PD IEC TS 62257-9-5:2018

BSI Standards Publication

Recommendations for renewable energy and hybrid systems for rural electrification

Part 9-5: Integrated systems - Laboratory evaluation of stand-alone renewable energy products for rural electrification

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National foreword

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RECOMMENDATIONS FOR RENEWABLE ENERGY AND HYBRID SYSTEMS FOR RURAL ELECTRIFICATION –

Part 9-5: Integrated systems – Laboratory evaluation of stand-alone renewable energy products for rural electrification

FOREWORD

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The main task of IEC technical committees is to prepare International Standards. In exceptional circumstances, a technical committee may propose the publication of a Technical Specification when

- 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.

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Full document details: PD IEC TS 62257-9-5:2018

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

This fourth edition cancels and replaces the third edition issued in 2016. It constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) Replaced the term "stand-alone lighting kits" with "stand-alone renewable energy products" throughout the document (including the title) to reflect that the revised document is applicable to a broader range of products with a more diverse set of capabilities.
b) Removed the distinction between Class A, Class B, and Class C procedures.
c) Added an option for the AVM method in which the AVM-VE test can be conducted with a sample size of 6 and the follow-up test can be conducted with a sample size of 2.
d) Provided guidance on how to accept test results from other approved test methods.
e) Added test methods for flooded lead-acid batteries.
f) Significantly revised the protection tests, assessment of DC ports, appliance tests, and energy service calculations based on field experience.
g) Revised the voltage operating points at which testing is carried out to better reflect actual operation and to simplify the procedures for testing products without lights.
h) Revised the energy service calculations to include the effect of multiple simultaneously connected loads on the port voltage and battery-to-port efficiency and to accommodate products with grid or electromechanical charging.
i) Removed the restriction that all connections shall be "plug-and-play."
j) Added discussion of measurement error and accuracy for DC power measurements.

This part of IEC 62257 is to be used in conjunction with IEC 62257 (all parts).

The text of this Technical Specification is based on the following documents:

Enquiry draft	Reports on voting
82/1346/DTS	82/1385A/RVDTS

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.

A list of all parts in the IEC 62257 series, published under the general title *Recommendations for renewable energy and hybrid systems for rural electrification*, can be found on the IEC website.

Future standards in this series will carry the new general title as cited above. Titles of existing standards in this series will be updated at the time of the next edition.

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The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC website 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.

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Full document details: PD IEC TS 62257-9-5:2018

INTRODUCTION

IEC 62257 (all parts) provides support and strategies for institutions involved in rural electrification projects. It documents technical approaches for designing, building, testing, and maintaining off-grid 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 support buyers who want to connect with good quality options in the market:

- 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 technical aspects of rural off-grid electrification concentrating on, but not specific to, developing countries. They are not considered as all inclusive to rural electrification. The documents do not describe a range of factors that can determine project or product success: environmental, social, economic, service capabilities, and others. 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 costs. The main objectives are to support the capabilities of households and communities that use small renewable energy and hybrid off-grid systems and inform organizations and institutions in the off-grid power market.

The purpose of this document is to specify laboratory test methods for evaluating the quality assurance of stand-alone renewable energy products. This document is specifically related to renewable energy products that are packaged and made available to end-use consumers at the point of purchase as single, stand-alone products that do not require additional system components to function.

The term "stand-alone renewable energy product" is used in this document to describe this class of products. Other equivalent terms, including "off-grid solar" or "rechargeable," are often used by manufacturers, distributors, and other stakeholders to describe these products. Many of these systems meet the definition of type T_2I (individual electrification systems with energy storage) in IEC TS 62257-2.

The intended users of this document are:

- Market support programmes that support the off-grid lighting market with financing, consumer education, awareness, and other services;
- Manufacturers and distributors that need to verify the quality and performance of products;
- Bulk procurement programmes that facilitate or place large orders of products; and,
- Trade regulators such as government policymakers and officials who craft and implement trade and tax policy.

This document 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 and warranty requirements. 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. The tests and inspections are designed to be widely applicable across different markets, countries, and regions.

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RECOMMENDATIONS FOR RENEWABLE ENERGY AND HYBRID SYSTEMS FOR RURAL ELECTRIFICATION –

Part 9-5: Integrated systems – Laboratory evaluation of stand-alone renewable energy products for rural electrification

1 Scope

This part of IEC 62257, which is a Technical Specification, applies to stand-alone renewable energy products having the following characteristics:

- All components required to provide basic energy services are sold/installed as a kit or integrated into a single component, including at a minimum:
  - A battery/batteries or other energy storage device(s)
  - Power generating device, such as a solar panel, capable of charging the battery/batteries or other energy storage device(s)
  - Cables, switches, wiring, connectors and protective devices sufficient to connect the power generating device, power control unit(s) and energy storage device(s)
  - Loads (optional), such as lighting, load adapter cables (e.g., for mobile devices), and appliances (television, radio, fan, etc.).
- The PV module maximum power point voltage and the working voltage of any other components in the kit do not exceed 35 V. Exceptions are made for AC-to-DC converters that meet appropriate safety standards.

NOTE This voltage limit corresponds to the definition of decisive voltage classification A (DVC-A) for wet locations in Table 6 of IEC 62109-1:2010.

- The peak power rating of the PV module or other power generating device is less than or equal to 350 W.
- No design expertise is required to choose appropriate system components.

This document was written primarily for off-grid renewable energy products with batteries and solar modules with DC system voltages not exceeding 35 V and peak power ratings not exceeding 350 W. The tests contained herein are capable in many cases of adequately assessing systems at higher voltages and/or power ratings. In situations where the specifying organization agrees to apply these tests to products with higher voltages and power ratings, the test laboratory is responsible for ensuring that adequate safety measures are employed to protect technicians and test equipment. The specifying organization is also responsible for defining the consumer safety requirements of these products.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

IEC 60891:2009, *Photovoltaic devices – Procedures for temperature and irradiance corrections to measured I-V characteristics*

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IEC 60904-1:2006, *Photovoltaic devices – Part 1: Measurement of photovoltaic current-voltage characteristics*

IEC 61056-1:2012, *General purpose lead-acid batteries (valve-regulated types) – Part 1: General requirements, functional characteristics – Methods of test*

IEC 61215 (all parts), *Terrestrial photovoltaic (PV) modules – Design qualification and type approval*

IEC 61215-2, *Terrestrial photovoltaic (PV) modules – Design qualification and type approval – Part 2: Test procedures*

IEC 61427-1:2013, *Secondary cells and batteries for renewable energy storage – General requirements and methods of test – Part 1: Photovoltaic off-grid application*

IEC 61951-2:2017, *Secondary cells and batteries containing alkaline or other non acid electrolytes – Secondary sealed cells and batteries for portable applications – Part 2: Nickel-metal hydride*

IEC 61960-3:2017, *Secondary cells and batteries containing alkaline or other non-acid electrolytes – Secondary lithium cells and batteries for portable applications – Part 3: Prismatic and cylindrical lithium secondary cells and batteries made from them*

IEC 62087-2:2015, *Audio, video, and related equipment – Determination of power consumption – Part 2: Signals and media*

IEC 62087-3:2015, *Audio, video, and related equipment – Determination of power consumption – Part 3: Television sets*

IEC 62087-6:2015, *Audio, video, and related equipment – Determination of power consumption – Part 6: Audio equipment*

IEC TS 62257-12-1:2015, *Recommendations for renewable energy and hybrid systems for rural electrification – Part 12-1: Selection of lamps and lighting appliances for off-grid electricity systems*

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

CIE 15:2004, *Colorimetry*

CIE 084, *The measurement of luminous flux*

CIE 13.3, *Method of measuring and specifying colour rendering properties of light sources*

CIE 127, *Measurement of LEDs*

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

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

IESNA LM-79-08, *IES approval method for electrical and photometric measurements of solid state lighting products*

IESNA LM-80-08, *Approved method: measuring lumen maintenance of LED light sources*

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3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1
illuminance
illuminance of an elementary surface
E
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/m^2).

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

3.2
capacity
capacity of a cell or a battery
electric charge which a cell or battery can deliver under specified discharge conditions

Note 1 to entry: The SI unit for electric charge, or quantity of electricity, is the coulomb (1 C = 1 A·s) but in practice, capacity is usually expressed in ampere hours (Ah).

[SOURCE: IEC 60050-482:2004, 482-03-14]

3.3
device under test
DUT
particular sample that is being measured or observed

[SOURCE: IEC TS 62257-12-1:2015, 3.29]

3.4
lux
illuminance produced on a surface of area 1 square metre by a luminous flux of 1 lumen uniformly distributed over that surface

Note 1 to entry: Lux is the SI unit of illuminance.

[SOURCE: IEC 60050-845:1987, 845-01-52, modified – The formula has been omitted, and the note has been replaced by a new note to entry.]

3.5
colour rendering index
CRI
measure of the degree to which the psychophysical colour of an object illuminated by the test illuminant conforms to that of the same object illuminated by the reference illuminant, suitable allowance having been made for the state of chromatic adaptation

[SOURCE: IEC 60050-845:1987, 845-02-61, modified – The symbol "R" has been replaced by "CRI" and the note has been omitted.]

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3.6
correlated colour temperature
CCT
temperature of the Planckian radiator whose perceived colour most closely resembles that of a given stimulus at the same brightness and under specified viewing conditions

Note 1 to entry: The correlated colour temperature is expressed in kelvin (K).

[SOURCE: IEC 60050-845:1987, 845-03-50, modified – Notes 1 and 2 have been replaced by a new note to entry.]

3.7
full width half maximum
FWHM
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]

3.8
multimeter
multi-range multi-function measuring instrument intended to measure voltage, current and sometimes other electrical quantities such as resistance

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

3.9
illuminance meter
instrument for measuring illuminance

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

3.10
photometer
instrument for measuring light

[SOURCE: IEC 60050-845:1987, 845-05-15, modified – The term "photometric quantities" has been replaced by "light".]

3.11
pyranometer
instrument for measuring incident global (direct-beam and diffuse) solar radiation

3.12
integrating sphere
hollow sphere whose internal surface is a diffuse reflector, as non-selective as possible.

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

Note 2 to entry: An integrating sphere is used to determine the total luminous flux (lumen output) of a lighting device.

[SOURCE: IEC 60050-845:1987, 845-05-24, modified – A second note to entry has been added.]

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3.13
goniophotometer
photometer for measuring the directional light distribution characteristics of sources, luminaires, media or surfaces

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

3.14
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]

3.15
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]

3.16
IP class
IP rating
degree of protection provided by enclosures for electrical equipment against penetration by foreign bodies and dust/water

Note 1 to entry: IP classes are defined in IEC 60529.

3.17
portable
connected in a way that makes a product or subsystem easy for an individual to carry

Note 1 to entry: Products or subsystems are portable when two or more of the main components (energy source, energy storage, and light source) are connected in this way.

3.18
fixed
designed for permanent or semi-permanent mounting and use in place

Note 1 to entry: Products or subsystems are fixed when the main components (energy source, energy storage, and light source) are designed in this way.

3.19
separate
without solar module or with a solar module connected to other components via a cable that is sufficiently long to allow the solar module to collect energy outdoors while the other product components remain indoors

3.20
integrated
with a solar module integrated into the same casing as the other components or 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

3.21
metadata
information that relates a test result to a specific sample and provides context about the result (e.g. specific test method used)

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Full document details: PD IEC TS 62257-9-5:2018

3.22
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]

3.23
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

Note 1 to entry: This is a specific case of a "load disconnect point" as defined by IEC 62509:2010, 3.11.

3.24
standby loss
quantity of electricity (electric charge), expressed as a fraction of the total battery capacity, drawn from a product's battery with the product switched off over a specific length of time

3.25
coefficient of variation
ratio of the standard deviation to the mean

3.26
appliance
device that performs a specific function providing service to an end user, such as a light, radio, or television set

3.27
mobile device
basic mobile phone, feature phone, smartphone, tablet computer, or similar portable communication and/or computing device having an internal rechargeable battery

Note 1 to entry: Larger portable devices, such as laptop computers, can also be considered mobile devices, but some provisions (e.g. related to charging current and ports) may not be applicable.

3.28
port
connector (typically a socket) on a component that can supply power to an appliance

3.29
power control unit
component of a stand-alone renewable energy product that includes a battery and one or more ports plus, typically, the associated battery management, voltage regulation and overload protection components

Note 1 to entry: In the case of a product with a single power control unit, the power control unit is often referred to as the "main unit" or "control box." A power control unit can include appliance functionality such as a light or built-in radio. A portable appliance (such as a light) with internal battery is a power control unit if it includes a port.

3.30
main unit
component or assembly including an input for connecting the primary energy source (e.g. solar, grid or mechanical charger), a battery, and one or more built-in appliance(s) or port(s).

Note 1 to entry: A power control unit can be a main unit, though a main unit does not necessarily have a port.

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3.31
standard operating voltage
standardized voltage corresponding to a typical battery operating point during discharge

3.32
typical battery discharge voltage
battery voltage corresponding to the "typical operating point" (e.g. the operating point resulting in the average value of power) during discharge

Note 1 to entry: The typical battery discharge voltage is an outcome of the full-battery run time test, while the standard operating voltage depends only on the battery chemistry and number of cells.

3.33
appliance operating voltage
voltage supplied to an appliance by a port when the appliance is operating at a particular setting and the power control unit battery is at the typical battery discharge voltage

4 Product components and characteristics

4.1 Components

4.1.1 Overview

A stand-alone renewable energy product typically comprises:

- The 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),
  - power control unit(s) (see 3.29), which can be integrated into the same casing as the light sources or in a separate enclosure,
  - battery/batteries, and
  - loads (optional), such as appliances (lighting, television, radio, fan, etc.), and load adapter cables (e.g. for mobile devices).

NOTE In more complex products, some loads can include their own battery and power control unit.

- 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,
  - protective devices,
  - status indicators/user feedback,
  - accessories (auxiliary power outlet, mobile device charging or other appliance interface, radio, fan, television set, etc.), and/or
  - hardware for mounting.

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Throughout this document, the terms "product" and "stand-alone renewable energy product" refer to the complete product or kit as described in 4.1.1.

4.1.2 Component categories

Components of stand-alone renewable energy products can be placed into five categories based on the arrangement of components. The four general categories are fixed indoor, fixed outdoor, portable separate, and portable integrated; photovoltaic modules are in an additional, separate category. It is important to categorize components because components in different categories have different inherent utility to the user and will encounter different environmental conditions based on their design.

Different quality standards may apply to different categories.

Each product can contain components from multiple categories. Appliances included with the product may also be categorized according to this same system.

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

- Fixed components are designed for permanent or semi-permanent mounting and use in place. In addition to many large battery packs and installed light points, certain appliances, such as television sets, are typically considered to be fixed.
- Portable components are inherently portable and generally contain an internal energy source. For example, a stand-alone renewable energy product can include a portable light with a battery that can be charged from the solar module or from another battery in a fixed enclosure.

Fixed components are further classified based on the expected use location:

a) Fixed indoor components are not inherently portable and are used indoors. If a fixed indoor component is connected to a component that is intended to be used outdoors (such as a PV module), the cable connecting the two components shall be sufficiently long to place the outdoor component outdoors in an appropriate location while the indoor component remains indoors. Otherwise, the fixed outdoor category shall apply. See Figure 1 for an example.

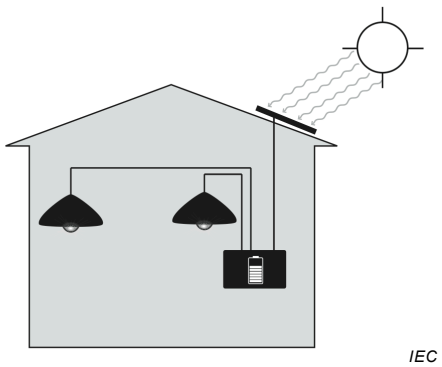

Figure 1 – Fixed indoor components and PV module – Example

b) Fixed outdoor components are not inherently portable and are intended to be used outdoors, or are connected to components intended to be used outdoors by a cable that is too short to allow the component in question to be placed indoors. Fixed outdoor components may contain integrated PV modules; however, PV modules without additional components form their own category. See Figure 2 for an example.

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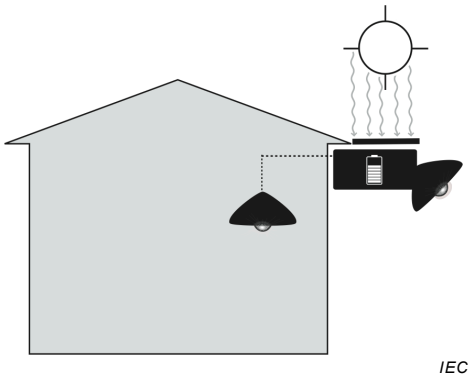

Figure 2 – Fixed outdoor components with an indoor light point – Example

Portable components are further classified by the presence or absence of an integrated solar module:

c) Portable separate components are portable, with a battery and load permanently or temporarily joined. If the component is intended to be connected to a fixed outdoor or portable integrated component or a PV module, the cable connecting the two components shall be sufficiently long to place the outdoor component outdoors in an appropriate location while the indoor component remains indoors; otherwise, the portable integrated category shall apply. See Figure 3 for an example.

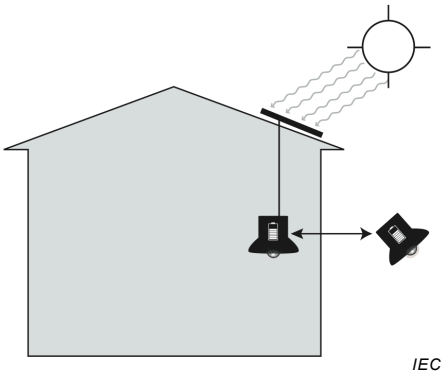

Figure 3 – Portable separate components – Example

d) Portable integrated components are portable and are charged with a solar module that is integrated in the casing or is otherwise designed so that the whole component is left outdoors to charge via the solar module. This includes portable components that are intended to be connected to fixed outdoor or portable integrated components, or a PV module, by a cable that is too short to allow the component in question to be placed indoors. Portable integrated components may contain PV modules; however, PV modules without additional components form their own category. See Figure 4 for an example.

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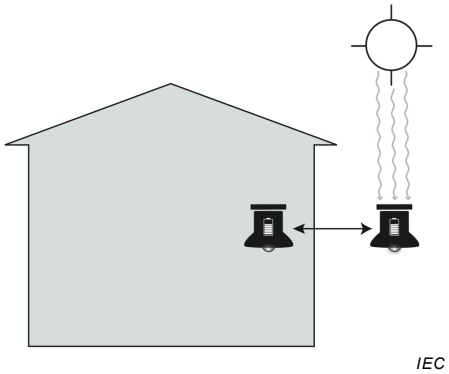

Figure 4 – Portable integrated components – Example

PV modules may be subjected to different standards for durability (including physical and water ingress protection), and are therefore considered a separate category:

e) PV modules include one or more PV cells surrounded by encapsulating or laminating materials with a transparent glass or plastic covering, plus a junction box mounted on the back of the module for electrical connections. A PV module can be surrounded by a frame, typically of metal or plastic, and can include mounting brackets or other hardware. This category applies only to PV modules; assemblies containing one or more PV modules plus additional electrical or electronic components, such as circuit boards or batteries, shall be considered fixed outdoor components.

NOTE The requirement regarding assemblies containing PV modules is not intended to apply to PV modules with small circuit boards or discrete electronic components such as diodes installed in their junction boxes.

4.1.3 Lighting parts definitions

The portion of the product which provides lighting can also be divided into several subsystems, as defined below. The subsystems are nested beginning with the smallest subsystem and working down to complete product.

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) or lighting appliance(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 product, each with an independent battery that powers one or more light points.

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

e) Stand-alone renewable energy product: the overall package of integrated components, including one or several lighting units and potentially other loads or appliances.

Figure 5 below illustrates how a hypothetical product 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 product 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) can be categorized as portable separate; the other light unit (D2) can be categorized as fixed indoors. Both units are included in a single product (E). Note that although only lights are illustrated below, other appliances are often included as part of the product.

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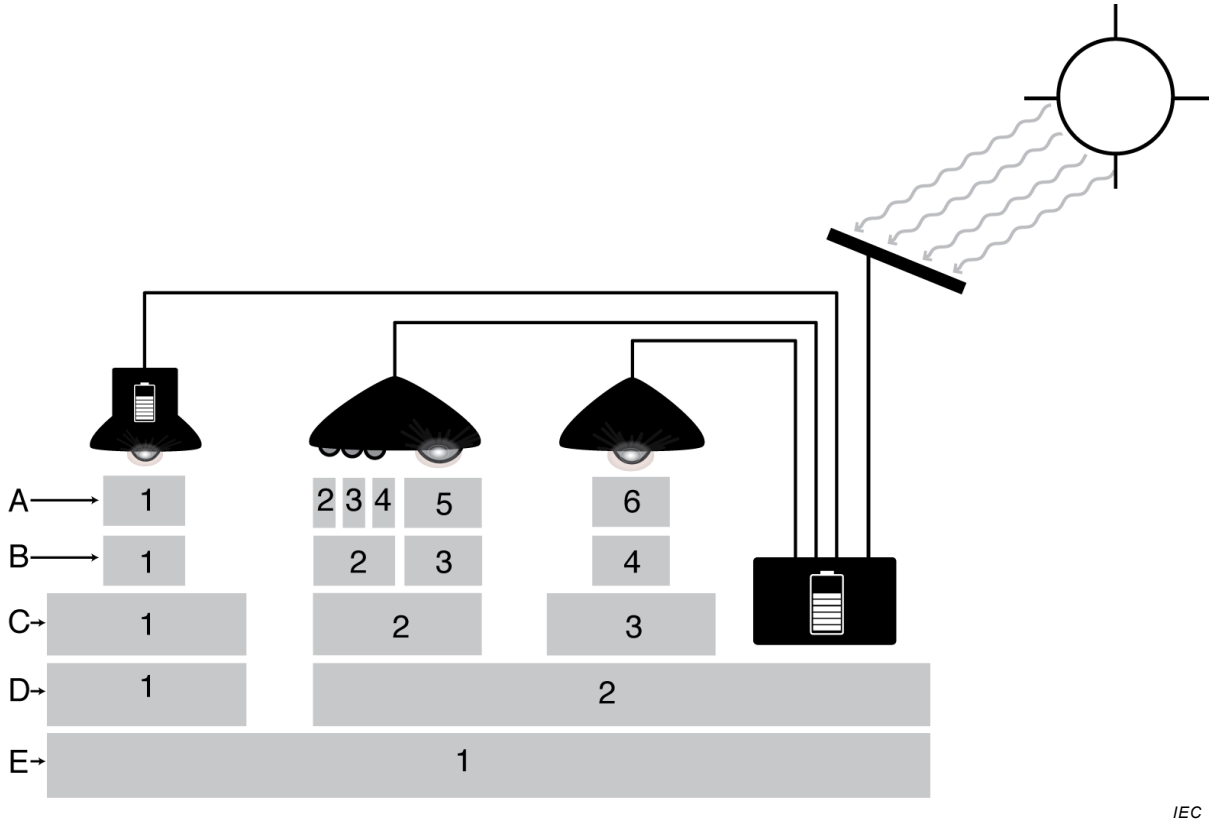

Figure 5 – Division of a product into subsystems – Illustrative example

4.1.4 Appliance definitions

Some products may include or advertise compatibility with one or more appliances, such as lights, radios, and mobile devices. Two categories of appliances are addressed in this document:

- Included appliances are packaged with and sold as part of the product, so their performance (e.g., power consumption) can be measured directly by the test laboratory.
- Advertised appliances are not included as part of the product but are mentioned in the accompanying advertising material, such as the product packaging or the manufacturer's website. This advertising can be a simple statement that the appliance can be used with the product or an estimate of the run time or service provided by the appliance with a full battery or after a day of solar charging. Methods are provided for evaluating these claims even though the appliances are not provided to the test laboratory.

In addition, appliances can be categorized by how they are connected to the other components of the product:

- Removable appliances can be powered or charged from the product by plugging a cable into a port, and can be disconnected when not in use.
- Built-in appliances are integrated into another component of the product so that they are not intended to be removed by the end user. These appliances include built-in radios and lights. The following are also considered built-in appliances for the purposes:
  - appliances (such as light points) connected to the product by a permanently attached cable that is not intended to be removed by the end user;
  - appliances (such as light points) that can be removed, but that depend on a circuit or assembly internal to another part of the product for their functionality. For example, a light point where some or all of the driver or ballast circuit is internal to the power control unit of the product is considered a built-in appliance. In some cases, such

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appliances can be tested as removable appliances with some modifications to the test procedures; see EE.4.2.5.

In some cases, an appliance can be considered both "built-in" and "removable." For example, a product could have external lights that can be plugged into specially designated ports with brightness controls or into general-purpose appliance ports. These appliances may be tested as built-in appliances or removable appliances; the decision should be made based on how the appliance is likely to be used most often. It is not necessary to test such appliances using both sets of test methods (for built-in and removable appliances).

Removable appliances can be further divided into appliances with and without internal batteries. Different test methods for power consumption and voltage compatibility apply to these two categories. (The term "appliance with internal battery" in this document does not refer to built-in appliances.)

4.1.5 Additional system elements

In addition to technical elements, a system can 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,
- warranty support from the manufacturer, and/or
- hardware for mounting the PV module and other components.

4.2 System measurements and observations

4.2.1 General

Subclause 4.2 describes aspects of an off-grid lighting product that can 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 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) Test procedure(s): Annex F: visual screening.

b) Result: qualitative description of each separate electronic enclosure and what is housed in or mounted on each.

c) Units: qualitative description.

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 5 m cable. A solar module with a 6 m cable 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 performance aspects (see 4.2.8).

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a) Test procedure(s): Annex F: visual screening, Annex D: manufacturer self-reported information.

b) Result (for each charging option): charger type; central or independent.

c) Units: qualitative type.

EXAMPLE Two charging options: independent solar charging via the included module, and 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) Test procedure(s): Annex F: visual screening, Annex D: manufacturer self-reported information.

b) Result: qualitative description of the type, number, and arrangement of light sources.

c) Units: qualitative description.

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) Test procedure(s): Annex F: visual screening, Annex D: manufacturer self-reported information.

b) Result: the type and number of batteries in the system.

c) Units: qualitative description.

EXAMPLE Unit A has a 3,7 V lithium-ion battery with a rating of 2,0 Ah; Unit B has a 3,7 V lithium-ion battery with a rating of 1,0 Ah.

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.

a) Test procedure(s): Annex F: visual screening.

b) Result: a yes or no result on whether it is "easy" to replace the battery.

c) Units: yes/no.

4.2.2.6 Battery general aspects

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

a) Test procedure(s): Annex F: visual screening, Annex D: manufacturer self-reported information or reference component rating.

b) Result (for each battery present): battery chemistry; nominal voltage; package type; package size; connection type.

c) Units: qualitative type.

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. 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

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components; thorough documentation of the packaging, user's manual, and other consumer-facing information allows compliance with these requirements to be assessed.

a) Test procedure(s): Annex F: visual screening.

b) Result: there are five 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;

3) description of the method or pathway for replacing components, including the battery;

4) specifications of components that could require replacement (fuses, batteries, PV);

5) instructions for PV and product installation and operation.

c) Units: qualitative type and photographs.

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) Test procedure(s): Annex F: visual screening, Annex D: manufacturer self-reported information.

b) Result: detailed warranty terms and a "concise" version that highlights the key points of coverage and duration.

c) Units: qualitative description.

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 24 months from the time of purchase; the PV module is warranted for 5 years.

4.2.2.9 Auxiliary outlets, ports and adapters information

This notes all the auxiliary outlets and ports present on the product. The inclusion of USB ports, outlets or mobile device adapters can be an important purchasing factor for a consumer.

a) Test procedure(s): Annex F: visual screening, Annex D: manufacturer self-reported information.

b) Result: list of included auxiliary outlets, ports and adapters, including receptacle type and nominal voltage.

c) Units: qualitative description.

EXAMPLE The product includes two 12 V ports with barrel jacks (5,5 mm outer diameter; 2,5 mm pin diameter) and three 5 V USB ports (type A receptacle).

4.2.2.10 Appliances information

This notes all the appliances included with the product and all appliances the product is advertised to support. Some products include appliances such as radios. Others include advertising stating that they support certain appliances or making claims as to how long they can power certain appliances.

a) Test procedure(s): Annex F: visual screening, Annex D: manufacturer self-reported information.

b) Result: list of included appliances and list of claims related to supporting appliances.

c) Units: qualitative description.

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4.2.2.11 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) Test procedure(s): Annex F: visual screening, Annex D: manufacturer self-reported information.

b) Result: various results including qualitative descriptions and quantitative measurements.

c) Units: qualitative descriptions and quantitative measurements.

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 components intended to be used and/or charged outside, water protection is important for product function as well as user safety.

a) Test procedure(s): Annex U: Physical and water ingress protection test according to IEC 60529 or the alternative methods if the alternative method results are unequivocal.

b) Result: pass or fail for IP class (second digit) and a description of degree of water protection provided by enclosure.

c) Units: pass or fail and qualitative description.

EXAMPLE The portable lamp included with the product passes IP x3. The lamp's enclosure contains tight fitting components, all of which have gaskets to prevent water intrusion. The battery, charge controller and TV are all fixed indoor components that do not require water ingress protection.

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 portable or used outdoors that have enclosures providing little to no water intrusion protection.

a) Test procedure(s): Annex F: visual screening combined with Annex D: manufacturer self-reported information.

b) Result: qualitative description of drainage or circuit protection methods used.

c) Units: qualitative description.

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 Water protection – overall

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

a) Test procedure(s): Annex V: level of water protection.

b) Result: descriptive assessment of exposure protection by enclosure only, technical means, and overall system. The assessment categories are "no protection," "occasional rain," "frequent rain, "permanent rooftop installation for PV modules," and "permanent outdoor exposure."

c) Units: qualitative type.

EXAMPLE Enclosure only: no protection. Technical means: occasional rain. Overall: occasional rain.

4.2.3.4 Water protection – solar module

This provides a description of an external solar module's ability to keep out water in terms of IP class. (If the solar module is integrated into the product enclosure, then 4.2.3.1 already

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covers the solar module.) Solar modules need to be left outside to collect solar energy; therefore, water protection is important for solar module function as well as user safety.

a) Test procedure(s): Annex U: Physical and water ingress protection test according to IEC 60529 or using the alternative methods (U.4.4) if the alternative method results are unequivocal.

b) Result: pass or fail for IP class (second digit) and a description of degree of water protection.

c) Units: pass or fail and qualitative description.

EXAMPLE The product's solar module passes IPx4; the solar module is well sealed, providing an adequate level of protection against water ingress.

4.2.3.5 Physical ingress protection

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

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) Result: pass or fail for IP class (first digit) and description of degree of physical ingress protection.

c) Units: pass or fail and qualitative description.

EXAMPLE The product components pass IP 2x; the product enclosure's components fit together well, with vents smaller than 12,5 mm.

4.2.3.6 Physical ingress protection – solar module

This provides a description of an external solar module's ability to prevent the intrusion of foreign objects in terms of IP class (if the solar module is integrated into the product enclosure, then 4.2.3.5 already covers the solar module). Solar modules need to be left outside to collect solar energy; therefore, physical ingress protection is important for solar module function as well as user safety.

a) Test procedure(s): Annex U: Physical and water ingress protection test according to IEC 60529 or using the alternative methods (U.4.4) if the alternative method results are unequivocal.

b) Result: pass or fail for IP class (first digit) and description of degree of physical ingress protection.

c) Units: pass or fail and qualitative description.

EXAMPLE The product's solar module is estimated to pass IP 3x; the solar module is well sealed so that only small particles could intrude.

4.2.3.7 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 in portable components.

a) Test procedure(s): Annex W: mechanical durability test.

b) Result: pass or fail for functionality, damage, and the presence of user safety hazards.

c) 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.

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4.2.3.8 Gooseneck and moving part durability

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

a) Test procedure(s): Annex W: mechanical durability test.

b) Result: a pass or fail for functionality, damage, and the presence of user safety hazards.

c) 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/moving part 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.

4.2.3.9 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) Test procedure(s): Annex W: mechanical durability test.

b) Result: a pass or fail for functionality, damage, and the presence of user safety hazards.

c) 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.

4.2.3.10 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) Test procedure(s): Annex W: mechanical durability test.

b) Result: a pass or fail for functionality, damage, and the presence of user safety hazards.

c) 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 light switch stopped turning on the DUT. Functional: fail. Damage: fail. Safety: pass.

4.2.3.11 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) Test procedure(s): Annex W: mechanical durability test.

b) Result: a pass or fail for functionality, damage, and the presence of user safety hazards.

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

EXAMPLE The strain reliefs all withstood the strain relief test without incurring any damage. Functional: pass. Damage: pass. Safety: pass.

4.2.3.12 Wiring quality

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

a) Test procedure(s): Annex F: visual screening.

b) Result: a qualitative description of wiring quality.

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c) Units: qualitative description and number of failures with respect to key indicators.

EXAMPLE The product'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.

4.2.3.13 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) Test procedure(s): Annex S: charge controller behaviour test or Annex FF: appliance tests.

b) Result: deep discharge and overvoltage protection voltages.

c) Units: quantitative description.

4.2.4 Lighting durability aspects

4.2.4.1 500 h 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 product's circuitry.

a) Test procedure(s): Annex J: lumen maintenance test.

b) Result: percentage of lumen output maintained after 500 h of constant operation.

c) Units: percentage (%).

4.2.4.2 2 000 h 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 product's circuitry.

a) Test procedure(s): Annex J: lumen maintenance test.

b) Result: percentage of lumen output maintained after 1 000 h and 2 000 h of constant operation.

c) Units: percentage (%).

4.2.4.3 Fluorescent light durability

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

a) Test procedure(s): Cycling test of IEC TS 62257-12-1.

b) Result: a pass or fail for the cycling test of IEC TS 62257-12-1.

c) Units: pass or fail.

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) Test procedure(s): Annex K: battery test (all chemistries), Annex D: manufacturer self-reported information or reference component rating.

b) Result: capacity of the battery at a particular discharge rate.

c) Units: ampere-hours (Ah) at a discharge rate expressed in terms of I_t A (as defined in K.4.1).

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EXAMPLE 3,5 Ah at 0,2 I_t A.

4.2.5.2 Battery round-trip energy efficiency

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

a) Test procedure(s): Annex K: battery test.

b) Result: storage efficiency of the battery pack.

c) Units: percentage (%).

4.2.5.3 Battery storage durability

This is a measure of battery capacity degradation from storage, which can indicate batteries that could degrade prematurely under typical use.

a) Test procedure(s): Annex BB: battery durability test.

b) Result: percent capacity loss from storage.

c) Units: percentage (%).

4.2.5.4 Battery nominal 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) Test procedure(s): Annex F: visual screening, Annex D: manufacturer self-reported information or reference component rating.

b) Result: nominal voltage of the battery pack.

c) Units: voltage (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/m^2 irradiance) and typical module operating temperature (TMOT: AM 1,5, 50 °C cell temperature, 1 000 W/m^2 irradiance).

a) Test procedure(s): Annex Q: photovoltaic module I-V characteristics test, IEC 60904-1.

b) 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 (relative to the open-circuit voltage at STC).

c) Units: volts (V), amperes (A), watts (W), per degree Celsius (1/°C).

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 Cable length

The length of solar module cables and other cables connected to fixed outdoor components are 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, or other component, outdoors while the other

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components remain indoors. This has implications for the degree of water protection in quality standards.

a) Test procedure(s): Annex F: visual screening.

b) Result: There are two main outputs:

   1) the length of any cables that connect a portable component or fixed indoor component to a solar module; and

   2) the length of any cables that connect any fixed outdoor or portable integrated component to any other component (other than another fixed outdoor component).

c) Units: metres (m).

4.2.7 Electrical characteristics

4.2.7.1 Appliance voltage compatibility

This provides an assessment of whether an included appliance can safely and properly operate over the entire set of operating conditions of the DUT, including discharging with a deeply discharged battery and charging with a nearly full battery.

a) Test procedure(s): Annex EE: assessment of DC ports, or Annex FF: appliance tests.

b) Result: pass or fail for functionality, damage, and safety.

c) Units: pass/fail; qualitative description.

4.2.7.2 Power consumption

The power consumed by an appliance or lighting appliance in use is an important metric for off-grid applications in which the supply of energy is limited. The power consumption is measured in order to calculate the run time for systems with included appliances. Appliances with internal batteries will have a power consumption when in use, and a different power consumption when charging; the latter is measured in the appliance charging efficiency test.

a) Test procedure(s): Annex FF: appliance tests.

b) Result: DC power.

c) Units: watts (W).

4.2.7.3 Circuit and overload protection

This provides an assessment of the system's PV overvoltage protection, output overload protection, and safeguards against miswiring in systems that include ports or outlets.

a) Test procedure(s): Annex DD: protection tests, Annex D: manufacturer self-reported information.

b) Result: a pass or fail result on whether the unit had adequate protection, functioned, or showed damage, fault indications or safety hazards after tests. Tables with quantitative and qualitative results of the voltage range and miswiring protection tests.

c) Units: volts (V), pass or fail results on whether the unit had adequate protection, functioned, or showed damage, fault indications or safety hazards after test.

EXAMPLE The DUT uses appropriately sized fuses to provide adequate circuit protection. Spare fuses are included and the fuse size is noted on the product casing.

4.2.7.4 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) Test procedure(s): Annex R: solar charge test,

b) Result: battery-charging circuit efficiency.

c) Units: percentage (%).

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4.2.7.5 DC ports

This provides an assessment of the system's DC ports.

a) Test procedure(s): Annex EE: assessment of DC ports.

b) Result: minimum and maximum port voltages, tables and plots of voltage, current, power and efficiency of each port.

c) Units: volts (V), amperes (A), watts (W), percentage (%).

4.2.7.6 Appliance charging efficiency

The charging efficiency and power consumed by an appliance during charging is an important metric for use in off-grid applications in which the supply of energy is limited. The charging efficiency is measured for appliances with internal batteries charging from the main unit. The power consumption during charging is measured in order to calculate the run time for systems with included appliances that have internal batteries.

a) Test procedure(s): Annex FF: appliance tests.

b) Result: appliance charging efficiency, DC power.

c) Units: percentage (%), watts (W).

4.2.8 Performance aspects

4.2.8.1 General

Energy availability, component run times and light output are key elements of performance for stand-alone renewable energy products. Some of the aspects listed below will be different for different light settings and appliance combinations.

4.2.8.2 Daily energy service

The daily energy service is the duration of service provided to end users after 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/m^2. This is an important metric because it is an estimate of the day-to-day services users can expect in ideal charging conditions. The daily energy service depends on the system-level performance for a particular light setting and combination of appliances.

a) Test procedure(s): Annex M: full-battery run time test, Annex R: solar charge test, Annex FF: appliance tests, Annex GG: energy service calculations.

b) Result: watt·hours per day of energy available after a battery is charged from empty for one standard solar day.

c) Units: watt·hours (Wh).

4.2.8.3 Solar-day lighting 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/m^2. 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) Test procedure(s): Annex R: solar charge test; or Annex M: full-battery run time test, Annex R: solar charge test, and Annex GG: energy service calculations.

b) Result: hours of operation to 70 % of the initial brightness after the battery is charged for one standard solar day.

c) Units: hours (h).

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4.2.8.4 Solar-day appliance 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/m^2. 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) Test procedure(s): Annex R: solar charge test; or Annex M: full-battery run time test, Annex R: solar charge test, Annex FF: appliance tests, and Annex GG: energy service calculations.

b) Result: hours of operation after the battery is charged for one standard solar day.

c) Units: hours (h).

4.2.8.5 Solar charging time

The solar charging time is the duration of solar charging required for the product to receive a full charge. The standard solar charging day is defined as an incident solar resource of 5 kWh/m^2. 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) Test procedure(s): Annex R: solar charge test; or Annex M: full-battery run time test, Annex R: solar charge test, Annex FF: appliance tests, and Annex GG: energy service calculations.

b) Result: hours of solar charging required for the product's battery(-ies) to receive a full charge from empty to full.

c) Units: hours (h).

4.2.8.6 Main unit full-battery run time

The main unit 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. This is an important metric because it is an estimate of the services that can be provided by the product's main battery. If a product is submitted with no lighting appliances, other included or generic appliances may be used to determine the main unit's full-battery run time.

a) Test procedure(s): Annex M: full-battery run time test, alone or in conjunction with Annex GG: energy service calculations.

b) Result: hours of operation to 70 % of the initial brightness when beginning with a fully charged battery; sometimes also known as "autonomous run time."

c) Units: hours (h).

4.2.8.7 Appliance full-battery run time

The appliance full-battery run time is the duration of service provided to end-users from a fully charged appliance battery, such as a lantern, radio, fan or TV with an internal battery. This is an important metric because it is an estimate of the services that can be provided by the appliance once it receives full charge from the main system.

a) Test procedure(s): Annex M: full-battery run time test or Annex FF: appliance tests (measurement according to Clause FF.9 or calculation according to FF.6.8.5).

b) Result: hours of operation to the run time endpoint after the battery is fully charged.

c) Units: hours (h)

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4.2.8.8 Grid-charge energy

The grid-charge energy is the energy delivered to the battery in an 8 h period 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) Test procedure(s): Annex O: grid charge test.

b) Result: energy delivered to the battery in 8 h.

c) Units: watt·hours (Wh).

4.2.8.9 Electromechanical charger power or energy output

The electromechanical charger power output is an important metric because it allows one to estimate the duration of user effort required each day for a given level of service for an electromechanically charged product (e.g. one with a hand crank or bicycle pedals). In some products, as detailed in Annex P, energy is a more appropriate metric than power.

a) Test procedure(s): Annex P: electromechanical charge test.

b) Result: power output of the electromechanical charger.

c) Units: watts (W) or watt·hours (Wh).

4.2.8.10 Standby loss

The standby loss measurement quantifies the current drawn by a DUT when not in use. If the standby loss is substantial, it can affect the use of the DUT.

a) Test procedure(s): Annex S: charge controller behaviour test.

b) Result: average current over 10 min period.

c) Units: amperes (A).

4.2.9 Light output aspects

4.2.9.1 Luminous flux output

Luminous flux output is the light output of a DUT when it is operated at the typical battery discharge voltage or when an individual lighting appliance is measured at the appliance operating voltage. This is a key metric that compares the overall light output of DUTs.

a) Test procedure(s): Annex I: light output test.

b) Result: average luminous flux.

c) Units: lumens (lm).

4.2.9.2 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 half the illumination at the brightest point in the plane.

a) Test procedure(s): Annex T: light distribution test.

b) Result: vertical and horizontal FWHM angles.

c) Units: degrees (°).

4.2.9.3 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) Test procedure(s): Annex T: light distribution test.

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b) Result: constant-voltage usable area at a specified distance, and illuminance on a work surface of 0,3 m × 0,4 m.

NOTE The work surface dimensions were selected to correspond to two adjacent sheets of A4 paper.

c) Units: square metres (m^2) and lux (lx).

EXAMPLE The usable area at a distance of 0,75 m is 0,76 m^2 and the work surface illuminance is 40 lux.

4.2.9.4 Colour characteristics

The colour characteristics of light include the colour rendering index (CRI) and the correlated colour temperature (CCT).

a) Test procedure(s): Annex I: light output test.

b) Result: CRI value and colour temperature.

c) Units: CRI is unitless and the colour temperature is in kelvins (K).

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) Test procedure(s): Annex D: manufacturer self-reported information.

b) Result: various qualitative and quantitative information.

c) Units: qualitative and quantitative.

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) Test procedure(s): Annex D: manufacturer self-reported information.

b) Result: qualitative description.

c) Units: qualitative description.

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 or ISO) can be an important aspect in the eyes of consumers and investors, alike.

a) Test procedure(s): Annex D: manufacturer self-reported information.

b) Result: qualitative marks and certifications.

c) Units: qualitative description.

4.2.10.4 PAYG manufacturer declaration

In cases where products are pay-as-you-go (PAYG) or fee-for-service enabled, an additional declaration form shall be submitted that provides more information on the PAYG aspects of the product. The PAYG declaration form also serves as an affirmation from the manufacturer that their product meets specific standards (e.g., that the solar module will still charge the battery when the product is in a "locked" state).

a) Test procedure(s): Annex D: manufacturer self-reported information.

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b) Result: qualitative marks and certifications.

c) Units: qualitative description.

4.3 Constructions not specifically covered

If it is evident from the design and construction of the stand-alone renewable energy product that a particular test is not applicable, the test is either not made or reasonable adjustments may be made to apply the test to the product. Any modifications shall provide a level of accuracy equivalent to the original method and shall be fit for the intended use. All modifications shall be documented in the test report. The need for additional detailed requirements to cope with new situations should be brought promptly to the attention of the appropriate committee.

5 Product specification

5.1 General

Quality standards and warranty requirements 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.

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 and requirements 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.

Clause 5 describes the framework for standards and requirements in general and offers insights on the best practices for creating a product specification. It includes a template product specification followed by guidance on completing each section.

5.2 Applications

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

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Table 1 – Applications of product specifications

Type of QA framework	Example(s) of applying 4.3
General market support	Use quality standards and general warranty requirements to qualify for institutional market support. Use quality standards to qualify for "verified product" programs. Use quality standards and other requirements to qualify for investment or financing.
Manufacturing/ distribution	For manufacturers: incorporate quality standards from market support programmes or distributors in the design and production QC processes. For distributors: set minimum quality standards and warranty requirements for products to identify suppliers.
Bulk procurement	Set minimum quality standards and warranty requirements 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

The framework for considering quality standards and warranty requirements 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.

5.4 Product specification framework description

5.4.1 General

Subclause 5.4 describes a framework for creating product specification documents for off-grid lighting. First, a blank specification (5.4.2) is provided that lists all the pieces that may be specified. Next, 5.4.3 describes guidelines for setting tolerances in a product specification. Finally, the main sections in a specification are described in more detail with notes and guidance (5.4.4, 5.4.5).

An example product specification for general market support programmes is in Annex A.

A product specification has five parts:

a) Scope: defines the applicability and use of the quality standards.

b) Test requirements: defines requirements for test result validity.

c) Product category requirements: unambiguously defines the categories that may be referenced later.

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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.

5.4.2 Product specification template

5.4.2.1 General

Subclause 5.4.2 is a blank, rough template for setting quality standards and warranty requirements to support the goals of a programme or institution. Note that in many applications certain criteria or entire categories of criteria do 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).

Describe which tests and standards apply to each appliance type included with a product. Describe if any external test results (such as test results from other IEC standards) could be used in place of results from this document.

Describe any product sampling requirements for qualification testing.

Specify the number of light output settings required to be measured for products with multiple settings. Typically, at least one set of test results should fully characterize the performance on the highest light output setting.

5.4.2.4 Product category requirements

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

Describe any other requirements or eligibility criteria for products that are categorical (e.g. shall be solar charged, shall be low-voltage).

Qualification as a "separate" PV module requires meeting the criteria listed in Table 2:

Table 2 – Qualification as separate PV module

Criterion	Aspect(s)	Required value
PV module cable length	4.2.6.2 Cable length	*Define the length in metres that is required for qualification as a separate PV module.*

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.

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Table 3 – Truth-in-advertising tolerance

Truth-in-advertising criterion	Aspect(s) considered in assessment	Requirement
System performance tolerance – numeric ratings	4.2.8 Performance aspects 4.2.9 Light output aspects Others, if applicable	*Define the tolerance for deviation from ratings.*
System components tolerance – numeric ratings	4.2.5 Battery performance aspects 4.2.6 Solar module aspects 4.2.7.1 Appliance voltage compatibility 4.2.7.2 Power consumption 4.2.7.5 DC ports Others, if applicable	*Define the tolerance for deviation from ratings.*
Other numeric ratings tolerance	Multiple	*Define the tolerance for deviation from ratings.*
Overall truth–in-advertising statement	Multiple	*Include an overall description of the requirements for truth in advertising that are not covered by the requirements above.*

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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 (*overall, technical, or enclosure-only*)	4.2.3.1 Water protection – enclosure 4.2.3.2 Water protection – circuit protection and drainage 4.2.3.3 Water protection – overall 4.2.3.4 Water protection – solar module 4.2.10.1 Product and manufacturer information 4.2.2.7 Packaging and user's manual information	Category 1	*Define level of protection in terms of water protection integrated assessment:* *No protection, occasional rain, frequent rain, or permanent outdoor exposure.*
		Category 2, Category 3, etc.	*Define level of protection in terms of water protection integrated assessment.*
Physical ingress protection	4.2.3.5 Physical ingress protection 4.2.3.6 Physical ingress protection – solar module	Category 1	*Define level of protection in terms of IP class.*
		Category 2, Category 3, etc.	*Define level of protection in terms of IP class.*
Mechanical durability – drop test	4.2.3.7 Drop resistance	Category 1	*Define type of drop test (2 drops or 6 drops per sample). Define maximum number of failures out of the number that are tested for damage, functionality, and safety.*
		Category 2, Category 3, etc.	*Define type of drop test (2 drops or 6 drops per sample). Define maximum number of failures out of the number that are tested for damage, functionality, and safety.*
Mechanical durability – goosenecks and moving parts	4.2.3.8 Gooseneck and moving part durability	Products with goosenecks/moving parts	*Define maximum number of failures out of the number that are tested for damage, functionality, and safety.*
Mechanical durability – connectors	4.2.3.9 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	4.2.3.10 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	4.2.3.11 Strain relief durability	Products with connectors	*Define maximum number of failures out of the number that are tested for damage, functionality, and safety.*
Workmanship	4.2.3.12 Wiring quality	All products	*Define maximum number of samples with bad solder joints, poor wiring, etc., out of the number that are tested.*

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Safety or durability criterion	Aspect(s) considered in assessment	Product category (form factor and/or technology)	Requirement
Battery durability	4.2.3.13 Battery protection strategy 4.2.5.3 Battery storage durability 4.2.10.1 Product and manufacturer information 4.2.10.3 Third-party marks and certifications	All products	*Define a minimum level of battery protection that will protect the product's battery and the user. Define maximum capacity loss following battery durability test.*
Lumen maintenance	4.2.4.2 2 000 h 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.*
AC-DC charger safety	4.2.10.1 Product and manufacturer information 4.2.10.3 Third-party marks and certifications	Products with AC-DC chargers included	*Define acceptable safety approval marks and certifications for AC-DC chargers.*
Hazardous substances ban	4.2.2.4 Energy storage system information 4.2.2.6 Battery general aspects 4.2.10.1 Product and manufacturer information	All products	*Define allowable battery chemistries.*
Cable specifications	4.2.10.1 Product and manufacturer information 4.2.10.3 Third-party marks and certifications	All products	*Define acceptable approval marks and certifications for outdoor cables*
Circuit and overload protection, PV overvoltage protection, and miswiring protection	4.2.7.3 Circuit and overload protection	All products	*Define maximum number of failures and number of samples to be 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	*Define if there are requirements for consumer-facing information on packaging or in a user's manual, such as end-of-life disposal instructions, specifications of replaceable components, and instructions for product installation and maintenance.*
Other	4.2.2.11 Other visual screening results	*Define other product requirements that support end users to maintain the quality of the product.*

5.4.2.6 Warranty requirements

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

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