



BSI Standards Publication

Recommendations for small renewable energy and hybrid systems for rural electrification

Part 9-5: Integrated system —
Selection of stand-alone lighting
kits for rural electrification

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National foreword

This Published Document is the UK implementation of IEC/TS 62257-9-5:2013. It supersedes DD IEC/TS 62257-9-5:2007 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee GEL/82, Photovoltaic Energy Systems.

A list of organizations represented on this committee can be obtained on request to its secretary.

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TECHNICAL SPECIFICATION



**Recommendations for small renewable energy and hybrid systems for rural electrification –
Part 9-5: Integrated system – Selection of stand-alone lighting kits for rural electrification**

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

RECOMMENDATIONS FOR SMALL RENEWABLE ENERGY AND HYBRID SYSTEMS FOR RURAL ELECTRIFICATION –

Part 9-5: Integrated system – Selection of stand-alone lighting kits for rural electrification

FOREWORD

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- the required support cannot be obtained for the publication of an International Standard, despite repeated efforts, or
- the subject is still under technical development or where, for any other reason, there is the future but no immediate possibility of an agreement on an International Standard.

Technical specifications are subject to review within three years of publication to decide whether they can be transformed into International Standards.

IEC 62257-9-5, which is a technical specification, has been prepared by IEC technical committee 82: Solar photovoltaic energy systems.

This second edition cancels and replaces the first edition issued in 2007. It constitutes a technical revision.

The main technical changes with regard to the previous edition are as follows:

- Overall, shifted from narrow focus on the needs of bulk procurement programmes to a wider framework for structuring quality assurance using appropriate methods for a range of stakeholders including governments, manufacturers, buyers, and others.
- Revised structure of document with modular methods (located in annexes) that are applied using four distinct test regimes.
- Added normative references and definitions to support new document structure.
- Added a framework for categorizing products based on the arrangement of components.
- Expanded the range of aspects that are considered and formalized a framework for product specification that can be customized based on stakeholder needs, with example, informative product specifications in the annexes.
- Added a “Quality test method” that prescribes a set of rigorous laboratory tests using randomly-selected samples. The description includes a comprehensive list of tests and guidance for test labs on staging.
- Added a “Market check method” that is a targeted set of tests to confirm results.
- Added an “Initial screening method” that provides rapid laboratory feedback on product quality and performance.
- Updated and strengthened the previously defined test programme using the “Field screening method” that can be achieved at low cost without laboratory facilities.
- Added a description for “Standardized specifications sheets” that can be used to disseminate test results to the market.
- Created or modified several key test procedures:
 - Full battery run time
 - Durability
 - Water protection assessment
 - Solar run time
 - Light output, distribution, and maintenance
 - Visual screening
 - Random product sampling

This technical specification shall be used in conjunction with:

- IEC 62257-1: Recommendations for small renewable energy and hybrid systems for rural electrification – Part 1: General introduction to rural electrification
- IEC 62257-2: Recommendations for small renewable energy and hybrid systems for rural electrification – Part 2: From requirements to a range of electrification systems
- IEC 62257-3: Recommendations for small renewable energy and hybrid systems for rural electrification – Part 3: Project development and management
- IEC 62257-4: Recommendations for small renewable energy and hybrid systems for rural electrification – Part 4: System selection and design
- IEC 62257-5: Recommendations for small renewable energy and hybrid systems for rural electrification – Part 5: Protection against electrical hazards
- IEC 62257-6: Recommendations for small renewable energy and hybrid systems for rural electrification – Part 6: Acceptance, operation, maintenance and replacement

It is also to be used with future parts of this series as and when they are published.

The text of this technical specification is based on the following documents:

Enquiry draft	Report on voting
82/731/DTS	82/759/RVC

Full information on the voting for the approval of this technical specification can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "<http://webstore.iec.ch>" in the data related to the specific publication. At this date, the publication will be

- transformed into an International standard,
- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

The IEC 62257 series intends to provide to different players involved in rural electrification projects (such as project implementers, project contractors, project supervisors, installers, etc.) guidelines for the setting up of renewable energy and hybrid systems with AC nominal voltage below 500 V, DC nominal voltage below 750 V and nominal power below 100 kVA.

These documents are recommendations

- to choose the right system for the right place,
- to design the system, and
- to operate and maintain the system.

These documents are focused only on rural electrification concentrating on but not specific to developing countries. They shall not be considered as all inclusive to rural electrification. The documents try to promote the use of renewable energies in rural electrification; they do not deal with clean mechanism developments at this time (CO₂ emission, carbon credit, etc.). Further developments in this field could be introduced in future steps.

This consistent set of documents is best considered as a whole with different parts corresponding to items for safety, sustainability of systems, and at the lowest life cycle cost as possible. One of the main objectives is to provide the minimum sufficient requirements, relevant to the field of application that is: small renewable energy and hybrid off-grid systems.

The purpose of this part of IEC 62257 series is to specify quality assurance strategies for stand-alone lighting kits, including product specifications, tests, and a standardized specifications sheet format. In addition to supporting the selection of products by project developers and implementers, quality assurance can help market support organizations, manufacturers, and governments achieve the goals they have for off-grid lighting projects.

RECOMMENDATIONS FOR SMALL RENEWABLE ENERGY AND HYBRID SYSTEMS FOR RURAL ELECTRIFICATION –

Part 9-5: Integrated system – Selection of stand-alone lighting kits for rural electrification

1 Scope

This part of IEC 62257 applies to stand-alone rechargeable electric lighting appliances or kits that can be installed by a typical user without employing a technician.

This technical specification presents a quality assurance framework that includes product specifications (a framework for interpreting test results), test methods, and standardized specifications sheets (templates for communicating test results).

The intended users of this technical specification are listed below. In some clauses and subclauses of this technical specification, a description of the application of the subclause contents is offered to help provide context for each type of user.

- **Market support programmes** are programmes that support the off-grid lighting market with financing, consumer education, awareness, and other services. Market support programmes often use quality assurance to qualify for access to services like
 - greenhouse gas reduction certifications or other incentives,
 - access to financing (trade or consumer finance),
 - use of a buyer seal and certification (government or non-governmental institutional backing, consumer or “business to business” seals),
 - participation in a public product information database (e.g., standardized specifications sheets),
 - access to a business network or trade group,
 - business support and development services,
 - access to market intelligence, and
 - participation in consumer awareness campaigns.
- **Manufacturers and distributors** need to verify the quality and performance of products from different batches and potential business partners. Manufacturers and distributors often use quality assurance plans or requirements to
 - support quality control processes at a manufacturing plant or upon receipt of goods from a contract manufacturer, and
 - choose products to distribute.
- **Bulk procurement programmes** facilitate or place large orders for devices from a distributor or manufacturer. Bulk procurement programmes may use quality assurance to
 - provide devices to a particular, relatively small group of end-users whose needs are understood (e.g., project developers and implementers for an electrification project may include quality assurance requirements in the GS of an electrification project (see IEC/TS 62257-3)), and
 - organize a subsidy, buy-down, or giveaway programme that will serve a broad set of users.
- **Trade regulators** are typically government policymakers and officials who craft and implement trade and tax policy. Regulators may use quality assurance requirements to
 - qualify for exemption from tax or duties, and

- establish requirements for customs.

This technical specification establishes the framework for creating a product specification — the basis for evaluating quality for a particular context. Product specifications include minimum requirements for quality standards, warranty requirements, and/or performance targets. Products are compared to specifications based on test results and other information about the product. The product specification framework is flexible and can accommodate the goals of diverse organizations and institutions.

There is a range of tests outlined in this technical specification; some are simple enough to be completed in the field by project developers while others require laboratory equipment. The tests and inspections are designed to be widely applicable across different markets, countries, and regions.

Standardized specifications sheets are also defined that can be used to communicate the test results. Combined with a set of product specifications, the information in the standardized specifications sheet can inform the use of a quality and/or performance label.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60081:1997, *Double-capped fluorescent lamps – Performance specifications*
Amendment 1:2000
Amendment 2:2003
Amendment 3:2005
Amendment 4:2010

IEC 60529, *Degrees of protection provided by enclosures (IP Code)*

IEC 60891, *Photovoltaic devices – Procedures for temperature and irradiance corrections to measured I-V characteristics*

IEC 60904-1, *Photovoltaic devices – Part 1: Measurement of photovoltaic current-voltage characteristics*

IEC 61951-1:2003, *Secondary cells and batteries containing alkaline or other non-acid electrolytes – Portable sealed rechargeable single cells – Part 1: Nickel-cadmium*

IEC 61951-2:2011, *Secondary cells and batteries containing alkaline or other non-acid electrolytes – Portable sealed rechargeable single cells – Part 2: Nickel-metal hydride*

IEC 61960:2011, *Secondary cells and batteries containing alkaline or other non-acid electrolytes – Secondary lithium cells and batteries for portable applications*

IEC 62509:2010, *Battery charge controllers for photovoltaic systems – Performance and functioning*

ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories*

ISO 9001, *Quality management systems – Requirements*

PVRS 7A, *DC supplied lighting systems with fluorescent lamps for PV stand-alone systems*

IESNA LM-78-07, *IESNA approved method for total luminous flux measurement of lamps using an integrating sphere photometer*

IESNA LM-79-08, *Electrical and photometric measurement of solid state lighting products*

CIE 13.3:1995, *Method of measuring and specifying colour rendering properties of light source*

CIE 15:2004, *Colorimetry*

CIE 084, *The measurement of luminous flux*

CIE 127, *Measurement of LEDs*

CIE 177:2007, *Colour rendering of white LED light sources*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1

illuminance

illuminance of an elementary surface

symbol E

the luminous flux received by an elementary surface divided by the area of this surface

Note 1 to entry: In the SI system of units illuminance is expressed in lux (lx) or lumens per square metre (lm/m²).

[SOURCE: IEC 60050-723:1997, 723-08-30]

3.2

capacity

capacity of a cell or a battery

the quantity of electricity (electric charge), usually expressed in ampere-hours (Ah), which a fully charged battery can deliver under specified conditions

[SOURCE: IEC 60050-482:2004, 482-03-01]

3.3

device under test

DUT

a particular sample that is being measured or observed

3.4

life

life of a lamp

the total time for which a lamp has been operated before it becomes useless, or is considered to be so according to specified criteria

Note 1 to entry: Lamp life is usually expressed in hours.

[SOURCE: IEC 60050-845:1987, 845-07-61]

3.5

life test

test in which lamps are operated under specified conditions for a specified time or to the end of life and during which photometric and electrical measurements may be made at specified intervals

[SOURCE: IEC 60050-845:1987, 845-07-62]

3.6

service life

service life of a battery

the period of useful life of a battery under specified conditions

[SOURCE: IEC 60050-482:2004, 482-03-23]

3.7

light unit

assembly inside a casing of all parts such as lamps, optical apparatus, coloured glass, terminals, necessary to exhibit a light aspect

[SOURCE: IEC 60050-821:1998, 821-02-38]

3.8

lux

SI unit of illuminance: illuminance produced on a surface of area 1 square metre by a luminous flux of 1 lumen uniformly distributed over that surface

[SOURCE: IEC 60050-845:1987, 845-01-52]

3.9

full width half maximum

FWHM

the range of a variable over which a given characteristic is greater than 50 % of its maximum value

Note 1 to entry: FWHM may be applied to characteristics such as radiation patterns, spectral linewidths, etc. and the variable may be wavelength, spatial or angular properties, etc., as appropriate.

[SOURCE: IEC 60050-731:1991, 731-01-57]

3.10

Ampere

symbol A

SI unit of electric current, equal to the direct current which, if maintained constant in two straight parallel conductors of infinite length, of circular cross-section with negligible area, and placed 1 metre apart in vacuum, would produce between these conductors a force per length equal to 2×10^{-7} N/m

Note 1 to entry: CGPM definition is as follows: "The ampere is that constant current which, if maintained in two straight parallel conductors of infinite length, of negligible circular cross-section, and placed 1 metre apart in vacuum, would produce between these conductors a force equal to 2×10^{-7} newton per metre of length."

[SOURCE: IEC 60050-112:2010, 112-02-07]

3.11

multimeter

multirange multifunction measuring instrument intended to measure voltage, current and sometimes other electrical quantities such as resistance

[SOURCE: IEC 60050-312:2001, 312-02-24]

3.12

ammeter

instrument intended to measure the value of a current

[SOURCE: IEC 60050-313:2001, 313-01-01]

3.13

voltmeter

instrument intended to measure the value of a voltage

[SOURCE: IEC 60050-313:2001, 313-01-03]

3.14

illuminance meter

instrument for measuring illuminance

[SOURCE: IEC 60050-845:1987, 845-05-16]

3.15

photometer

instrument for measuring light

[SOURCE: IEC 60050-845:1987, 845-05-15]

3.16

pyranometer

instrument for measuring incident global (direct-beam and diffuse) solar radiation

3.17

integrating sphere

hollow sphere whose internal surface is a diffuse reflector, as non-selective as possible. Used to determine the total luminous flux (lumen output) of a lighting device

Note 1 to entry: An integrating sphere is used frequently with a radiometer or photometer.

[SOURCE: IEC 60050-845:1987, 845-05-24]

3.18

goniophotometer

photometer for measuring the directional light distribution characteristics of sources, luminaires, media or surfaces

[SOURCE: IEC 60050-845:1987, 845-05-22]

3.19

power supply

electric energy converter which draws electric energy from a source and supplies it in a specified form to a load

[SOURCE: IEC 60050-151:2001, 151-13-76]

3.20

overvoltage protection

protection intended to operate when the power system voltage is in excess of a predetermined value

[SOURCE: IEC 60050-448:1995, 448-14-32]

3.21

undervoltage protection

low voltage protection

protection intended to operate when the power system voltage is reduced to less than a predetermined value

[SOURCE: IEC 60050-448:1995, 448-14-33]

3.22

GS

General Specification of the electrification project

3.23

IP class

IP rating

ingress protection—Degree of protection provided by enclosures for electrical equipment against penetration by foreign bodies and dust/water

3.24

portable

products or subsystems are portable when two or more of the main components (energy source, energy storage, and light source) are connected in a way that makes the product or subsystem easy for an individual to carry

3.25

fixed

products or subsystems are fixed when the main components (energy source, energy storage, and light source) are designed for permanent or semi-permanent mounting and use in place

3.26

separate

products are separate when no solar module is present or the solar module is connected to other components via a long enough cable that the solar module could collect energy outdoors while the other product components remain indoors

3.27

integrated

products are integrated when the solar module is integrated into the same casing as the other components or the solar module is connected to other components via a cable that is too short to allow the solar module to collect energy outdoors while the other product components remain indoors

3.28

metadata

information that relates a test result to a specific sample and provides context about the result (e.g., specific test method used)

3.29

light emitting diode

LED

solid state device embodying a p-n junction, emitting optical radiation when excited by an electric current

[SOURCE: IEC 60050-845:1987, 845-04-40]

3.30

low-voltage disconnect

LVD

battery voltage at which the load terminals of the charge controller are switched off to prevent the battery from over discharging

[SOURCE: IEC 62509:2010]

3.31

standby loss

the quantity of electricity (electric charge), expressed in ampere-hour (Ah), drawn from a product's battery with the product switched off over a specific length of time

3.32

compact fluorescent lamp

CFL

a discharge lamp of the low pressure mercury type in which most of the light is emitted by one or several layers of phosphors excited by the ultraviolet radiation from the discharge, typically self-ballasted with a tube that is wound in a spiral or arched shape to make it “compact” as opposed to linear fluorescent lamps

4 System limits

4.1 System description

4.1.1 Components

A stand-alone lighting kit typically comprises:

- The following main components:
 - an **energy source**:
 - a) solar photovoltaic module (integrated, supported by or completely separate from the casing),
 - b) electromechanical charger (hand crank, pedal power, or other), and/or
 - c) general DC power input (normally used with a central charging station or AC-DC converters to charge via grid power).
 - one or several **light sources** (typically CFL or LED), and
 - an **energy storage** device (one of several battery types).
- The enclosure and other components:
 - **casing or several casings** (including some translucent parts in many cases),
 - **circuits** (battery charge and discharge controller, regulated voltage and current sources),
 - **wiring** to connect the circuits to each other and the main components,
 - **fasteners** to secure components in the casings,
 - **switches** for light control/selection,
 - **cables and connectors**,
 - **status indicators** / user feedback,
 - **accessories** (auxiliary power outlet, mobile phone charging interface, radio, fan, etc.), and/or
 - **hardware** for mounting.

4.1.2 Product categories

Stand-alone lighting kits can be placed into one of four categories based on the arrangement of components. It is important to categorize them because they have different inherent utility to the user and will encounter different environmental conditions based on their design.

Different quality standards and performance targets may apply to different categories.

Some kits that have multiple, independent lighting points may fit into more than one category, with different parts of the kit in different categories.

The first word in each category name refers to the portability of the system.

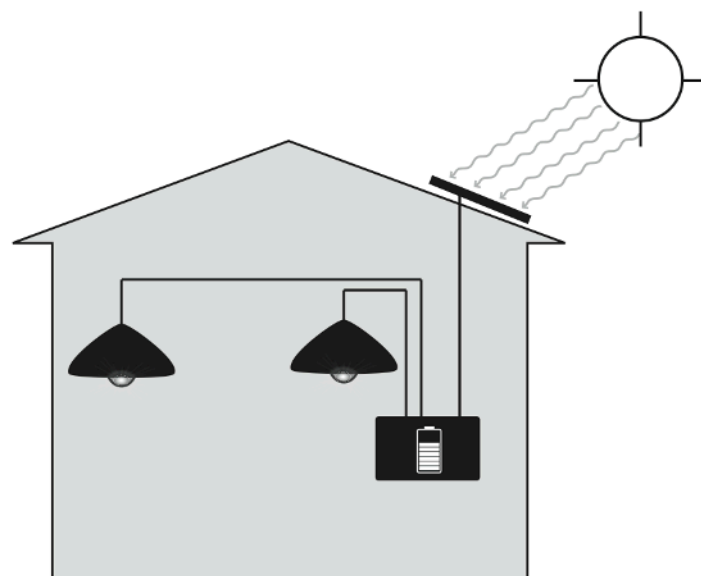
- *Fixed* systems are designed for permanent or semi-permanent mounting and use in place.
- *Portable* systems are inherently portable, with the light source and energy storage components permanently or temporarily joined.

The second word refers to the arrangement of a solar module, if one is present, with respect to the other main components.

- *Separate* systems have no solar module present or the solar module is connected to other components by a cable that is sufficiently long to place the solar module outdoors in a location with good solar access while the other components remain indoors.
- *Integrated* systems have a solar module integrated in the same casing as the other components or it is otherwise designed so the whole product shall be left outdoors to charge via the solar module.

The four system types that can be derived from the categories listed above are:

- Fixed separate (fixed indoors):** products that are not inherently portable and are used indoors. The light source(s) are separated from the battery by cables and cannot easily be used beyond the reach of the cables. If the product is solar-charged, the solar module is also separate from the battery and connected by a cable that is sufficiently long to place the solar module outdoors in a location with good solar access while the battery remains indoors (see Figure 1).



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Figure 1 – Fixed separate (fixed indoors) system—example arrangement of components

- b) **Portable separate:** products that are portable, with a battery and light source permanently or temporarily joined. If the product is solar-charged, the solar module is also separate from the battery and connected by a cable that is sufficiently long to place the solar module outdoors in a location with good solar access while the battery remains indoors (see Figure 2).

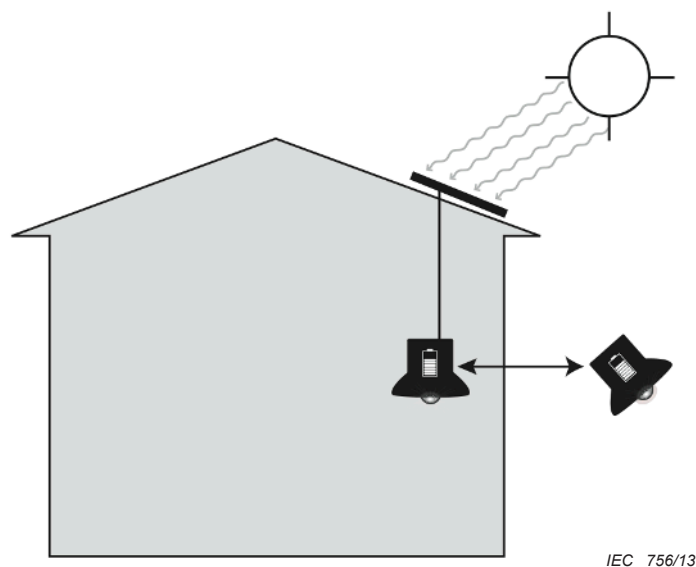


Figure 2 – Portable separate system—example arrangement of components

- c) **Portable integrated:** products that are portable and are charged with a solar module that is integrated in the casing or is otherwise designed so the whole product shall be left outdoors to charge via the solar module (see Figure 3).

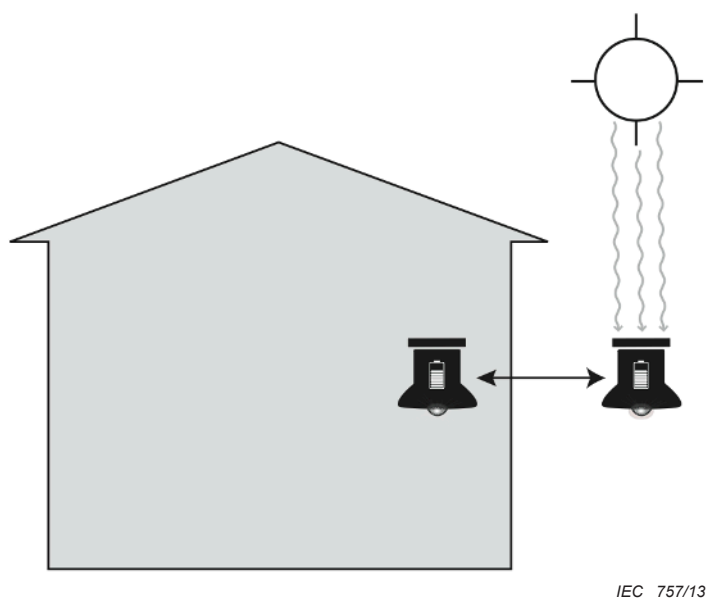


Figure 3 – Portable integrated system—example arrangement of components

- d) **Fixed integrated (fixed outdoors):** products that are not inherently portable and are charged with a solar module that is integrated in the casing or is otherwise designed so the whole product shall be left outdoors to charge via the solar module. These may also include lighting points that can be placed indoors (see Figure 4).

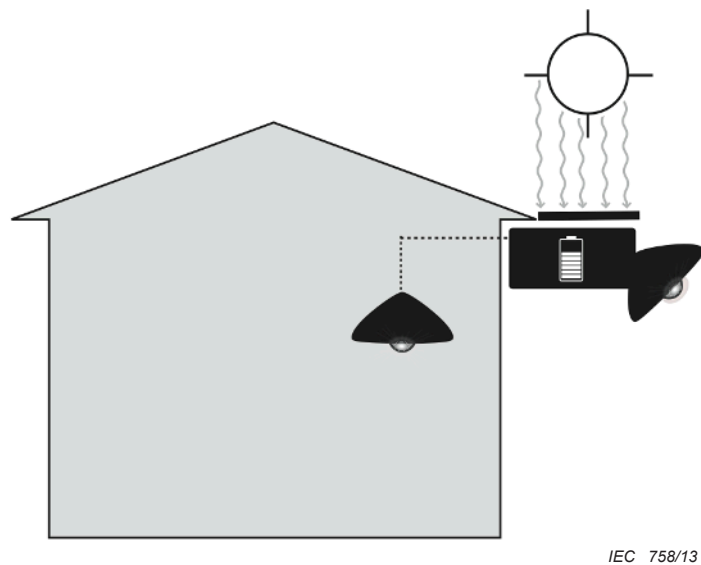


Figure 4 – Fixed integrated (fixed outdoors) system – example arrangement of components

4.1.3 Lighting kit parts

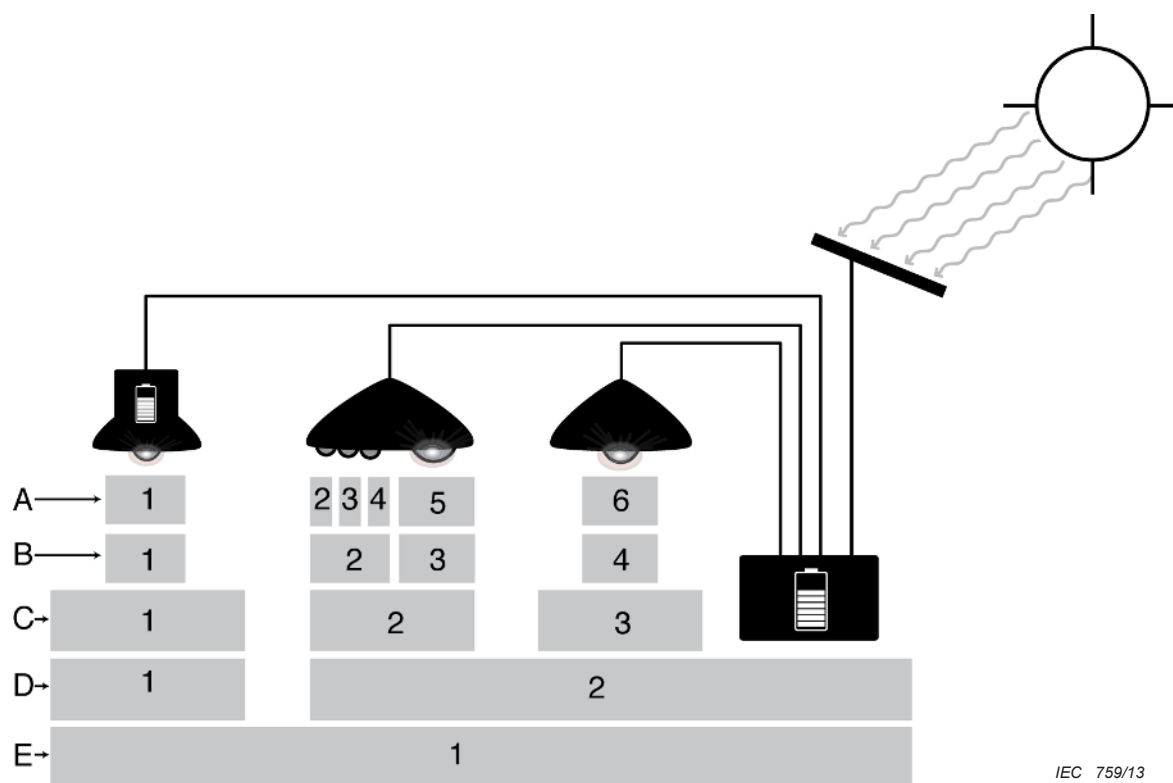
Lighting kits may also be divided into several subsystems, as defined below. The subsystems are nested beginning with the smallest subsystem and working down to complete kits.

- a) Light source(s): individual LED, CFL, or other light emitting components.
- b) Array(s): single or grouped light sources that can be controlled independently from other arrays.
- c) Light point(s): house one or more arrays and can be moved with respect to other light points, if there are more than one.
- d) Lighting unit(s): stand-alone parts of the kit, each with an independent battery that powers one or more light points.

NOTE It is appropriate to categorize each light unit (as described in 4.1.2) separately, since the arrangement of battery and light point(s) may be different in different light units.

- e) Lighting kit: the overall package of integrated components, including one or several lighting units.

Figure 5 below illustrates how a hypothetical lighting kit can be subdivided and categorized. The levels of division are labelled with letters, corresponding to the descriptions above. There are six light sources (A) in this kit divided among four arrays (B). Two of the three light points (C) have one array; the third light point (in the middle—C2) has two arrays. Note that one of the arrays—the one with three light sources—is turned off and the other is on. There are two light units (D). The light unit on the left (D1) may be categorized as portable separate; the other light unit (D2) may be categorized as fixed separate (fixed indoors). Both units are included in a single lighting kit (E).



IEC 759/13

Figure 5 – Division of a lighting kit into subsystems—illustrative example

4.1.4 Additional system elements

In addition to technical elements, a system may also include:

- **packaging** with information about the product,
- **user's manual(s)**,
- various **advertising** for the product across media: print, radio, television, internet, and others, and/or
- **warranty** support from the manufacturer.

4.2 System measurements and observations

4.2.1 General

This subclause describes aspects of an off-grid lighting product that may be measured and/or observed to ascertain its quality and performance. The aspects are grouped into categories, and each aspect begins with a description of its relevance. The aspects may be measured and/or observed using test procedures, which are generally classified as “A” or “B.” Class A test procedures will generally result in measurements that are more accurate or less subjective than class B procedures, but class A procedures are also generally more costly to implement. The appropriateness of class A or class B procedures depends on the particular aspect and context of the testing. A class C procedure is specified for selected procedures that may be done with “field modifications” (see Annex AA). The description of each aspect concludes with a description of the result from the test procedure, the units, and an example result. In some cases, multiple pieces of information are grouped in a single aspect for clarity and concision.

4.2.2 Product design, manufacture, and marketing aspects

4.2.2.1 Arrangement of components

The arrangement of components is a critical aspect to observe because it determines the product category. Different arrangements will offer different utility to the end-user.

- a) Class A test procedure(s): Annex F: visual screening
- b) Class B test procedure(s): n/a
- c) Result: qualitative description of each separate electronic enclosure and what is housed in or mounted on each.
- d) Units: qualitative description
- e) Example: Enclosure A contains the battery and has a gooseneck light point protruding from the top. Enclosure B is a remote lighting point with ambient, omnidirectional LEDs mounted on the outside; it is connected to enclosure A with a cable. A solar module with a cable for connection powers enclosure A.

4.2.2.2 Charging system information

This notes all the available options for charging the device. The key items to note are whether the device can be charged by “central” charging (e.g., via electric grid connection or at a central charging station), “independent” charging (e.g., via an included photovoltaic or electromechanical generator), or both. The available charging options can help determine the utility of the device for users based on the run time aspects (see subclause 4.2.7).

- a) Class A test procedure(s): Annex F: visual screening
- b) Class B test procedure(s): Annex D: manufacturer self-reported information
- c) Result: for each charging option,
 - 1) Charger type
 - 2) Central or independent
- d) Units: qualitative type
- e) Example: Two charging options:
 - 1) independent solar charging via the included module;
 - 2) central grid charging via an auxiliary input designed for use with mobile phone chargers (not included).

4.2.2.3 Lighting system information

This describes the types of light sources used in the product and their arrangement. This is important for understanding the general product design.

- a) Class A test procedure(s): Annex F: visual screening.
- b) Class B test procedure(s): Annex D: manufacturer self-reported information.
- c) Result: qualitative description of the type, number, and arrangement of light sources.
- d) Units: qualitative description.
- e) Example: See 4.1.3.

4.2.2.4 Energy storage system information

This describes the type and number of energy storage systems included in the product.

- a) Class A test procedure(s): Annex F: visual screening
- b) Class B test procedure(s): Annex D: manufacturer self-reported information
- c) Result: the type and number of batteries in the system
- d) Units: qualitative description

- e) Example: Unit A has a 3,7 V lithium-ion battery with a rating of 2 000 mAh; Unit B has a 3,7 V lithium-ion battery with a rating of 1 000 mAh.

4.2.2.5 Battery easy replaceability

This is an assessment of whether a low-skill technician can easily replace the battery with only a screwdriver (i.e., no soldering). It is important for considering the relevance of battery replacement information. Some batteries have longer lifetimes than others, so replaceability may be less important.

- a) Class A test procedure(s): Annex F: visual screening
- b) Class B test procedure(s): n/a
- c) Result: a yes or no result on whether it is “easy” to replace the battery
- d) Units: yes/no
- e) Example: Yes, battery is easily replaceable.

4.2.2.6 Battery general aspects

Those aspects of the battery(-ies) that are important for understanding selection of replacement batteries.

- a) Class A test procedure(s): Annex F: visual screening
- b) Class B test procedure(s): Annex D: manufacturer self-reported information or reference component rating
- c) Result (for each battery present):
 - 1) Battery chemistry
 - 2) Nominal voltage
 - 3) Package type
 - 4) Package size
 - 5) Connection type
- d) Units: qualitative type
- e) Example: A sealed lead-acid 4 V prismatic package, 20 mm × 20 mm × 60 mm, wire lead connections.

4.2.2.7 Packaging and user’s manual information

Information about the packaging, user’s manual, and other consumer-facing information helps establish a baseline for comparing measured values in truth-in-advertising assessments. It may also be important to document if certain programmes require particular information to be included in the manual, such as instructions for end-of-life disposal, particularly for batteries and other potentially hazardous components.

- a) Class A test procedure(s): Annex F: visual screening
- b) Class B test procedure(s): n/a
- c) Result: there are two types of result
 - 1) Photographic documentation of the packaging and manual (or digital copies of the original proofs)
 - 2) Notes on the type of manual and which languages are included
- d) Units: qualitative type and photographs
- e) Example: [Photographs attached to test reports], “the user’s manual is a single-sheet included in the package and includes pictograms with explanations in Hindi, English, French, and Swahili.”

4.2.2.8 Warranty information

The terms and duration of warranty coverage provided to end-users are important factors for engendering confidence in stand-alone off-grid lighting and trying to prevent early failure. In practice, servicing warranties is highly variable depending on the structure of supply and service chains.

- a) Class A test procedure(s): Annex F: visual screening
- b) Class B test procedure(s): Annex D: manufacturer self-reported information
- c) Result: detailed warranty terms and a “concise” version that highlights the key points of coverage and duration.
- d) Units: qualitative type
- e) Example: [Detailed warranty terms are documented in scanned attachments to test report], Coverage is against manufacturing defects or under normal use conditions. The product in general is covered for 6 months from the time of purchase; the PV module is warranted for 2 years.

4.2.2.9 Auxiliary features information

This notes all the auxiliary features present on the product. The incorporation of mobile phone charging or power for radios, for instance, may be important purchasing factors for a consumer.

- a) Class A test procedure(s): Annex F: visual screening
- b) Class B test procedure(s): Annex D: manufacturer self-reported information
- c) Result: list of included auxiliary features
- d) Units: qualitative type
- e) Example: The product has mobile phone charging capability and a radio.

4.2.2.10 Other visual screening results

This incorporates various other important results obtained from visual screening (Annex F), including, but not limited to, component dimensions, component masses, the number of light output settings, and provided specifications.

- a) Class A test procedure(s): Annex F: visual screening
- b) Class B test procedure(s): Annex D: manufacturer self-reported information
- c) Result: various results including qualitative descriptions and quantitative measurements.
- d) Units: qualitative descriptions and quantitative measurements
- e) Example (for one result): The product’s lamp unit and control box have masses of 0,3 kg and 1,5 kg, respectively.

4.2.3 Product durability and workmanship aspects

4.2.3.1 Water protection – enclosure

This provides a description of the product enclosure’s ability to keep out water in terms of IP class. For products intended to be used and/or charged outside, water protection is important for product function as well as user safety.

- a) Class A test procedure(s): Annex U: Physical and water ingress protection test according to IEC 60529 or using the alternative methods (U.4.3) if the alternative method results are unequivocal.
- b) Class B test procedure(s): Annex U: Physical and water ingress protection test
- c) Result: pass or fail for IP class (second digit) and a description of degree of water protection provided by enclosure
- d) Units: pass or fail and qualitative description

- e) Example: The product passes IP x3. The product's enclosure contains tight fitting components, all of which have gaskets to prevent water intrusion.

4.2.3.2 Water protection – circuit protection and drainage

This provides a description of any drainage means incorporated into a product and/or circuit board protection methods used in the product. The incorporation of drainage or circuit board protection is crucial for products intended to be outdoors that have enclosures providing little to no water intrusion protection.

- a) Class A test procedure(s): Annex F: visual screening combined with Annex D: manufacturer self-reported information
- b) Class B test procedure(s): Annex D: manufacturer self-reported information
- c) Result: qualitative description of drainage or circuit protection methods used.
- d) Units: qualitative description
- e) Example: The product has a conformal coating on its circuit board as well as drainage holes in the base of the enclosure to allow drainage of collected water.

4.2.3.3 Physical ingress protection

This provides a description of the degree of protection from the intrusion of foreign objects a product's enclosure provides in terms of IP class. Physical ingress protection is important for user safety as well as product functionality.

- a) Class A test procedure(s): Annex U: Physical and water ingress protection test according to IEC 60529 or using the alternative methods (U.4.2) if the alternative method results are unequivocal.
- b) Class B test procedure(s): Annex U: Physical and water ingress protection test
- c) Result: pass or fail for IP class (first digit) and description of degree of physical ingress protection.
- d) Units: pass or fail and qualitative description
- e) Example: The product passes IP 4x; the product enclosure's components fit together snugly without gaps, so that only tiny particulate matter (e.g., dust) could intrude.

4.2.3.4 Drop resistance

This provides an evaluation of a product's robustness and ability to withstand being dropped. Drop resistance is important for product functionality and user safety and satisfaction.

- a) Class A test procedure(s): Annex W: mechanical durability test
- b) Class B test procedure(s): n/a
- c) Result: pass or fail for functionality, damage, and the presence of user safety hazards.
- d) Units: a pass or fail result on whether the DUT functions, incurred damage, and presented a safety hazard to the user.

Example: When dropped, the product stopped working and its glass LED cover shattered, presenting a safety hazard to the user. Functional: Fail, Damage: Fail, Safety hazard: Fail.

4.2.3.5 Gooseneck durability

This provides an evaluation of a product's gooseneck's robustness and ability to withstand being torqued through its expected range of motion. Gooseneck durability is important for product functionality and user safety and satisfaction.

- a) Class A test procedure(s): Annex W: mechanical durability test
- b) Class B test procedure(s): n/a
- c) Result: a pass or fail for functionality, damage, and the presence of user safety hazards.

- d) Units: a pass or fail result on whether the DUT functions, incurred damage, and presented a safety hazard to the user.

Example: After the gooseneck test, the LEDs worked properly but there was visible damage (a cracked housing) that did not pose a hazard. Functional: pass. Damage: fail. Safety: pass.

4.2.3.6 Connector durability

This provides an evaluation of a product's connectors' robustness and ability to withstand plug cycling. Connector durability is important for product functionality and user safety and satisfaction.

- a) Class A test procedure(s): Annex W: mechanical durability test
- b) Class B test procedure(s): n/a
- c) Result: a pass or fail for functionality, damage, and the presence of user safety hazards.
- d) Units: a pass or fail result on whether the DUT functions, incurred damage, and presented a safety hazard to the user.

Example: After 400 cycles in the connector test, the PV module's barrel plug socket detached from the DUT enclosure, rendering the PV module connector unusable. Functional: fail. Damage: fail. Safety: pass.

4.2.3.7 Switch durability

This provides an evaluation of a product's switches' robustness and ability to withstand switch cycling. Switch durability is important for product functionality and user safety and satisfaction.

- a) Class A test procedure(s): Annex W: mechanical durability test
- b) Class B test procedure(s): n/a
- c) Result: a pass or fail for functionality, damage, and the presence of user safety hazards.
- d) Units: a pass or fail result on whether the DUT functions, incurred damage, and presented a safety hazard to the user.

Example: After 600 cycles in the switch test, the DUT's light switch stopped turning on the DUT. Functional: fail. Damage: fail. Safety: pass.

4.2.3.8 Strain relief durability

This provides an evaluation of a product's strain reliefs' robustness and ability to withstand being pulled. Strain relief durability is important for product functionality and user safety and satisfaction.

- a) Class A test procedure(s): Annex W: mechanical durability test
- b) Class B test procedure(s): n/a
- c) Result: a pass or fail for functionality, damage, and the presence of user safety hazards.
- d) Units: a pass or fail result on whether the DUT functions, incurred damage, and presented a safety hazard to the user.

Example: The DUT's strain reliefs all withstood the strain relief test without incurring any damage. Functional: pass. Damage: pass. Safety: pass.

4.2.3.9 Wiring quality

This provides a qualitative evaluation of a product's wiring quality, including (but not limited to) neatness and connection quality.

- a) Class A test procedure(s): Annex F: visual screening
- b) Class B test procedure(s): n/a

- c) Result: a qualitative description of wiring quality.
- d) Units: qualitative description and number of failures with respect to key indicators.

Example: The DUT's wires are neatly arranged (i.e., not tangled or wrapped around one another) and the solder joints are of good quality. No bad joints, pinched wires, or other poor wiring indicators.

4.2.3.10 Battery protection strategy

This provides a quantitative evaluation of a product's battery discharge-recharge protection strategy / algorithm, which is important for battery longevity as well as user safety.

- a) Class A test procedure(s): Annex S: charge controller behaviour test
- b) Class B test procedure(s): Annex D: manufacturer self-reported information
- c) Result: deep discharge and overvoltage protection voltages.
- d) Units: quantitative description

Example: The DUT has a deep discharge protection voltage of 1,92 V/cell and an overvoltage protection voltage of 2,4 V/cell.

4.2.4 Lighting durability aspects

4.2.4.1 500 hour lumen maintenance

This is a measure of the amount of light degradation after 500 h of operation at a constant voltage, which can provide valuable insight into the quality of the LEDs and/or the DUT's circuitry.

- a) Class A test procedure(s): Annex J: lumen maintenance test
- b) Class B test procedure(s): n/a
- c) Result: percentage of lumen output maintained after 500 h of constant operation.
- d) Units: percentage (%)
- e) Example: The DUT maintained 96 % of its original lumen output after 500 h of operation.

4.2.4.2 2 000 hour lumen maintenance

This is a measure of the amount of light degradation after 1 000 h and 2 000 h of operation at a constant voltage, which can provide valuable insight into the quality of the LEDs and/or the DUT's circuitry.

- a) Class A test procedure(s): Annex J: lumen maintenance test
- b) Class B test procedure(s): n/a
- c) Result: percentage of lumen output maintained after 1 000 h and 2 000 h of constant operation.
- d) Units: percentage (%)
- e) Example: The DUT maintained 96 % and 93 % of its original lumen output after 1 000 h and 2 000 h of operation, respectively.

4.2.4.3 Fluorescent light durability

These are additional checks of durability for fluorescent lights that account for their unique characteristics.

- a) Class A test procedure(s): PVRs 7A
- b) Class B test procedure(s): n/a
- c) Result: a pass or fail for durability tests in PVRs 7A

- d) Units: pass or fail
- e) Example: The DUT passed the durability tests in PVRs 7A.

4.2.5 Battery performance aspects

4.2.5.1 Battery capacity

This is a measure of the quantity of electricity (electric charge), usually expressed in ampere-hours (Ah), which a fully charged battery can deliver under specified conditions, which affects the run time of products.

- a) Class A test procedure(s): Annex K: battery test (all chemistries), 7.2.1 of IEC 61951-1 for nickel-cadmium batteries, 7.2.1 of IEC 61951-2 for nickel-metal hydride batteries, or 7.2.1 of IEC 61960 for lithium-based batteries.
- b) Class B test procedure(s): Annex D: manufacturer self-reported information or reference component rating
- c) Result: capacity of the battery at a particular discharge rate.
- d) Units: milliampere-hours (mAh) at a discharge rate expressed as the fraction of the battery capacity that is used each hour (I_t A)
- e) Example: 3 500 mAh at 0,2 I_t A

4.2.5.2 Battery storage efficiency

This is a measure of how efficient the DUT's battery is at storing energy to deliver for later use.

- a) Class A test procedure(s): Annex K: battery test
- b) Class B test procedure(s): n/a
- c) Result: storage efficiency of the battery pack.
- d) Units: percentage (%)
- e) Example: 95 %

4.2.5.3 Battery durability parameters

These are measures of battery capacity degradation from cycling and storing, which can indicate batteries that may degrade prematurely under typical use.

- a) Class A test procedure(s): Annex BB: battery durability test
- b) Class B test procedure(s): n/a
- c) Result: percent capacity loss from cycling, percent capacity loss from storing, and number of cycles necessary to reach 60 % of initial battery capacity.
- d) Units: percentage (%), cycles
- e) Example: The battery's capacity losses from cycling and storing are 80 % and 90 %, respectively. It takes 400 cycles to reach 60 % of the lithium-ion battery's initial capacity.

4.2.5.4 Battery voltage

This is important for matching to the other components and determines, along with the battery ampere-hour capacity, the energy capacity of the battery. It depends on the battery chemistry (what materials are used to store energy) and the number of electrochemical cells that are in series.

- a) Class A test procedure(s): Annex F: visual screening
- b) Class B test procedure(s): Annex D: manufacturer self-reported information or reference component rating
- c) Result: nominal voltage of the battery pack.

- d) Units: voltage (V)
- e) Example: 3,6 V

4.2.6 Solar module aspects

4.2.6.1 Solar I-V curve parameters

These are the key parameters describing solar module performance at standard test conditions ("STC"—AM 1,5, 25 °C cell temperature, 1 000 W/m² irradiance) and typical module operating temperature ("TMOT"—AM 1,5, 50 °C cell temperature, 1 000 W/m² irradiance).

- a) Class A test procedure(s): IEC 60904-1
- b) Class B test procedure(s): Annex Q: outdoor photovoltaic module I-V characteristics test
- c) Result (for both STC and TMOT):
 - 1) Open circuit voltage (V_{oc})
 - 2) Short circuit current (I_{sc})
 - 3) Maximum power voltage (V_{mpp})
 - 4) Maximum power current (I_{mpp})
 - 5) Peak power (P_{mpp})
 - 6) Voltage temperature coefficient (not dependent on STC nor TMOT)
- d) Units: volts (V), amperes (A), watts (W), per degree Celsius (1/°C)
- e) Example, STC values: $V_{oc} = 7,5$ V, $I_{sc} = 0,55$ A, $V_{mpp} = 5,8$ V, $I_{mpp} = 0,50$ A, and $P_{mpp} = 2,9$ W. The module's voltage temperature coefficient is $-0,004$ 2/°C.

4.2.6.2 Solar module cable length

The length of solar module cables is important because it is one aspect that determines the product category; a minimum length is typically specified for products to "qualify" as having separate PV modules to ensure that a user can place the solar module outdoors in a location with good solar access while the other components remain indoors. This has implications for the degree of water protection in quality standards.

- a) Class A test procedure(s): Annex F: visual screening
- b) Class B test procedure(s): n/a
- c) Result: the length of a solar module cable that is useful for separating the solar module from the enclosure that contains the battery being charged.
- d) Units: metres (m)
- e) Example: 3,5 m

4.2.7 Run time aspects

4.2.7.1 General

Run time is a key element of performance for lighting products. Each of the run time aspects listed below will be different for different light settings.

4.2.7.2 Full-battery run time

The full-battery run time is the duration of service provided to end-users from a fully charged battery and depends on the system-level performance for a particular setting. Regardless of the charging method, the full-battery run time is a relevant metric. For products that recharge centrally, it represents their hours of autonomy until the product shall be returned to a charging station (and potentially a fee shall be paid). For solar-charged products, it represents the ability to store excess energy for a rainy day. For electromechanically-charged products, it represents the maximum period the product can be operated in between charges.

- a) Class A test procedure(s): Annex M: full-battery run time test
- b) Class B test Standards(s): n/a
- c) Class C test procedure: Annex AA: field testing methods
- d) Result: hours of operation to 70 % of the initial brightness when beginning with a fully charged battery; sometimes also known as “autonomous run time.”
- e) Units: hours (h)
- f) Example: 9,3 h

4.2.7.3 Solar-day run time

The solar-day run time is the duration of service provided to end-users from one day of solar charging and depends on the system-level performance for a particular setting. The standard solar charging day is defined as an incident solar resource of 5 kWh/m². This is an important metric because it is an estimate of the day-to-day services users can expect in ideal charging conditions. It is important to note that variations in available solar energy (due to climate, weather, or user behaviour) will result in commensurate differences in actual run time from solar charging.

- a) Class A test procedure(s): Annex R: solar charge test
- b) Class B test procedure(s): n/a
- c) Class C test procedure: Annex AA: field testing methods
- d) Result: hours of operation to 70 % of the initial brightness after the battery is charged from empty for one standard solar day (defined above).
- e) Units: hours (h)
- f) Example: 4,5 h

4.2.7.4 Grid-charge run time

The grid-charge run time is the run time for DUTs that are centrally charged (i.e., with a central charging station or the grid). This is an important metric because it provides the expected run time after a full day of grid charging.

- a) Class A test procedure(s): Annex O: grid charge test
- b) Class B test procedure(s): n/a
- c) Result: hours of operation to 70 % of the initial brightness after the battery is grid charged from empty.
- d) Units: hours (h)
- e) Example: 6,3 h

4.2.7.5 Electromechanical charge ratio

The electromechanical charge ratio is the response factor for electromechanical (i.e., dynamo) charging—a ratio of run time to charging time (i.e., with an electromechanical charger that is included with the device and not at a central electromechanical charging station). The electromechanical charging is done at a controlled rate. This is an important metric because it allows one to estimate the duration of user effort required each day for a given level of service.

- a) Class A test procedure(s): Annex P: electromechanical charge test
- b) Class B test procedure(s): n/a
- c) Result: ratio of time of operation to charging time.
- d) Units: unitless
- e) Example: 12 min run time per 1 min of charging time

4.2.8 Light output aspects

4.2.8.1 Average luminous flux output

Average luminous flux output is the light output of a DUT when it is operated at the average operating point from the full-battery run time test. This is a key metric that compares the overall light output of DUTs.

- a) Class A test procedure(s): CIE 084, CIE 127, IESNA LM-78-07, or IESNA LM-79-08
- b) Class B test procedure(s): Annex I: light output test
- c) Class C test procedure(s): Annex AA: field testing methods
- d) Result: average luminous flux.
- e) Units: lumens (lm)
- f) Example: 95,6 lm

4.2.8.2 Full width half maximum (FWHM) angles

The full width half maximum angle is a metric used to understand the light distribution of a DUT and is the total included angle for which the illumination is greater than or equal to half the illumination at the brightest point in the plane.

- a) Class A test procedure(s): CIE 084, CIE 127, IESNA LM-79-08
- b) Class B test procedure(s): Annex T: light distribution test
- c) Result: vertical and horizontal FWHM angles.
- d) Units: degrees (°)
- e) Example: The DUT's horizontal and vertical FWHM angles are both 65°.

4.2.8.3 Average light distribution characteristics

A light distribution is the illuminance "map" of a DUT. This metric is useful for determining the utility with respect to task lighting. The test is done with the DUT operating at the average operating point from the full-battery run time test.

- a) Class A test procedure(s): CIE 084, CIE 127, IESNA LM-79-08
- b) Class B test procedure(s): Annex T: light distribution test
- c) Class C test procedure(s): Annex AA: field testing methods
- d) Result: constant-voltage useable area at a specified distance.
- e) Units: square metres (m²)
- f) Example: The DUT's useable area at a distance of 0,5 m is 0,76 m².

4.2.8.4 Colour characteristics

The colour characteristics of light determine how accurately the light renders colours (CRI) and the colour of the light expressed as a temperature in kelvin.

- a) Class A test procedure(s): Annex I: light output test
- b) Class B test procedure(s): n/a
- c) Result: CRI value and colour temperature
- d) Units: CRI is unitless and the colour temperature is in kelvin (K)
- e) Example: The CRI is 80 and the colour temperature is 7 000 K.

4.2.9 Battery-charging circuit efficiency

The battery-charging circuit efficiency, or generator-to-battery charging efficiency, is a measure of how efficient the DUT electronics are at feeding generated energy into the battery.

- a) Class A test procedure(s): IEC 62509
- b) Class B test procedure(s): Annex R: solar charge test
- c) Result: battery-charging circuit efficiency.
- d) Units: percentage (%)
- e) Example: 90 %

4.2.10 Self-certification aspects

4.2.10.1 Product and manufacturer information

Manufacturer-reported product and manufacturer information is important for tracking purposes as well as for ensuring the test lab has up-to-date product information.

- a) Class A test procedure(s): Annex D: manufacturer self-reported information
- b) Class B test procedure(s): n/a
- c) Result: various qualitative and quantitative information
- d) Units: qualitative and quantitative

Example: The product's free-on-board price is 30 \$USD, it is sold in Kenya and India, etc.

4.2.10.2 Warranty coverage

Warranty coverage goes beyond the terms of a warranty and provides detail on coverage in a particular location. It is typically only provided in cases where it is necessary to verify coverage in a particular town or region.

- a) Class A test procedure(s): Annex D: manufacturer self-reported information
- b) Class B test procedure(s): n/a
- c) Result: qualitative description
- d) Units: qualitative description
- e) Example: The support in [region name] is provided by a small network of technicians who have been trained to repair products by [manufacturer or distributor name]. For repairs that are beyond the scope of their capabilities, replacement products are provided. The consumers in [region name] can access warranty service by dialling a phone number that is on a sticker placed on the original packaging.

4.2.10.3 Third-party marks and certifications

Third-party marks and certifications (e.g., UL) can be an important aspect in the eyes of consumers and investors, alike.

- a) Class A test procedure(s): Annex D: manufacturer self-reported information
- b) Class B test procedure(s): n/a
- c) Result: qualitative marks and certifications
- d) Units: qualitative type
- e) Example: ISO 9001-certified.

4.2.11 Water protection integrated assessment

This combines the protection afforded by the enclosure, circuit protection, and consumer labelling to assess the overall protection from water exposure.

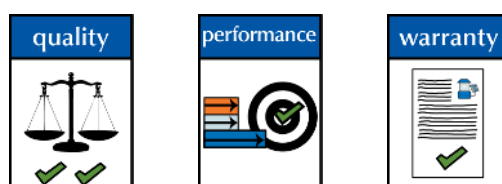
- a) Class A test procedure(s): Annex V: level of water protection
- b) Class B test procedure(s): n/a

- c) Result: descriptive assessment of exposure protection by enclosure only, technical means, and overall system. The assessment categories are “no protection,” “occasional rain,” and “frequent rain.”
- d) Units: qualitative type
- e) Example: Enclosure only: no protection. Technical means: occasional rain. Overall: occasional rain

5 Product specification

5.1 General

Quality standards, warranty requirements, and performance targets are used to interpret the measurements and observations made about a product. Together they form a product specification.



- **Quality standards** set a minimum level of durability and protect buyers and users from false advertising claims.
- **Warranty requirements** set a minimum level of user protection from early failure.
- **Performance targets** set a recommended level of service and features.

Each criterion in a specification refers to a particular aspect of the product, as listed in 4.2, and requires a minimum level of quality, service, or performance.

The standards, requirements, and targets should be appropriate for the goals of the organization or individual who is using them as a framework for quality assurance and should consider the following factors:

- Availability of products on the market with the necessary quality and performance.
- Ability of buyers to pay for the products.
- Diversity of end-user needs.
- Tolerance for manufacturing variation.

This clause describes the framework for standards, requirements, and targets in general and offers insights on the best practices for creating a product specification. It includes a “blank” product specification followed by guidance on “filling in” each section. Annex A presents an example specification for off-grid lighting market support programme qualification. Annex B presents another example, for bulk procurement.

5.2 Applications

Product specifications that include some combination of quality standards, warranty requirements, and performance targets can support a broad range of quality assurance needs. Table 1 below lists examples of how they are applied depending on the type of quality assurance framework:

Table 1 – Applications of product specifications

Type of QA framework	Example(s) of applying this clause
General market support	Use quality standards and general warranty requirements to qualify for market support; provide additional services if performance targets are also met. Use quality standards to qualify for a business-to-business seal.
Manufacturing / distribution	For manufacturers: incorporate quality standards and performance targets from market support programmes or distributors in the design and production QC processes. For distributors: set minimum quality standards, warranty requirements, and/or performance targets for products to identify suppliers.
Bulk procurement	Set minimum quality standards, warranty requirements, and/or performance targets for products to qualify in a request for offers. If the project is in a specific location, the warranty requirements may also include specific levels of service in that particular area.
Trade regulation	Set minimum quality standards for tax exemption or customs.

5.3 Quality assurance principles

5.3.1 General

The framework for considering quality standards, warranty requirements, and performance targets presented in this document is designed to support broad types of programmes and institutions in the off-grid lighting market. The following key principles guide the framework:

- Balance quality and affordability for price-sensitive buyers—it does not matter how well products perform if the target users cannot afford them.
- Encourage innovation and technological diversity. Wherever possible, be open-ended in the technical approaches that are allowed.
- Empower buyers to choose the right product for their needs and budget by focusing product specifications and communication on outcomes for end-users.
- Use low-cost, rigorous, targeted tests to match the general affordability requirements for the market and accommodate both incremental and innovative changes to product design. The tests should be feasible for use by a broad set of potential users.
- Focus quality standards on elements of a product that are difficult for typical buyers to assess themselves, like truth-in-advertising and durability.
- Focus warranty requirements on providing a baseline of support.
- Focus performance targets on bottom-line user experience metrics like run time and brightness.

5.3.2 Rationale for dividing quality, warranty, and performance

Quality standards, warranty requirements, and performance targets are considered separately for two reasons:

- Allows programmes and institutions the flexibility to establish targets with their goals in mind:
 - Quality standards deal with basic consumer protection (from early product failure, unsafe operation, or false advertising) and typically are a “baseline” or minimum level.
 - Warranty requirements deal with aspects of the product that are not controlled at the factory—the service available for products is typically very dependent on the supply chain and geography.
 - Performance targets are typically in addition to quality standards and define service levels that should be met. The diversity of needs and ability of end-users to pay shall be known to properly set performance targets.
- Enables tiered service offerings for market support programmes. For instance, it is possible to have a tiered support system in which certain services only require fee.

quality standards and warranty requirements while others also require performance targets.

5.4 Product specification framework description

5.4.1 General

This subclause describes the framework for creating a product specification for off-grid lighting. First, a blank specification is provided that lists all the pieces that may be specified. It is followed by a subclause describing guidelines for setting tolerances in a product specification. Finally, the main sections in a specification are described in more detail with notes and guidance.

There are example product specifications in Annex A and Annex B; one is for general market support programmes and the other is a “sample tender” for bulk purchasing.

A product specification has six parts:

- a) **Scope:** defines the applicability and use of the quality standards and performance targets
- b) **Test requirements:** defines requirements for test result validity
- c) **Product category requirements:** unambiguously defines the categories that may be referenced later
- d) **Quality standards:** lists quality-related aspects and minimum or required results for each aspect with a tolerance; may be subdivided by product category
- e) **Warranty requirements:** lists requirements for minimum levels of warranty support
- f) **Performance targets:** lists performance-related aspects and minimum or required results for each aspect with a tolerance; may be subdivided by product category

5.4.2 Blank product specification document

5.4.2.1 General

This subclause is a blank framework for setting quality standards, warranty requirements, and performance targets to support the goals of a programme or institution. Note that in many applications certain criteria or entire categories of criteria may not apply and should be removed. Text in *italics* is intended for replacement and describes what should go in each space.

5.4.2.2 Scope

Describe the intended use of the product specification. Describe the contents in general and provide guidance on how to use the document.

5.4.2.3 Test requirements

Specify the level of testing that is required. Typically this is Quality Test Method (QTM) testing (see Clause 6).

5.4.2.4 Product category requirements

Describe which product categories (see 4.1.2) are covered / allowed.

Describe any other requirements for products that are categorical (e.g., shall be solar charged).

Qualification as a “separate” PV module requires meeting the criteria listed below (Table 2):

Table 2 – Qualification as separate PV module

Criterion	Aspect(s)	Required value
PV module cable length	4.2.6.2 Solar module cable length	<i>Define the length in metres that is required for qualification as a separate PV module.</i>

5.4.2.5 Quality standards

The product shall meet each of the criteria listed in the truth-in-advertising (Table 3), safety and durability (Table 4), and end-user support (Table 5) tables.

Table 3 – Truth-in-advertising tolerance

Truth-in-advertising criterion	Aspect(s) considered in assessment	Requirement
System performance tolerance – numeric ratings	4.2.7 Run time aspects 4.2.8 Light output aspects Others, if applicable	<i>Define the tolerance for deviation from ratings.</i>
System components tolerance – numeric ratings	4.2.6 Solar module aspects 4.2.5 Battery performance aspects Others, if applicable	<i>Define the tolerance for deviation from ratings.</i>
Other numeric ratings tolerance	Multiple	<i>Define the tolerance for deviation from ratings.</i>
Overall truth-in-advertising statement	Multiple	<i>Include an overall description of the requirements for truth-in-advertising that may not be covered by the requirements above.</i>

Table 4 – Safety and durability standards

Safety or durability criterion	Aspect(s) considered in assessment	Product category (form factor and/or technology)	Requirement
Level of water exposure protection (<i>overall, technical, or enclosure-only</i>)	4.2.11 Water protection integrated assessment	Category 1	Define level of protection in terms of water protection integrated assessment: No protection, occasional rain, frequent rain, or permanent outdoor exposure.
	4.2.3.1 Water protection – enclosure 4.2.3.2 Water protection – circuit protection and drainage 4.2.10.1 Product and manufacturer information 4.2.2.7 Packaging and user's manual information	Category 2...	Define level of protection in terms of water protection integrated assessment.
Physical ingress protection	4.2.3.3 Physical ingress protection	Category 1	Define level of protection in terms of IP class.
		Category 2...	Define level of protection in terms of IP class.
Mechanical durability – drop test	4.2.3.4 Drop resistance	Category 1	Define maximum number of failures out of the number that are tested for damage, functionality, and safety.
		Category 2...	Define maximum number of failures out of the number that are tested for damage, functionality, and safety.
Mechanical durability – goosenecks	4.2.3.5 Gooseneck durability	Products with goosenecks	Define maximum number of failures out of the number that are tested for damage, functionality, and safety.
Mechanical durability – connectors	4.2.3.6 Connector durability	Products with connectors	Define maximum number of failures out of the number that are tested for damage, functionality, and safety.
Mechanical durability – switches	4.2.3.7 Switch durability	All products	Define maximum number of failures out of the number that are tested for damage, functionality, and safety.
Mechanical durability – strain relief	4.2.3.8 Strain relief durability	Products with connectors	Define maximum number of failures out of the number that are tested for damage, functionality, and safety.
Workmanship	4.2.3.9 Wiring quality	All products	Define maximum number of samples with bad solder joints, poor wiring, etc. out of the number that are tested.
Battery durability	4.2.3.10 Battery protection strategy	All products	Define a minimum level of battery protection that will protect the product's battery and the user.
Lumen maintenance	4.2.4.2 2 000 hour lumen maintenance	All products	Define maximum number of samples that may fail specified lumen maintenance criteria out of the number that are tested.
Fluorescent light durability	4.2.4.3 Fluorescent light durability	Products with fluorescent lights	Define maximum number of failures out of the number that are tested.

Table 5 – End-user support standards

Truth-in-advertising criterion	Aspect(s) considered in assessment	Requirement
Information on product design, utilization, and care	4.2.2.7 Packaging and user's manual information	<i>Define if there are requirements for consumer-facing information on packaging or in a user's manual, such as end-of-life disposal instructions.</i>
Other	4.2.2.10 Other visual screening results	<i>Define other product requirements that support end-users to maintain the quality of the product.</i>

5.4.2.6 Warranty requirements

The product shall meet each of the end-user support requirements listed in Table 6.

Table 6 – End-user support requirements

Support type	Aspect(s)	Requirement
Maintenance and warranty terms	4.2.2.8 Warranty information	<i>Define minimum warranty requirements (length, components covered, etc.)</i>
Service capabilities	4.2.10.2 Warranty coverage	<i>Define "on the ground" requirements for warranty service (typically only for projects in a specific location)</i>

5.4.2.7 Performance targets

In addition to meeting the quality standards and warranty requirements, at least one product setting shall meet one of the run time criteria (Table 7) and one of the lighting service criteria (Table 8). The product shall also meet the additional features criteria (Table 9).

Table 7 – Run time criteria for performance targets

Run time criterion	Aspect(s)	Requirement
Central charged product full-battery run time	4.2.7.4 Grid-charge run time 4.2.7.2 Full-battery run time	<i>Define minimum full-battery run time in hours (h) and compliance tolerance (%).</i>
Independently solar charged product – solar-day run time	4.2.7.3 Solar-day run time	<i>Define minimum solar-day run time in hours (h) and compliance tolerance (%).</i>
Independently electromechanically-charged product – electromechanical run time characteristics	4.2.7.5 Electromechanical charge ratio 4.2.7.2 Full-battery run time	<i>Define minimum electromechanical charge run time ratio (unitless) and full-battery run time in hours (h) with compliance tolerances (%).</i>

Table 8 – Lighting service criteria for performance targets

Light output criterion	Aspect(s)	Requirement
General illumination service	4.2.8.1 Average luminous flux output	<i>Define minimum average lumen output (lm) through the product's discharge and compliance tolerance (%).</i>
Task lighting service	4.2.8.3 Average light distribution characteristics	<i>Define minimum average useable area (m²) at a specified distance through the product's discharge and compliance tolerance (%).</i>

Table 9 – Additional features criteria for performance targets

Support Type	Aspect(s)	Requirement
Mobile phone charging	4.2.2.9 Auxiliary features information	<i>Define minimum included auxiliary features (e.g., mobile phone charging with at least three different connectors).</i>
Other	4.2.2.9 Auxiliary features information	<i>Define other required features.</i>

5.4.3 Tolerances

Tolerances are an allowable deviation from the target value for a particular criterion in a product specification and are part of the product specification. In the case of truth-in-advertising the target value is what is advertised. For performance targets, the target value is the minimum performance level. Durability tests and other pass/fail criteria also have a target—passing the test.

Tolerances should be set carefully, considering how the measured or observed values from a test (with a limited number of samples) characterize the true quality or performance aspects of every product in the market. The sample size, expected manufacturing tolerance, and testing uncertainty should each be considered.

There are trade-offs between protecting buyers/end-users and suppliers from “false positive” and “false negative” results, respectively. Tighter tolerance tends to protect buyers/end-users better from poor quality or performance products but will also result in a higher number of good quality or performance products being excluded based on non-representative sampling or test results. The dynamic is reversed for looser tolerances.

The type of tolerance depends on the aspect being specified:

- a) Qualitative: aspects that are descriptive (e.g., type of light source) do not typically have a tolerance.
- b) Numeric: aspects that are described with a measured value (e.g., battery capacity) should have a tolerance defined in terms of percent deviation of the average DUT measurement from a particular value. Often it is allowable for the test result to deviate in one “direction” but not the other. For instance, it is allowable to over-perform on the run time but not underperform. There may also be a tolerance defined for the variance in results of the DUT.

In general, the percent deviation from a target value is calculated using the following formula:

$$D = 100\% \times \frac{x_{\text{meas}} - x_{\text{target}}}{x_{\text{target}}}$$

where:

D is the percent deviation in a numeric value;

x_{target} is the target value;

x_{meas} is a measured value or the average of the measured values for each sample.

- c) Boolean: aspects that are described in terms of “pass/fail” (e.g., drop test) should have a tolerance defined in terms of the number of allowable failures out of a set number of trials or tests. Note that the statistical power of Boolean results for predicting population pass/fail rates is not very high with small sample sizes. The implication is that it is not possible to accurately predict population failure rates for a particular aspect from a small sample size, and it is often appropriate to allow some small but reasonable failure rate to avoid false negative results.

5.4.4 Quality standards criteria

5.4.4.1 General

The following subclauses describe the quality standards aspects and give guidance on how to implement a quality standard.

There are several categories of quality criteria listed below. For each category, it is important for a set of quality standards to specify:

- Which aspects are referenced by the criteria.
- What level of failure or minimum quality level is acceptable for each aspect.
- Which product categories are subject to each criterion if there are differences across categories.

5.4.4.2 Truth-in-advertising

The goal of a truth-in-advertising standard (see Table 10) is to protect buyers and end-users from false advertising claims. It is particularly important to ensure that the description of advertised values corresponds with test results in cases where end-users will make product purchasing decisions based partly or solely on advertising and packaging.

In practice it is ideal to check **any** advertised quality or performance statements against the test results, keeping in mind that often the framing or messaging for advertised statements is different from test conditions and that there is inherent uncertainty in the test result. In those cases where the advertised values will not be directly comparable to test results, care should be taken to avoid wrongly identifying false advertising.

For aspects that are described with numeric information, a tolerance should be defined for truth-in-advertising.

For aspects that are described with qualitative or Boolean information, judgement is required to discern if the test results match advertised values.

Table 10 – Truth-in-advertising criteria for quality standards

Truth-in-advertising criterion	Aspect(s) considered in assessment	Standard specification	Notes
System performance tolerance – numeric ratings	4.2.7 Run time aspects 4.2.8 Light output aspects Others, if applicable	The tolerance between the rated performance and measured performance.	These are key aspects for end-user experiences with the product, but also tend to have test results with higher uncertainty due to a combination of intrinsic manufacturing variation and test uncertainty due to the system-level nature of the aspects.
System components tolerance – numeric ratings	4.2.6 Solar module aspects 4.2.5 Battery performance aspects Others, if applicable	The tolerance between the rated performance and measured performance.	These aspects, while important, have less impact on the overall user experience in general. They are more important for identifying replacement parts.
Other numeric ratings tolerance	Multiple	The tolerance between the rated performance and measured performance.	n/a
Overall truth-in-advertising statement	Multiple	Describe the general policy for interpreting truth-in-advertising requirements. Suggested statement: “Each description of the product that appears on the packaging, inside the package, and in any other media should be truthful and accurate. No statements should mislead buyers or end users about the features or utility of the product.”	It is important to lay out a broad expectation of truth-in-advertising and to interpret it on a case-by-case basis.

Table 11 includes notes with guidance on aspects that are often part of a truth-in-advertising check because they are commonly advertised.

Table 11 – Notes on common truth-in-advertising aspects

Aspect(s)	Notes
4.2.7.2 Full-battery run time	Depends on the setting.
4.2.7.3 Solar-day run time	Depends on the setting and often depends on the assumptions about solar resource, which may be location-dependent.
4.2.7.4 Grid-charge run time	Depends on the setting.
4.2.7.5 Electromechanical charge ratio	Depends on the setting.
4.2.8.1 Average luminous flux output	Normally listed as peak luminous flux instead, but other times as the average during discharge, which is more representative of typical service levels.
4.2.2.6 Battery general aspects 4.2.5 Battery performance aspects 4.2.2.5 Battery easy replaceability	Package type, nominal voltage, capacity are all important for understanding if spares will be available; the replaceability determines if it is easy to service.
4.2.5 Battery performance aspects 4.2.2.4 Energy storage system information 4.2.2.6 Battery general aspects	This information is useful for ensuring the correct replacement battery can be obtained.
4.2.8.3 Average light distribution characteristics	Peak illuminance at a specified distance is often advertised in lieu of luminous flux. It is important to carefully adjust the test result to match the distance specified in the advertised value using known light propagation relationships ("inverse square law").
4.2.6 Solar module aspects	Peak power capacity and type are often listed.
4.2.2.9 Auxiliary features information	The presence of functional auxiliary features (e.g., a mobile phone charger or USB power source) may be very important to some end-users.
4.2.3.1 Water protection – enclosure 4.2.3.2 Water protection – circuit protection and drainage	Ensure that there is no information that misleads consumers about the level of protection afforded them by the combination of the enclosure and other water protection systems.
4.2.4.2 2 000 hour lumen maintenance	Lifetime is often given for much longer durations (e.g., 20 000 h). These may be compared to the 2 000 h lifetime to ensure the claim is possible.

5.4.4.3 Safety and durability

5.4.4.3.1 General

Safety and durability criteria protect the user from harm and the product from early failure during typical use. It is important to balance the safety and durability requirements with cost implications and reasonable expectations of consumer care, or the safety and durability criteria risk being over-prescribed. It is helpful to consider the expected minimum product lifetime when determining durability-related criteria.

For pass/fail tests, tolerances for failure rates should be specified (see Table 12).

Table 12 – Safety and durability criteria for quality standards

Safety or durability criterion	Aspect(s) considered in assessment	Standard specification	Notes
Level of water exposure protection (overall, technical, or enclosure-only)	4.2.11 Water protection integrated assessment 4.2.3.1 Water protection – enclosure 4.2.3.2 Water protection – circuit protection and drainage 4.2.10.1 Product and manufacturer information 4.2.2.7 Packaging and user's manual information	The required level of water protection (see list below) and which aspects may contribute to protection. Levels of water protection: No protection Occasional rain Frequent rain Permanent outdoor exposure	The degree of protection should include consideration of product category and expected exposure. Specify the aspects that may contribute to the level of water exposure protection by choosing an overall, technical, or enclosure-only criterion.
Physical ingress protection	4.2.3.3 Physical ingress protection	The required level of physical ingress protection in terms of the minimum IP Class.	Degree of protection should include consideration of product category and expected exposure. Also, consider how connectors will be incorporated. Most external power connectors are not protected above IP2x.
Mechanical durability – drop test	4.2.3.4 Drop resistance	The required success rates in the drop test for functionality and safety (two success rates).	Failure allowance should consider Boolean nature of results and consider product category (i.e., fixed products are unlikely to be dropped compared to portable products).
Mechanical durability – goosenecks	4.2.3.5 Gooseneck durability	The required success rates in the gooseneck durability test for functionality and safety (two success rates).	Only applies to lamps with a gooseneck.
Mechanical durability – connectors	4.2.3.6 Connector durability	The required success rates in the connector test for functionality and safety (two success rates).	Failure allowance should consider Boolean nature of results.
Mechanical durability – switches	4.2.3.7 Switch durability	The required success rates in the switch test for functionality and safety (two success rates).	Failure allowance should consider Boolean nature of results.
Mechanical durability – strain relief	4.2.3.8 Strain relief durability	The required success rates in the strain relief test for functionality and safety (two success rates).	Failure allowance should consider Boolean nature of results.
Workmanship	4.2.3.9 Wiring quality	The required success rate for each aspect of the wiring quality inspection.	Failure allowance should consider the prevalence of each fault type.
Battery durability	4.2.3.10 Battery protection strategy	The guidelines for determining if batteries are well protected from early failure and if users are protected from potential harm due to battery failure.	Be careful not to over-prescribe the requirements, since there are a wide range of battery protection strategies that may provide satisfactory results—particularly for emerging chemistries.
Lumen maintenance	4.2.4.2 2 000 hour lumen maintenance	The minimum average level of lumen maintenance after 2 000 h and the required success rate on a sample-to-sample basis.	Consider the expected rate of use and desired product lifetime.
Fluorescent light durability	4.2.4.3 Fluorescent light durability	The required success rate for each sample in additional tests for fluorescent light durability.	Failure allowance should consider Boolean nature of results.

5.4.4.3.2 Water exposure protection considerations

The specifying organization should consider several factors when establishing water exposure protection requirements for solar lighting products. The product category (as outlined in 4.1.2) is primarily responsible for determining these requirements, as some products are more likely than others to be exposed to water based on the product design. Cost is also a consideration, as products designed to be resistant to higher levels of water exposure are often more expensive because of the additional manufacturing costs associated with sealing the enclosure or internal circuit elements.

Table 13 describes how various levels of water protection are determined based on a combination of laboratory test results, product design and manufacturing information, and consumer information. The levels of protection are:

- No protection
- Occasional rain
- Frequent rain
- Permanent outdoor exposure

The results of an assessment will include several “types” of water protection level. A quality standard will need to specify which type is applicable. The types are:

- Overall protection: water protection by all the potential sources, including user behaviour
- Technical protection: protection from all product design and manufacturing aspects
- Enclosure-only protection: protection from the enclosure only

Table 13 – Recommended level of water protection by product category

Product category	Recommended level of water protection	Notes
Fixed separate (indoor)	No protection	Products intended for indoor use are unlikely to be exposed to water and do not require water protection.
Portable separate	Occasional rain	Portable products may experience occasional water exposure in service and should have some degree of water protection.
Portable integrated	Frequent rain	Portable integrated products are likely to be exposed to water when left outside to solar charge and should have good water exposure protection.
Fixed integrated (outdoor)	Permanent outdoor exposure	Outdoor products are certain to be exposed to rain and should have a high degree of water exposure protection.

5.4.4.4 End-user support

End-user support criteria describe the information (labelling, instructions, and built-in indicators) that enables end-users to maintain and fully realize the potential of a device (Table 14).

Table 14 – End-user support criteria for quality standards

End user support criterion	Aspect(s) considered in assessment	Standard specification	Notes
Information on product design, utilization, and care	4.2.2.7 Packaging and user's manual information	Requirements for end-user information.	Define if there are requirements for consumer-facing information on packaging or in a user's manual. This may be more appropriate for specific, targeted programmes than general market support or market offerings, since it is unlikely that a broad set of products will be available that meet any particular set of guidelines. In some cases, a specific piece of information may have implications for the required level of quality in another criterion (e.g., advising the user to protect the device from exposure to water on the packaging or in the user's manual may warrant a reduction in the requirements for water protection defined by 4.2.3.1 and 4.2.3.2)
Other	4.2.2.10 Other visual screening results	Requirements for particular aspects of the visual screening.	Define if there are requirements for other aspects of end-user support (e.g., indicator lights). As with requirements for consumer-facing information, these requirements should be added with care to avoid over-prescribing.

5.4.5 Warranty requirements criteria

Warranty requirements are generally narrow in scope, focusing on the minimum duration and coverage for product warranties. In situations where there is a specific need for service in a particular location, service capabilities may be added to the warranty requirements. Table 15 lists criteria that are included in a warranty standard.

Table 15 – Criteria for warranty standards

End user support criterion	Aspect(s) considered in assessment	Standard specification	Notes
Maintenance and warranty terms	4.2.2.8 Warranty information	Minimum warranty duration and coverage.	Define the minimum warranty terms with consideration for the implications on availability of service and reasonable expectations for guaranteed lifetime.
Service capabilities	4.2.10.2 Warranty coverage	Minimum availability of service to end-users in a particular location	These requirements are very specific to "local" projects typically.

5.4.6 Performance targets criteria

5.4.6.1 General

The following subclauses describe aspects that are appropriate for use as performance targets and gives guidance on implementing a set of targets.

There are several categories of performance criteria listed below. For each category, it is important for a set of performance targets to specify:

- What level of performance is acceptable for each aspect
- Whether minimum levels of performance are contingent on also meeting others (e.g., a combination of run time and brightness)
- How many product settings shall meet the criteria ¹⁾
- Which product categories are subject to each criterion if there are differences across categories

¹⁾ It is generally appropriate to set performance targets that should be met by one setting or more, but allow flexibility for the remaining settings.

5.4.6.2 Combined run time and lighting service targets

5.4.6.2.1 General

Each product setting (“brightness level”) may be described by a set of run times and lighting service. A set of performance targets includes a “combined” target to meet minimum run time(s) at a minimum lighting service level(s), and if at least one setting meets the combined target the product is in compliance. There may be more than one combined target.

5.4.6.2.2 Run time

Run time is a key performance indicator for lighting products; the duration of lighting service is directly related to end-user utility.

It is important to consider the range of charging options (see 4.2.2.2) available to end-users and their likely service needs when setting run time criteria. Often, an “or” requirement is appropriate that allows compliance with any one of the criteria to pass an overall run time assessment. Table 16 lists run time criteria for performance targets.

Table 16 – Run time criteria for performance targets

Run time criterion	Aspect(s) considered in assessment	Target specification	Notes
Central charged product full-battery run time	4.2.7.2 Full-battery run time 4.2.7.4 Grid-charge run time	The minimum full-battery run time and grid run time.	Set the target high enough to meet 1 day to 2 days of lighting service requirements for the end-user who will charge via centralized means. Note that many products with solar charging can also be charged via centralized means if they have an input port.
Independently solar charged product – solar-day run time	4.2.7.3 Solar-day run time	The minimum solar run time for a given solar resource.	Set the target high enough to meet typical daily needs given a standard or specific solar resource. Typically based on the standard solar day (5 kWh/m ²)
Independently electromechanically-charged product – electromechanical run time characteristics	4.2.7.2 Full-battery run time 4.2.7.5 Electromechanical charge ratio	The minimum full-battery run time and electromechanical run time.	Set an electromechanical charge run time that is reasonable in terms of user effort and a Full-battery run time that ensures the user can use a product for sufficiently long periods of time between charging.

Table 17 lists some benchmarks for run time requirements that may be helpful for setting performance targets:

Table 17 – Run time benchmarks

Service type / context	Service level	Notes and source
2008 evening / night time illumination in off-grid Sub-Saharan Africa using fuel-based lighting	Median 3,5 h – 4 h, range of 2 h – 6 h.	From a set of market research surveys across five countries in Sub-Saharan Africa (Lighting Africa). Note this does not include early morning illumination needs, which may be an hour or more.
2007 night fishing in India	4 h – 6 h for fish sorting; 10 h for night fishing; 1,5 h for household uses.	From a small-sample survey in a fishing village (<i>Improved Lighting for Indian Fishing Communities</i> , ER291-3 Final Report May 16, 2007)

5.4.6.2.3 Lighting service

Lighting service levels determine the usefulness of a device for particular activities.