verify that there are no exceptions in relation to equipment installed before the entry into force of the legislation.

2. If the EPR scheme has not been locally implemented, or does not affect the products, the responsibility for the collection and recycling/management of said products lies with the buyer of the new luminaire, as the final holder of the waste. However, the buyer can request appropriate agreement(s) with the manufacturer/seller/supplier for the management of the waste, but the conditions of this agreement must be included in the bidding rules for the acquisition of the new luminaires.

3. It should be noted that the environmentally appropriate treatment of used luminaires can be expensive, and the procurer must take this into account in considering their disposal cost in the offers.

4. For lighting replacement projects, if the luminaires to be replaced are of different types, it is recommended to separate them at source. This can lead to significant savings, particularly if there is a significant percentage of incandescent lamps. Nonetheless, it is not always easy to differentiate between incandescent lamps, LEDs and discharge lamps, in which case all lamps must be treated as if they were discharge lamps.

5. During the tendering process, it is recommended to include provision for the submission and verification of bidder certificates on appropriate EPR scheme membership and separate additional certification stating the destination of the mercury to guarantee its correct disposal (where mercury is relevant).

Annex 1. Definitions

A. General safety

The safety of Luminaires is defined by the international standard IEC 60598. Part 1 defines general safety and Part 2 defines particular requirements for different types of luminaires, such as, fixed general purpose luminaires (Part 2-1), recessed luminaires (Part 2-2) and road/street luminaires (Part 2-3). This standard makes sure the luminaire is safe to use, detailing requirements to protect against electric shock, it also has thermal, endurance and constructional requirements such as test for ingress protection (vital for outdoor luminaires to test for water ingress). This is accepted by over 60 countries worldwide.

B. Rated maximum ambient temperature

Temperature assigned to a luminaire by the manufacturer ta to indicate the highest sustained temperature in which the luminaire may be operated under normal conditions.

Note 1: This does not preclude temporary operation at a temperature not exceeding (ta + 10)°C.
Note 2: If not specified, the default value is 25°C.

C. Efficacy of the luminaire

Light sources are enclosed in a luminaire that protects them from shock and humidity and can help directing the light coming out from the light source to the space that has to be lit. A small part of the light produced by the light source can be trapped and absorbed inside the luminaire. The optical efficiency of the luminaire, known as the "Light Output Ratio" (LOR) of the luminaire is defined as the ratio of the light output of the luminaire and the light emitted by the individual light source(s), is noted as LOR that ranges from 60% for some discharge lamp luminaires to nearly 100% for LED luminaires. Indeed, discharge lamps are emitting light in all direction and reflection inside the luminaire cannot be avoided whereas planar LED modules are emitting light in one plane and reflection is not necessary to redirect light downward. However, some optical control is essential for the correct photometric output which also has some loses. The luminous flux of a light source is the amount of light produced and is measured in lumen (lm).

$$LOR = \frac{Luminous\ flux\ of\ the\ luminaire}{Luminous\ flux\ produced\ by\ the\ light\ source(s)}$$

LED luminaires have a typical efficiency of 95% (LOR).

The light source is transforming the electrical power (unit: watts, W) into light. Its luminous efficacy is measured in lumen per watt (lm/W). It ranges from 50 lm/W for compact fluorescent lamps and high-pressure mercury lamps used for street lighting to 160 lm/W for the best LED sources.

$$\eta = \frac{Luminous\ flux\ produced\ by\ the\ light\ source(s)}{Electrical\ power\ consumed\ by\ the\ light\ source}\left[\frac{lumen}{watt}\right]$$

LED light sources have a typical efficiency higher than 100 lm/W.

The power consumed by the light source can be different from the power consumed by the luminaire due to any separate driver (also known as "control gear") used with the light source and other electronic equipment (e.g., light sensor, RF communication). The electrical network cannot directly supply a non-integrated LED light source requiring a driver to be inserted between the power network and the LED light source. This driver and other possible electronic equipment also have an efficiency factor (η_{elec}) in converting the input power into useful power for the light source. Electronic control gears have efficiency ranges from 80% for old ferromagnetic ballasts used for an example with T8 fluorescent tubes to 98% for the best electronic control gear.
The electrical efficiency is expressed as:

$$\eta_{elec} = \frac{Power\ consumed\ by\ the\ light\ source}{Power\ consumed\ by\ the\ luminaire}$$

LED electronic control gear has an efficiency of typically around 95%.

It should be noted that the control gear is embedded inside most LED tubes, in contrast to fluorescent tubes which require an external electronic control gear. The efficacy of LED tubes given in the technical specifications' datasheet takes into account the control gear.
Luminous efficacy of the luminaire (η_{lum}) is defined as the quotient of the **total luminous flux** going out of the luminaire by the **power consumed**:

$$\eta_{lum} = \eta_{elec} * \eta * LOR$$

It is an expression of how energy efficient a luminaire is (lm/W). The higher the efficacy value, the more energy-efficient the lighting product. LEDs are more efficient in converting the electrical power received into light when the electrical power is high.

→ **Testing should be conducted according to CIE S 025.**

D. Lifetime

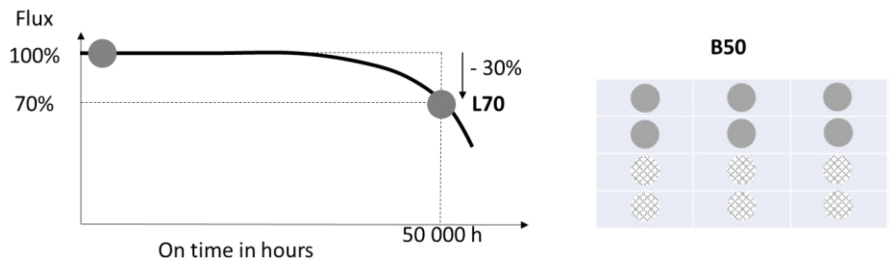
This is the total time for which a light source (i.e., lamp or integrated luminaire) has been operated before it becomes useless, or is considered to be so, according to specified criteria. Lifetime is usually expressed in hours and as the time at which half of the lamps (the median) are expected to have failed or become useless in providing the intended service, having dropped to 70% of its initial luminous flux. The variable used for this metric is L70B50 (time when 50% of samples have dropped to ≤ 70% luminous flux maintenance).

→ **50,000 hours for a L70B50**[14]

This is shown diagrammatically in Figure 4.

[14] *Following IEC 62722-2-1 and IEC 62717 definitions*

Figure 4: Lifetime $L_{70}B_{50}$



Note: For luminaires with the constant light output function[15], lifetime should be given as if this functionality is not active to avoid any over consumption due to increase of the current to compensate the light output depreciation.

This lifetime parameter can be tested in two different ways depending on whether tests are conducted on the module outside of the luminaire or on the luminaire itself:

Module outside of the luminaire

Apply the ANSI/IES standard ANSI/IES LM-80-20 "Approved method: Measuring Luminous Flux and Colour Maintenance of LED Packages, Arrays and Modules" to test the module until at least the 6,000 hours level is reached.

Then apply the standard ANSI/IES TM-21-21 "Technical Memorandum: Projecting Long Term Luminous, Photon and Radiant Flux Maintenance of LED Light Sources" to extrapolate the measurements.

It should be noted that the validity of the extrapolation method relies on the measured values of the LED chip drive current and junction temperature (measured by the in-situ temperature measurement test, ISMT) of the module when situated within the luminaire. Details are provided in IES TM 21-19.

Measurement of the luminaire

The method in ANSI/IES LM-84-20 "Approved method: Measuring Optical Radiation maintenance of LED lamps, light engines, and luminaires" can be applied directly to the luminaire until at least the 6,000 hours level is reached. A combination of an ANSI/IES LM-80-20 tests report and ANSI/IES LM-84-20 test data for as little as 3,000 hours can also be used.

Then apply the standard ANSI/IES TM-28-20 "Approved method: Projecting long term luminous flux maintenance of LED lamps and luminaires" to extrapolate the measurements from either method.

Abrupt or catastrophic failures

A critical part can fail to cause an LED luminaire to stop generating light altogether (catastrophic failure). Examples include a power supply failure, corrosion of an electrical connection that stops the electrical flow to critical components, or breakage of a critical part due to vibrations or stresses beyond what the luminaire can handle. This is denoted by the Cy factor where y is the percentage failed catastrophically at C hours[16].

[15] *Function where the current passing through a LED module is gradually increased through life to compensate for the gradual light output degradation of the LED module that could be expected to occur.*

[16] *Following IEC 62722-2-1 and IEC 62717 definitions*

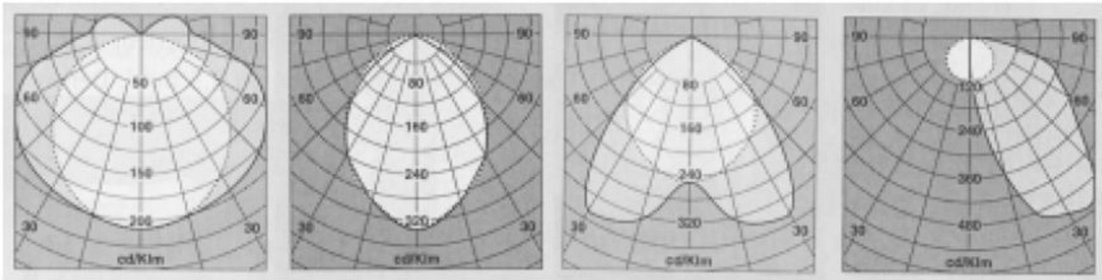
E. Distribution

The luminaire photometry distribution is its ability to direct the light from the source in the desired direction. For every luminaire, the manufacturer specifies its polar luminous intensity graph. That diagram illustrates the distribution of luminous intensity, in candelas, of the luminaire. This curve provides an intuitive indication of the light distribution expected from the luminaire (e.g., wide, narrow, direct, indirect) as well as its intensity for different directions used for lighting design.

→ **The standard for measurement is CIE S 025.**

Figure 5 shows the luminous intensity distribution for four types of luminaires.

Figure 5: Luminous intensity distribution for four types of luminaires



For street lighting, two parameters are used to limit the flux emitted upward the luminaire (not used for general lighting).

ULR stands for upward lumen ratio of the luminaire(s) and is defined as the proportion of the flux of a luminaire or installation that is emitted, at and above the horizontal, when the luminaire(s) is (are) mounted in its (their) installed position.

ULOR stands for upward lumen output ratio of the light sources and is defined as quotient of the upward luminous flux of a luminaire, measured under specified conditions with its own lamp(s) and equipment, and the sum of the individual luminous fluxes of the same lamp(s). This means ULOR includes the light losses within the luminaire whereas ULR does not.

→ **The difference between those parameters is the light losses within the luminaire and their relation defines the efficacy of the luminaire.**

$$\textbf{ULOR = ULR x efficacy of the luminaire } (\eta_{lum})$$

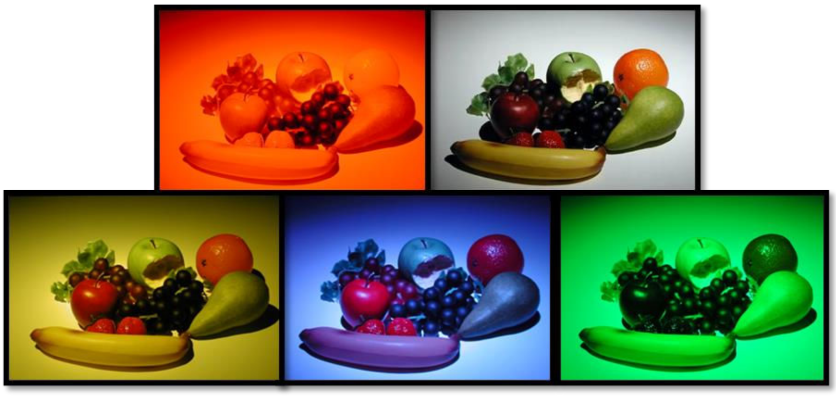
F. Colour rendering index (CRI)

CRI is a measure of the ability of a light source to accurately reveal the colours of various objects in comparison with an ideal or natural light source. Its value ranges from 0 (no colour) to 100 (corresponding to natural colour).

→ **The standard for measurement is CIE S 025 demonstrating the effect of CRI**

Figure 6 shows the effect of CRI on how a scene is perceived.

Figure 6: Same scene under different light sources

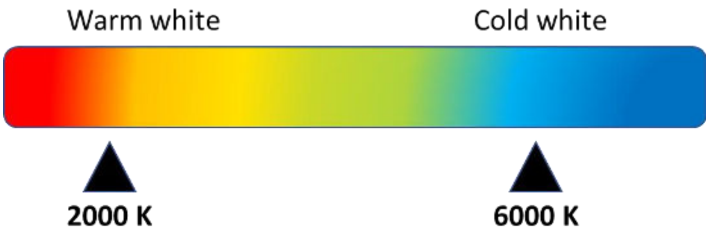


G. Correlated colour temperature (CCT)

This is the temperature of the Planckian (incandescent) radiator whose perceived colour most closely resembles that of a given stimulus at the same brightness and under specified viewing conditions (unit: Kelvin, K). Lamps with a high CCT, e.g., 5,000 K, produce a cool blueish-white light, whereas those with a low CCT, e.g., 2,700 K, produce light that is warm yellowish-white. This is shown diagrammatically in Figure 7.

→ **The standard for measurement is CIE S 025**

Figure 7: Colour temperature



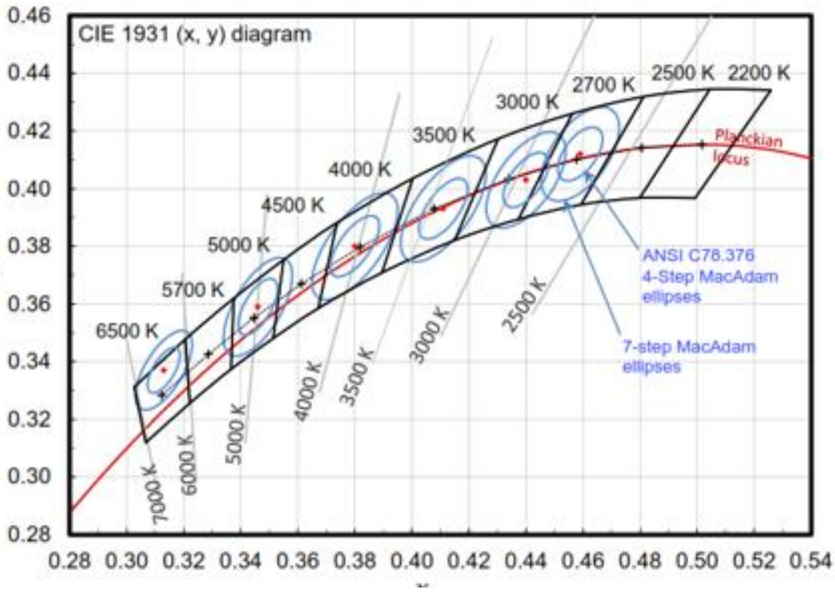
H. Colour consistency

This requirement specifies the deviation allowed in light's chromaticity. This deviation should be below the deviation of noticeable differences between two sources which have the same claimed colour temperature.

→ **Testing should be conducted according to CIE S 025**

A typical chromaticity diagram is shown in Figure 8.

Figure 8: Chromaticity specification of seven step quadrangles on the CIE (x,y) chromaticity diagram



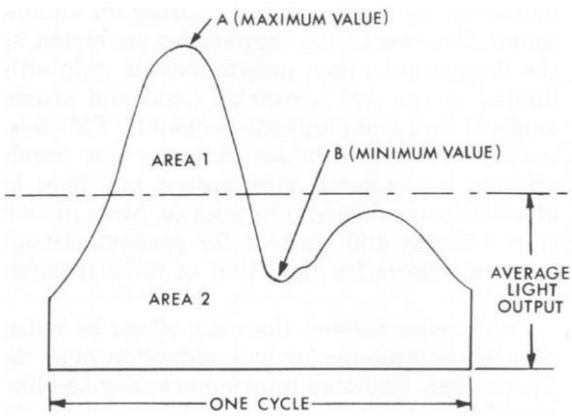
I. Flicker

The proposed metric for flicker is the ‘Pst^{LM}’, where ‘st’ stands for short term and ‘LM’ for light flickermeter method, as defined in standards. A value $Pst^{LM}=1$ means that the average observer has a 50% probability of detecting flicker.

→ Testing should be conducted according to IEC 61547-1 “Equipment for general lighting purposes – EMC immunity requirements – Part 1: Objective light flickermeter and voltage fluctuation immunity test method”

Figure 9 provides a diagrammatic representation of light flickering metrics.

Figure 9: For illustration only: Old light flickering metrics



J. Stroboscopic effect

The ‘stroboscopic effect’ refers to a change in motion perception induced by a light stimulus, the luminance or spectral distribution of which fluctuates with time, for a static observer in a non-static environment. The fluctuations can be periodic and non-periodic and may be induced by the light source itself, the power source or other influencing factors.

The metric for the stroboscopic effect used in this procurement specification is the stroboscopic visibility measure (SVM), as defined in standards. The value SVM = 1 represents the visibility threshold (50% detection rate) for an average observer.

→ **Testing should be conducted according to IEC TR 63158, “Equipment for general lighting purposes – Objective test method for stroboscopic effects of lighting equipment”**

K. Operational voltage range

A luminaire is manufactured to operate within a given operational parameter range (e.g. temperature, humidity, etc).

Concerning supply voltage range, under normal operating conditions, the supply voltage should not differ from the nominal voltage of the system by more than the specified value.

Note: For on-grid luminaires, the electric supply is operating at frequencies of 50 Hz or 60 Hz, depending on the country. This has no impact on the operating voltage range.
→ **Testing should be conducted according to IEC 61547-1**

L. Fundamental power factor or displacement factor

Also called the displacement power factor, it quantifies the displacement (phase-shift) between the fundamental current and sinusoidal voltage waveforms by calculating the cosine of the phase-shift angle. Fundamental power factor is a more detailed measure to quantify the displacement of the current and its effect on the load capacity and losses of the power supply network.
→ **Testing should be conducted according to IEC 62612**

M. Standby power

The standby power is the electric power consumption of a light source or of a separate control gear connected to the power supply when the light source is intentionally not emitting light, and the light source or control gear is awaiting a control signal to return to a state with light emission.

Connected luminaires interact with the environment via smartphones, tablets, the internet or other device protocols. This feature is very useful for the remote control of street lighting.

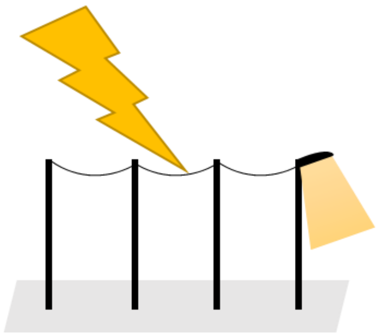
→ **The standard for measurement is IEC 63103, “Lighting equipment – non-active mode power measurement” which specifies methods of measurement of electrical power consumption in standby mode(s).**

N. Surge protection

Surges are typically generated by equipment when switched on and off and by lightning strike (Figure 10) and can damage LED luminaires. When electrical equipment is switched on/off, it produces transient voltage surges in the AC power lines. The ability of LED luminaires to handle these surges is normalized and termed the electromagnetic compatibility (EMC) immunity.

→ IEC 61547 "Equipment for general lighting purposes – EMC immunity requirements"

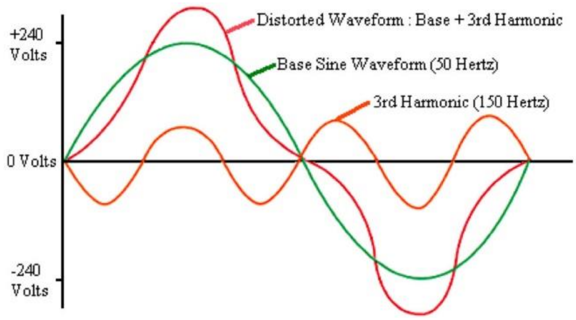
Figure 10: Lightning on a power line



O. Harmonic distortion

Harmonic distortions are non-linear distortions characterised by the generation of undesired spectral components harmonically related to the desired signal frequency. It induces disturbance on the network and should be limited. This is shown diagrammatically in Figure 11.

Figure 11: Harmonics and fundamental



→ The relevant standard is IEC 61000-3-2, Electromagnetic compatibility (EMC) – Part 3-2: "Limits for harmonic current emissions (equipment input current ≤16 A per phase)" which gives the limit values

This standard deals with the limitation of harmonic currents injected into the public supply system. It specifies the limits of the harmonic components of the input current which can be produced by equipment tested under specified conditions. It is applicable to electrical and electronic equipment having a rated input current up to and including 16 A per phase and intended to be connected to public low-voltage distribution systems.

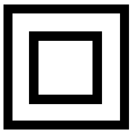
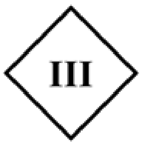
P. Protection against electric shock

An electric shock is the pathophysiological effect of an electric current through the human body. Its passage affects essentially the muscular, circulatory and respiratory functions and sometimes results in serious burns. The degree of danger for the victim is a function of the magnitude of the current, the parts of the body through which the current passes, and the duration of current flow.

Luminaires shall be classified according to the type of protection against electric shock provided, as Class I, Class II or Class III, as illustrated in Figure 12.

→ **The relevant standard is IEC 60598-1 Luminaires – Part 1: General requirements and tests**

Figure 12: Electric shock, IEC 60417-5172-02 classes

	**Class I luminaire**	**Class II luminaire**	**Class III luminaire**
			

Q. Class of ingress protection

In some circumstance, lighting fixtures have to withstand rough conditions: such as dust and humidity, among others. Liquid or solid particles which can penetrate into the lighting equipment can be harmful to the equipment, or even the operator.

Ingress protection classification is codified in international standard **IEC 60529., "Degrees of protection provided by enclosures (IP Code)"**. The designation used to indicate the degrees of protection provided consists of the characteristic letters IP followed by two numerals indicating the degree of protection for:

- Persons against contact with or approach to live parts and against contact with moving parts inside the enclosure and protection of the equipment against ingress of solid foreign bodies.
- The equipment inside the enclosure against the harmful ingress of water.

R. Class of impact resistance

This is an international numeric classification for the degrees of protection provided by enclosures for electrical equipment against external mechanical impacts. It provides a means of specifying the capacity of an enclosure to protect its contents from external impacts.

→ **The relevant international standard is IEC 62262**

S. Humidity and corrosion

Humidity

Humidity is directly related to performance degradation (product durability and efficiency) in many electronic devices, including LED lights, even if an LED light satisfies the IP66 grade, if it has an air vent, there is a strong possibility that condensation will occur in the lamp during a sudden change of temperature and humidity in an environment of high temperature and humidity.

→ All luminaires shall be humidity-proof where humid conditions may occur in normal use following the IEC 60598-1 humidity test.

Corrosion

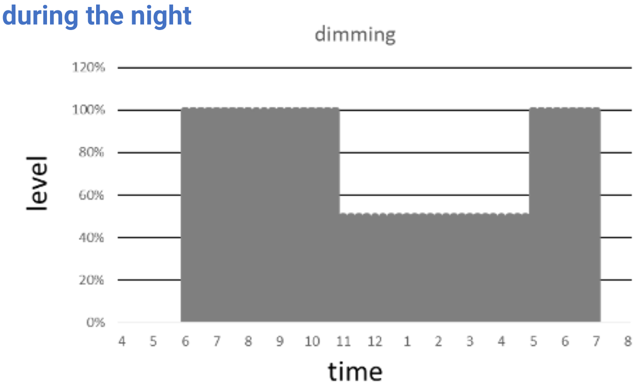
Moisture and small proportions of corrosive gases such as sulphur dioxide can cause severe corrosion over a long period of time. Luminaires which are used in atmospheres of high humidity should have adequate resistance to corrosion. An adequate level of corrosion resistance is provided by some metals or combinations of metals (as described in Sections 4.1.18 and 5.1.17).

Note: The interior of a closed luminaire is much less subject to corrosion than the exterior.

T. Dimming

This is the ability to control the intensity of light emitted by a luminaire by controlling the voltage or current available to it. Dimming the light means saving energy. For street lighting, dimming the light during the middle of the night, between midnight and 5 AM, for example, can save up to 50% in energy consumption, depending on the level of the light when it is dimmed. This is illustrated in Figure 13.

Figure 13: Dimming during the night



U. Battery capacity

The rated battery capacity is a measure of the ability of the battery to deliver the energy stored and is measured in Ampere hour (Ah). A fully charged battery of a given Ampere hour will be able to deliver a given amount of energy during one hour. The same battery would also be able to deliver X/2 Ampere during 2 hours or X/3 Ampere during 3 hours, for example. The capacity of the battery is determined by a number of factors such as the mass of the active material contained in the battery. For a given mass, the capacity of the battery will be determined by the energy density (Wh/kg) of the type of battery used. To store the same amount of energy, the weight of the battery will be smaller when the energy density is higher. Table 6 shows the typical energy density for each battery technology.

Table 6: Battery energy density

Technology of the battery	Typical energy density (Wh/kg)
Lead acid	30 to 50
NiMH	60 to 120
$LiFePO_4$	130 to 180

Note that battery power capacity is expressed in Watt-hour (Wh) and indicates the measure of the battery to store the power. Since the voltage at the output of a battery is constant, Wh is calculated by multiplying the number of Amps by the battery voltage.

V. Battery C-rate

The C-rate of a battery is a measure of the current in Ampere delivered by the battery and is proportional to the speed of the discharge. The C rate is expressed as "X"C, "X" being a number equal to the current in Ampere divided by the rated battery capacity in Ampere hour. When the capacity of the battery is fixed, the C rate is calculated knowing the current that is needed by the battery load.

W. Peak power of the photovoltaic panel

The peak power of a PV module is the electrical power delivered by this module when irradiated under standard conditions and is measured in Watt peak (Wp). Those conditions are an irradiance of 1000 W/m^2 (1 kW/m^2) at a standard ambient temperature of 25°C with a sea level Air Mass (AM) of 1.5 and an incidence angle = 90° (perpendicular to the plane of the panel)[17].

The maximum power produced by a solar panel under a given irradiance is proportional to the peak power, the ratio being equal to the ratio of the irradiance divided by the standard irradiance.

[17] *IEC 60904-3 Photovoltaic devices - Part 3: Measurement principles for terrestrial photovoltaic (PV) solar devices with reference spectral irradiance data*

Annex 2. Testing Standards Reference List

Performance criteria	Testing Standard
Norms for Luminaires	
Efficacy of the luminaire	CIE S 025 "Test Method for LED Lamps, LED Luminaires and LED Modules"
Lifetime	***Measurement outside of the luminaire:*** IES LM-80-20 "Measuring Luminous Flux and Colour Maintenance of LED Packages, Arrays and Modules" and IES TM-21-19 "Projecting Long Term Lumen Maintenance of LED Light Sources" ***Measurement within the luminaire:*** IES LM-84-14 "Measuring Luminous Flux and Colour maintenance of LED lamps, light engines, and luminaires" and IES TM-28-14 "Projecting Long Term Luminous Flux Maintenance of LED Lamps and Luminaires"
General safety	IEC 60598 "Luminaires – Part 1 General requirements and tests & Part 2 - particular requirements"
Photometry distribution	CIE S 025 "Test Method for LED Lamps, LED Luminaires and LED Modules"
Colour rendering index (CRI)	CIE S 025 "Test Method for LED Lamps, LED Luminaires and LED Modules"
Corelated colour temperature (CCT)	CIE S 025 "Test Method for LED Lamps, LED Luminaires and LED Modules"
CCT consistency	CIE S 025: 2015 "Test Method for LED Lamps, LED Luminaires and LED Modules"
Flicker (Pst^{LM})	IEC 61547-1 "Equipment for general lighting purposes - EMC immunity requirements - Part 1: Objective light flickermeter and voltage fluctuation immunity test method"
Stroboscopic effect (SVM)	IEC TR 63158 "Equipment for general lighting purposes - Objective test method for stroboscopic effects of lighting equipment"
Operational voltage range	IEC 61547-1 "Equipment for general lighting purposes - EMC immunity requirements - Part 1: Objective light flickermeter and voltage fluctuation immunity test method"
Fundamental power factor	IEC 62612 "Self-ballasted LED lamps for general lighting services with supply voltages > 50 V - Performance requirements"
Standby power and connected control devices	IEC 63103 "Lighting equipment - non-active mode power measurement"
Surge protection	IEC 61547 "Equipment for general lighting purposes – EMC immunity requirements"
Harmonic distortion	IEC 61000-3-2 "Limits for harmonic current emissions"
Protection against electrical shock	IEC 60598-1 "Luminaires – Part 1: General requirements and tests"
Class of ingress protection	IEC 60529 "Degrees of protection provided by enclosures (IP Code)"
Class of impact resistance	IEC 62262 "Degrees of protection provided by enclosures for electrical equipment against external mechanical impacts (IK code)"
Humidity and corrosion	IEC 60598-1, Luminaires –Part 1: General requirements and tests
Dimming	-
Performance criteria	-
Warranty	-
Maintenance	-

Performance criteria	Testing Standard
	Norms for Photovoltaic Panels
Performances	IEC 61853-1 “Photovoltaic (PV) module performance testing and energy rating – Part 1: Irradiance and temperature performance measurements and power rating”
Safety	IEC 61730-1 «Photovoltaic (PV) module safety qualification – Part 1: Requirements for construction» IEC 61853-2 «Photovoltaic (PV) module performance testing and energy rating - Part 2: Spectral responsivity, incidence angle and module operating temperature measurements»
	Norms for Batteries
Performances	IEC 61427-1 “Secondary cells and batteries for renewable energy storage - General requirements and methods of test - Part 1: Photovoltaic off-grid application”
Safety	IEC 63056 “Secondary cells and batteries containing alkaline or other non-acid electrolytes - Safety requirements for secondary lithium cells and batteries for use in electrical energy storage systems” IEC 62485-2 “Safety requirements for secondary batteries and battery installations –Part 2: Stationary batteries” (covers lead-acid and NiCd / NiMH batteries)
Electromagnetic compatibility	IEC 61000-3-2 «Electromagnetic compatibility (EMC) – Part 3-2: Limits – Limits for harmonic current emissions (equipment input current ≤ 16 A per phase)”

Note: the latest published version of the standards must be used.

Annex 3. Life Cycle Costs

This section shows how life cycle costs can be calculated for lighting products. Life cycle costing (LCC) is a good tool to quantify the impact of a given bid and help the tenderer to choose between different alternatives that exceed the minimum requirements.

Note that indirect emissions from the generation of the electricity supplying the lighting products is not accounted for as these depend on the energy mix of the country or region. A reduction in power consumed will have a corresponding reduction in generation emissions in line with the energy mix.

A. Life cycle cost (LCC)

To assess and compare the economic impact of energy using products, not only the acquisition cost but the entire cost of operation and ownership during the life cycle of the product should be considered. In this sense, the life cycle cost of an energy using product can be calculated as per Equation 1 (EQ.1).

$$LCC = PP + N \cdot \sum_{n=1}^{L} \left(\frac{AE \cdot EC}{(1+r)^n} + MC \right) + EOL \qquad \textbf{EQ.1}$$

Where:

- PP is the initial cost of the SPP purchase for a lighting product, including installation.
- AE is the annual energy consumption (in kWh) calculated from manufacturers declared power and the hours of operation per year.
- EC is the real cost of the supplied electricity in $/kWh.
- MC is the annual maintenance cost over the lifespan L, e.g., annual cleaning cost et al.
- EOL is the end-of-life cost (such as collection and recycling costs).
- L is the expected lifespan of the product in years calculated from the (average) annual hours of operation (dc) and declared lifetime (dl) both in hours. (L = dl/dc)
- N is the number of units of the lighting product in the tender. (*Note:* the equation assumes the same annual operating hours for each of these units. If that is not the case, calculate the LCC in separate annual operating hours groups before finally adding together.)
- r is the difference between the real discount rate and the real escalation rate of energy price. If the discount rate and escalation rate of energy price are similar, r≈0.

Since this guide is intended for public procurement, the real energy cost should be considered, i.e., the price of energy without governmental subsides. The maintenance costs might also be included in the contract (e.g., it might be included in the public procurement terms of agreement). The cost related to the product disposal at the end of life may also be included in the price of the product, especially in those countries with Extended Producer Responsibility (EPR) policies.

B. Early replacement (cost)

A life cycle costing is useful in comparing the total cost between two alternatives. When an early replacement is considered, i.e., the replacement of an existing lighting product that has not yet reached the end of its life (still working properly), a cost balance can be used to calculate the worthiness of the replacement of the old inefficient unit by a new efficient lighting product.

In this case, the savings will also depend on the difference in energy consumption, the initial price of the new product and the remaining life expectancy of the old lighting product, see Equation 2 (EQ.2).

$$\boldsymbol{balance\ cost} = \left(\frac{\boldsymbol{PP \cdot L_{exp}}}{\boldsymbol{L}} + \boldsymbol{N} \cdot \sum_{n=1}^{L_{exp}} \frac{\boldsymbol{AE \cdot EC}}{(\boldsymbol{1+r})^{\boldsymbol{n}}}\right) - \left(\boldsymbol{N_{old}} \cdot \sum_{n=1}^{L_{exp}} \frac{\boldsymbol{AE_{old} \cdot EC}}{(\boldsymbol{1+r})^{\boldsymbol{n}}}\right) \qquad \textbf{EQ.2}$$

The first term corresponds to the pro-rata cost of the new lighting product during the expected remaining life of the old light product (L_{exp}), e.g., if the existing lighting product is 8 years old and considered to have a lifespan[18] of 10 years, L_{exp} = 2 years. In this case, in the balance cost equation, the initial price of the new lighting product is considered pro-rata to the expected remaining life of the old lighting product and the lifespan of the new lighting product considered for the early replacement is substituted with the expected remaining life of the old light product, as after two years the old lighting product would be replaced anyway. The operating cost of the new and old lighting products are also only considered during the expected remaining life of the old product. AE_{old} refers to the annual energy consumption of the old lighting product in kWh. All other parameters are the same as described in Equation 1 (EQ.1).

The early replacement will lead to economical savings if the balance cost is negative, i.e., the cost of the continued operating cost old lighting product is higher than cost (i.e., early procurement and operation) of the new lighting product during the same period.

[18] 10 years is taken as a reference value in this example, but depending on the condition of the lighting product, this number can be reduced or increased.

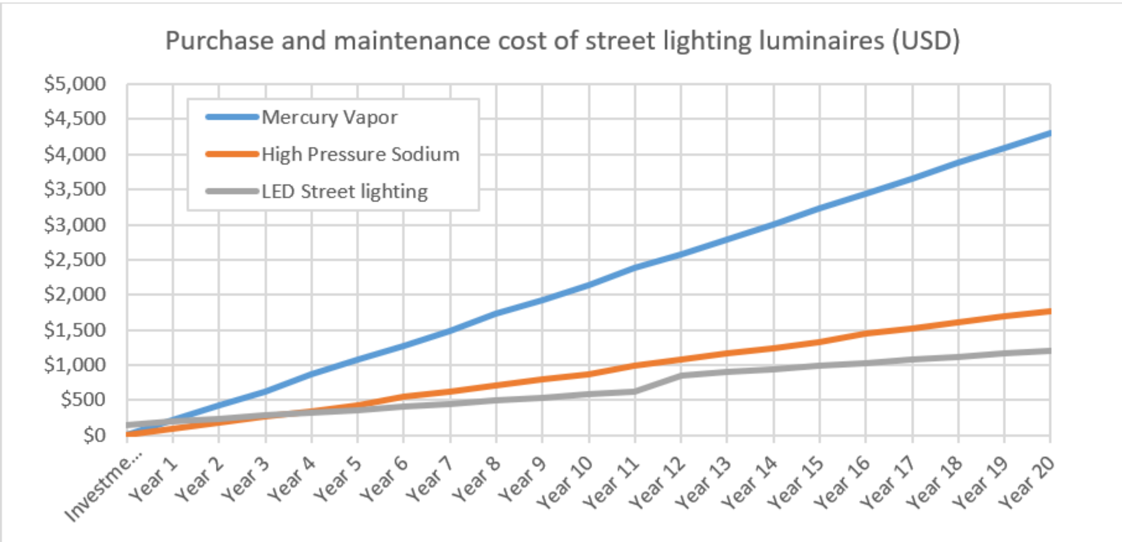
C. LCC technology comparison examples

Public procurement standards focus on LED products because of their lower energy consumption and lower LCC compared to other technologies, such as discharge lamps.

The following comparison has been made for the same output flux of the luminaire and LED luminaire efficacy recommended in these guidelines. Other assumptions that have been considered for the analysis are shown in Table 7.

In the case of street lighting, if we compare the LCC of changing discharge lamps inside an existing discharge luminaire (high pressure sodium or mercury vapor) against the LCC of replacing the luminaire with an LED luminaire, we obtain energy savings of more than 5.2 MWh per luminaire over a 20 year timeframe, equivalent to 2.6 tonnes of CO_2.This is illustrated in Figure 14.

Figure 14: LCC technology comparison for street lighting



The cost of replacement for mercury vapour and high-pressure sodium discharge lamps includes cleaning and the update of the old luminaire, which can include replacement of parts (e.g., glass). Discontinuity in the slope of the lines in Figure 14 is due to the end-of-life replacement of the lamp. Electricity price is assumed to be stable over the 20-year timeframe.

LED luminaire payback compared to high pressure sodium is 4 years (and less than one year for mercury vapor replacement), so after 20 years, $570 USD is saved ($3,100 USD for mercury vapor replacement). Additionally, energy savings over 20 years is 2.4 MWh per luminaire, equivalent to 1.2 tonnes of CO_2.

In the case of indoor lighting, comparison of LCC over 20 years has been made between T8 fluorescent tubes against LED tubes. This is illustrated in Figure 15.

LED tube payback compared to fluorescent tubes is less than 1 year, so after 20 years, $365 USD is saved just from one tube replacement. Additionally, energy savings over 20 years is 2.4 MWh per luminaire, equivalent to 1.2 tonnes of CO_2.

Figure 15: LCC technology comparison for indoor lighting

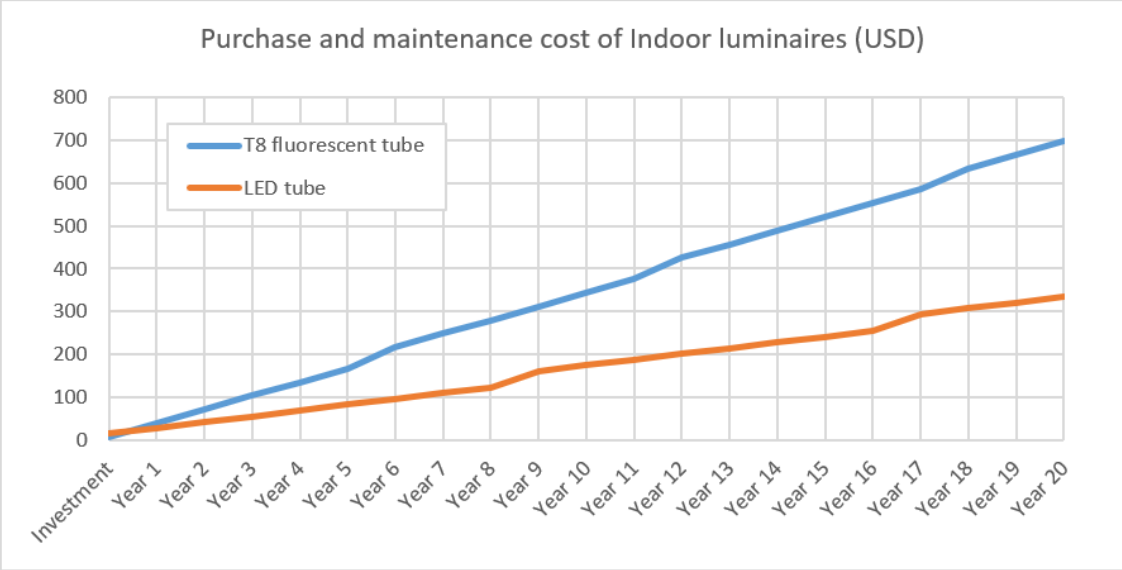


Table 7: Product assumptions for technology comparison

	Street Lighting			Indoor Lighting	
	Mercury vapour	**High pressure sodium**	**LED luminaire**	**T8 fluorescent tube**	**LED tube**
Product Price (USD)	10	15	150	7	15
Power	287.5	115	60	66.7	28
Electricity price (USD/kWh)	0.16	0.16	0.16	0.16	0.16
Lifetime (hours)	16,000	24,000	50,000	18,000	25,000
Operating time (hours/per year)	4,500	4,500	4,500	3,000	3,000
Replacement cost (USD)	20	20	40	10	10
Emission factor ($KgCO_2$/kWh)	0.5	0.5	0.5	0.5	0.5

Annex 4. Award criteria for tenders

These Guidelines have defined the energy and quality performance criteria recommended when specifying a lighting tender process. As all products must meet the minimum requirements, as set in the tender call, to be eligible, eliminating tenders where the products do not meet these requirements is straightforward. However, making a selection amongst the remaining tenders where all the products meet, or exceed, the minimum energy and performance requirements can be more difficult. One method to simplify the decision-making process is to focus on a few key performance characteristics and ascribe a weighting to them relative to their importance to the project.

To illustrate this, Table 8 shows an example of five key criteria which can be considered when deciding between alternative tenders. The selection of the parameters and weight entitled to each of them may be adapted depending on the particular project priorities. Please note that two parameters –price and operating temperature– are not part of the sustainable public procurement technical specifications. Price level is usually the first criteria and decision factor considered during public procurement and maximum operating temperature is a parameter that could be critical for hot regions. Luminous efficacy, lifetime and fundamental power factor (or displacement factor) are part of the SPP technical specifications.

Table 8: Award criteria weight example

Parameter	Weight	Formula
Price (USD)	30%	Points = 100 x (lowest cost of all proposals / cost of proposal)
Luminous efficacy (lm/W)	20%	Points = 100 x (luminous efficacy proposal / maximum luminous efficacy all proposals)
Lifetime (hours)	20%	Points = 100 x (lifetime of proposal / maximum lifetime all proposals)
Fundamental Power Factor (FPF)	15%	Points = 100 x (FPF of proposal /maximum FPF all proposals)
Max operating temperature (°C)	15%	Points = 100 x (Max. op. temp. / Max. op. temp. all proposals)

Each parameter has a formula to calculate the number of points to be attributed. Next, these points must be weighted based on the specific weight of the parameter. Over a 100 points notation, each bid will have a total score by adding the notes from each parameter. The awarded bid will be the one with the highest note.

$$note = \sum_{parameter\ 1}^{last\ parameter} Weight\ x\ points$$

Table 9 presents an example of a tender which received three different bids for LED tubes. All tubes comply with the SPP technical criteria for luminous efficacy, lifetime and fundamental power factor.

Table 9: Example of LED tubes bids

Parameter	Tube 1	Tube 2	Tube 3
Price ($)	5	10	15
Luminous efficacy (lm/W)	130	150	170
Lifetime (hours)	20 000	40 000	50 000
Fundamental power factor	0.70	0.85	0.92
Max operating temperature (°C)	40	50	70

Table 10 shows the results for each product after the weighting has been applied for each parameter.

Table 10: Example of notation bids for LED tubes

Parameter	Tube 1	Tube 2	Tube 3	Weight
Price	100	50	33	30%
Luminous efficacy	76	88	100	20%
Lifetime	40	80	100	20%
Fundamental power factor	76	92	100	15%
Operating temperature	57	71	100	15%
Score	**73.3**	**73.2**	**80.0**	

Based on this weighting calculation, Tube 3 achieves the highest overall score and would be selected. Tube 1 is in second position and Tube 3 in third. The difference between bids can sometimes be very small, as shown for Tube 1 and Tube 2, where it is only 0.1 over 100.

Annex 5. Invitation to Tender, Request for Tender and Lighting as a Service Contract Agreement

These guidelines provide the technical recommendations (summarized in Chapter 3) to be used when specifying lighting products on public projects for street/outdoor or large building indoor lighting, or when developing the lighting requirement for a lighting as a service (LaaS) contract.

The next step in the process is to put the requirements out to tender/contract. This is referred to as an 'invitation or request to tender' sent to potential suppliers and it will be specific to the individual project concerned.

The format of such documentation often follows a standard pattern, and many examples are available online. A few have been selected by the authors as representative examples. The documents that relate to these can be downloaded from the U4E website[19].

For reference, two examples of invitation to tender/request for tender documents have been selected. These have been chosen as typical examples for indoor and outdoor lighting, but each individual project will be different on a detailed level and shall follow the specific format/requirements indicated for its country or procurement organization.

- *Outdoor lighting tender example:*
  Market Drayton Town Council Street Lighting Tender[19]

This example has been chosen because of its clear structure with sections for the luminaire specification and requirements for the tenderer, including timescales and environmental requirements. The number of streetlights involved is only 247 and there is an audit document for the current installation as they required removal of the old product.

- *Indoor lighting tender example:*
  Great Hollands Primary School Indoor Lighting Tender[19]

This example has been chosen also because of its clear structure. It is for a school, a very common local authority public tender. It has a detailed electrical services specification in addition to the requirements for the lighting fittings which is more often the case in lighting tenders. The requirements for the tenderer are detailed and cover hazardous materials and legal obligations.

[19] *Available at: https://united4efficiency.org/resources/green-public-procurement-technical-guidelines-and-specifications-for-energy-efficient-lighting_annex-4/*

In the case of LaaS contracts, there are many examples of efficiency-as-a-service agreements, whether it is for lighting or other kinds of efficient product-as-a-service. Below are two examples for reference. Depending on the type of contract, the user can add technical requirements to ensure the lighting technologies meet rigorous efficiency standards.

- *LaaS terms and conditions*[19]

This example has been chosen because of the detailed terms and conditions clearly listed for LaaS agreements.

- *Cooling as a Service (CaaS) model contract*[19]

This private-private agreement example, prepared as part of the Cooling as a Service Initiative (www.caas-initiative-org), led by the Basel Agency for Sustainable Energy (www.energy-base.org) and supported by the Clean Cooling Collaborative (www.cleancoolingcollaborative.org), illustrates that the same business model can be applied and tailored to different type of products[20], with the structure and content of the agreement remaining the same. In the case of a public sector agreement, the base contract must be the public service contract and the maximum term allowed for public service contracts has to be checked. Normally a multi-year contract is needed to amortize the investment; and it is not unusual for the party supplying the service to finance the asset through a financier (which may be a bank, an investor, private equity fund or other) through specific financial agreements (such as sale-lease back mechanisms) which can vary in terms and conditions.

[20] *For more information of Energy as a Service business models, please visit: https://www.eaas-initiative.org/tools/*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