

Generally, standards are requirements or recommendations based on best practices and are created by bringing together the experience and expertise of diverse groups of interested parties – the manufacturers, sellers, buyers, users and regulators of a particular material, product, process or service. This site focuses on the activities related to standardisation of measurement protocols for Organic and Large Area Electronic devices, more specifically: Organic Photovoltaics (OPV), Organic Light Emitting Diodes/Lighting (OLED/Lighting) and Organic Thin Film Transistors (OTFT).

OPV

The International Electrotechnical Commission (IEC), the Institute of Electrical and Electronics Engineers (IEEE), ASTM International (originally known as the American Society for Testing and Materials) and Underwriters Laboratories Inc. (UL) all publish standards for photovoltaic (PV) products.

Standardized protocols for performance testing in terms of efficiency and stability are defined according to IEC and ASTM norms and are specifically adapted to well-established PV technologies like crystalline silicon and amorphous silicon for professional outdoor use. Adapted protocols for emerging and novel PV technologies like OPV are not existing yet. Main efforts that have started and are still ongoing are focusing on measurement protocols for determination of the efficiency and stability of OPV devices.

Efficiency

Accurate determination of the photovoltaic power conversion efficiency is essential for a comparison of results and product compatibility. Photovoltaic device efficiencies are notoriously difficult to measure accurately because, among other reasons, of the sensitivity of the device performance to deviations between the emission spectrum of the solar simulator used in the testing and the true AM1.5 spectrum. In order to quantify the cell performance in a comparable manner, a set of Standard Reporting Conditions (SRC) has been defined. These are specified as a radiant density of 1000 W/m^2 with a spectral distribution defined as “AM1.5G” ([ASTM G173](#)) at a cell temperature of $25 \text{ }^\circ\text{C}$.

Standardized efficiency measurements and reference cell calibrations are carried out in photovoltaic calibration laboratories like NREL (US), FhG ISE (D), AIST (Japan) and are based on the protocols that have been developed in the US in the 1980s [1,2]. Some efforts have been made in the past to motivate and educate the research community to use these protocols (or simplified forms) for the accurate performance determination of OPV [3,4,5,6]. An overview of maximum power conversion efficiencies for PV devices measured at “AM1.5” conditions is semi-annually published in the Solar Cell Efficiency Tables in [Progress in Photovoltaics](#). An excerpt for OPV from the January 2009 edition is shown in Table I

[1] C.H. Seaman, *Solar Energy*, 1982, 29, 291-298.

[2] K. Emery, C. Osterwald, *Solar Cells*, 1986, 17, 253.

[3] J. Rostalski, D. Meissner, *Solar Energy Materials & Solar Cells*, 2000, 61, 87-95.

[4] P.M. Sommeling et al., *Solar Energy Materials & Solar Cells*, 2000, 62, 399-410.

[5] J.M. Kroon et al., *Thin Solid Films*, 2002, 403-404, 223-228.

[6] V. Shrotriya et al., *Advanced Functional Materials*, 2006, 16, 2016-2023.

Table I. Confirmed terrestrial cell and submodule efficiencies measured under the global AM1.5 spectrum (1000 W/m²) at 25°C (IEC 60904-3: 2008, ASTM G-173-03 global)

Classification ^a	Effic. ^b (%)	Area ^c (cm ²)	V _{oc} (V)	J _{sc} (mA/cm ²)	FF ^d (%)	Test centre ^e (and date)	Description
Organic							
Organic polymer	5.15 ± 0.3 ^k	1.021 (ap)	0.876	9.39	62.5	NREL (12/06) ^f	Konarka ²⁶
Organic (submodule)	1.1 ± 0.3 ^k	232.8 (ap)	29.3	0.072	51.2	NREL (3/08) ^f	Plextronics (P3HT/PCBM) ²⁷

^bEffic. = efficiency.

^c(ap) = aperture area; (t) = total area; (da) = designated illumination area.

^dFF = fill factor.

^eFhG-ISE = Fraunhofer Institut für Solare Energiesysteme; JQA = Japan Quality Assurance; AIST = Japanese National Institute of Advanced Industrial Science and Technology.

^fRecalibrated from original measurement.

^kStability not investigated.

Stability

The current existing tests for PV are: IEC 61215 and 61646 for x-Si and thin film (a-Si) modules respectively. Internationally accepted (accelerated) ageing tests have not yet been established for organic-based solar cells, which is understandable considering the stage of development of these cells. At this stage of development of OPV, individual accelerated lifetime tests are carried out to identify critical stress factors as well as determination of acceleration factors when subjected to certain stress factors. A recent example of a setup for studying stability and degradation of polymer solar cells was published by Krebs et al.[7] The intention of these tests is to study the performance as a function of materials, compositions, processing schemes in the various processing lines with the aim to find material combinations that permit long-term stable cells and *not* to define the potential lifetime that can be obtained with OPV devices under outdoor conditions. Accelerated studies may be necessary, but it is important that the exact experimental conditions are given; otherwise the results will be impossible to reproduce and interpret. Finally, results from accelerated lifetime testing cannot be viewed as generally applicable to other device geometries than the one tested as different materials and different device constitutions may give widely different responses to accelerated test conditions.

The first International Summit on Organic Photovoltaic Stability (ISOS) took place in Golden, Colorado, USA July 14-16, 2008. It was sponsored by the Department of Energy (DOE), Plextronics and the National Renewable Energy Laboratory (NREL). Suggestions for [shelf-life measurements](#), [outdoor testing](#), [indoor accelerated light soaking](#), [packaging/encapsulation](#), and [determination of the stabilized efficiency](#) were done. Conclusions of the summit can be found in a presentation that is provided [here](#).

[7] Suren A. Gevorgyan, Mikkel Jørgensen, Frederik C. Krebs, Sol.Energy Mater.Sol.Cells 2008, 92, 736.

International Electrotechnical Commission (IEC) Technical Committee 82 Solar Photovoltaic Energy System (TC82)

The scope of TC82 is “To prepare international standards for systems of photovoltaic conversion of solar energy into electrical energy and for all the elements in the entire photovoltaic energy system.” The “dashboard” for accessing TC82 information is found [here](#), which you can also reach by typing “82” in Search Site box at the bottom of the IEC home page (www.iec.ch) and pressing the “TC Dashboard” button. IEC TC82 comprises five working groups (covering Glossary, non-concentrating and concentrator modules, systems and balance of system components) and a joint committee working group on decentralized rural electrification.

Table 1 Positions in IEC TC82

Position	Name	Organization	Country
TC Chairman	Heinz Ossenbrink	Joint Research Center	European Commission
TC Secretariat	Howard Barikmo	Sunset Technology	USA
WG 1 (Glossary) Convenor	Hidenori Shimizu	International Standards Engineering	Japan
WG 2 (Modules, non-concentrating) Convenor	John Wohlgemuth	BP Solar	USA
WG 3 (Systems) Convenor	Ted Spooner	University of New South Wales	Australia
	Martin Cotterell	Sundog Solar	UK
WG 6 (Balance of System Components) Convenor	Charles Whitaker	BEW Engineering	USA
WG 7 (Concentrator Modules) Convenor	Robert McConnell	Amonix	USA

WG1 glossary: Task

To prepare a glossary.

WG2 Modules, non-concentrating: Task

To develop international standards for non-concentrating, terrestrial photovoltaic modules. These standards will be in the general areas of photoelectric performance, environmental test, quality assurance and quality assessment criteria. The standards ultimately produced should be

universal and non-restrictive in their application, taking into account different environments and manufacturing technologies. In addition to the basic electrical and mechanical characteristics, standards will be written for other important factors such as module thermal performance, high voltage performance, fault resistance and fault-tolerant design.

WG3 Systems: Task

To give general instructions for the photovoltaic system design, construction and maintenance. For each particular user's application, each activity should be the object of a separate study area. The Working Group should incorporate the existing standards on the functional blocks that are different from the photovoltaic array field, and promote the production of new specific standards when necessary.

WG6 Balance-of-system components: Task

To develop international standards for balance-of-system components for PV systems. These standards will be in the general areas of performance, safety, environmental durability (reliability), quality assurance and quality assessment criteria. The standards ultimately produced should be universal and non-restrictive in their application, taking into account different environments and manufacturing technologies. In addition to the basic electrical and mechanical characteristics, standards will be written for other important factors such as thermal performance, electromagnetic interference, and climate applicability/rating.

WG7 Concentrator modules: Task

To develop international standards for photovoltaic concentrators and receivers. These standards will be in the general areas of safety, photoelectric performance and environmental reliability tests. The standards ultimately produced should be universal and non-restrictive in their application, taking into account different environments and manufacturing technologies. In addition to the basic electrical and mechanical characteristics, standards will be written for other important factors such as thermal performance, high voltage performance, fault resistance and fault-tolerant design.

A list of IEC standards can be found [here](#).

IEC 60891, Procedures for temperature and irradiance corrections to measured I-V characteristics of crystalline silicon photovoltaic devices

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

IEC 60904-2, Photovoltaic devices. Part 2: Requirements for reference solar cells

IEC 60904-2/A1, Photovoltaic devices. Part 2: Requirements for reference solar cells,

Amendment 1

IEC 60904-3, Photovoltaic devices. Part 3: Measurement principles for terrestrial photovoltaic (PV) solar devices with reference spectral irradiance data

IEC 60904-4 Ed.1: Photovoltaic Devices - Part 4: Procedure for establishing the traceability of the calibration of reference solar devices

IEC 60904-5, Photovoltaic devices - Part 5: Determination of the equivalent cell temperature (ECT) of photovoltaic (PV) devices by the open-circuit voltage method

IEC 60904-6, Photovoltaic devices - Part 6: Requirements for reference solar modules

IEC 60904-6/A1, Photovoltaic devices - Part 6: Requirements for reference solar modules, Amendment 1

IEC 60904-7, Photovoltaic devices - Part 7: Computation of spectral mismatch error introduced in the testing of a photovoltaic device

IEC 60904-8, Photovoltaic devices - Part 8: Measurement of spectral response of a photovoltaic (PV) device

IEC 60904-9, Photovoltaic Devices—Part 9: Solar Simulator Performance Requirements

IEC 60904-10, Photovoltaic devices - Part 10: Methods of linearity measurement

IEC 61277, Terrestrial photovoltaic (PV) power generating systems - General and guide

IEC/PAS 62011, Specifications for the use of renewable energies in rural decentralised electrification

IEC 61215, Crystalline silicon terrestrial photovoltaic (PV) modules - Design qualification and type approval

IEC 61345, UV test for photovoltaic (PV) modules

IEC 61646, Thin-film terrestrial photovoltaic (PV) modules - Design qualification and type approval

IEC 61701, Salt mist corrosion testing of photovoltaic (PV) modules

IEC 61721, Susceptibility of a photovoltaic (PV) module to accidental impact damage (resistance to impact test)

IEC 61829, Crystalline silicon photovoltaic (PV) array - On-site measurement of I-V characteristics

IEEE SCC21 – Standards Coordinating Committee on Fuel Cells, Photovoltaics, Dispersed Generation, and Energy Storage.

SCC21 oversees the development of standards in the areas of fuel cells, photovoltaics (PV), dispersed generation, and energy storage and coordinates efforts in these fields among the various IEEE Societies and other affected organizations to ensure that all standards are consistent and properly reflect the views of all applicable disciplines. IEEE SCC21 reviews all proposed IEEE standards in these fields before their submission to the IEEE-SA Standards Board for approval and coordinates submission to other organizations. The SCC21 Official web site is found [here](#).

American Society for Testing and Materials (ASTM) E44.09 Committee on Photovoltaic Electric Power Conversion

ASTM E44.09 has continued its pursuit of product and system test procedures with two new standards underdevelopment, one of which will define procedures for evaluating the performance of concentrator modules. The E44.09 web page with a list of active standards can be found [here](#).

A list of ASTM standards can be found here:

ASTM E 927, Standard Specification for Solar Simulation for Terrestrial Photovoltaic Testing.

ASTM E 948, Standard Test Method for Electrical Performance of Photovoltaic Cells Using Reference Cells Under Simulated Sunlight.

ASTM E 973, Standard Test Method for Determination of the Spectral Mismatch Parameter Between a Photovoltaic Device and a Photovoltaic Reference Cell.

ASTM E 973M, Standard Test Method for Determination of the Spectral Mismatch Parameter Between a Photovoltaic Device and a Photovoltaic Reference Cell.

ASTM E 1021, Test Methods for Measuring Spectral Response of Photovoltaic Cells.

ASTM E 1036, Standard Test Methods for Electrical Performance of Nonconcentrator Terrestrial Photovoltaic Modules and Arrays Using Reference Cells.

ASTM E 1036M, Standard Test Methods for Electrical Performance of Nonconcentrator Terrestrial Photovoltaic Modules and Arrays Using Reference Cells.

ASTM E 1038, Standard Test Method for Determining Resistance of Photovoltaic Modules to Hail by Impact with Propelled Ice Balls.

ASTM E 1040, Standard Specification for Physical Characteristics of Nonconcentrator Terrestrial Photovoltaic Reference Cells.

ASTM E 1125, Standard Test Method for Calibration of Primary Non-Concentrator Terrestrial Photovoltaic Reference Cells Using a Tabular Spectrum.

ASTM E 1143, Standard Test Method for Determining the Linearity of a Photovoltaic Device Parameter with Respect To a Test Parameter.

ASTM E 1171, Standard Test Method for Photovoltaic Modules in Cyclic Temperature and Humidity Environments.

ASTM E 1328, Standard Terminology Relating to Photovoltaic Solar Energy Conversion.

ASTM E 1362, Standard Test Method for Calibration of Non-Concentrator Photovoltaic Secondary Reference Cells.

ASTM E 1462, Standard Test Methods for Insulation Integrity and Ground Path Continuity of Photovoltaic Modules.

ASTM E 1596, Test Methods for Solar Radiation Weathering of Photovoltaic Modules.

ASTM E 1597, Standard Test Method for Saltwater Pressure Immersion and Temperature

Testing of Photovoltaic Modules for Marine Environments.

ASTM E 1799, Standard Practice for Visual Inspections of Photovoltaic Modules.

ASTM E 1802, Standard Test Methods for Wet Insulation Integrity Testing of Photovoltaic Modules.

ASTM E 1830, Standard Test Methods for Determining Mechanical Integrity of Photovoltaic Modules.

ASTM E 2047, Standard Test Method for Wet Insulation Integrity Testing of Photovoltaic Arrays.

ASTM E 2236, Standard Test Methods for Measurement of Electrical Performance and Spectral Response of Nonconcentrator Multijunction Photovoltaic Cells and Modules.

ASTM G 173, Standard Tables for Reference Solar Spectral Irradiances: Direct Normal and Hemispherical on 37° Tilted Surface.

Underwriters Laboratories Inc. (UL) Standards Technical Panels

UL's Standards Technical Panels (STPs) are an important part of the process by which UL develops and maintains its Standards for Safety. An STP is a group of individuals, representing a variety of interests, formed to review proposals related to UL Standards for Safety. When an American National Standards Institute (ANSI)/UL Standard for Safety is involved, an STP serves as the consensus body to review and vote on proposals prior to publication. The development of ANSI/UL Standards for Safety greatly benefits from the expertise of individuals interested in the products affected by ANSI/UL Standards.

UL Standards are recognized nationally and internationally as the benchmarks for product safety. The Standards Technical Panels (STPs) provide UL with the means to receive early input from those who are interested in the standards development process.

Two standards developed by UL in the field of photovoltaics can be found here.

UL 1703 Flat-Plate Photovoltaic Modules and Panels, third edition (Edition Date March 15, 2002)

Revisions: October 1, 2003

June 30, 2004

April 8, 2008

Subject 8703 Concentrator Photovoltaic Modules and Assemblies

Outline: Issue 1 September 9, 2008

Power conversion efficiency

The power conversion efficiency, η , of a solar cell is defined as:

$$\eta (\%) = (P_{\text{out}}/P_{\text{in}}) \times 100 = (FF \times V_{\text{oc}} \times J_{\text{sc}}) / P_{\text{in}}$$

η depends on:

- temperature
- illumination power
- spectral distribution light source

In order to be able to compare efficiency values, measured at different laboratories, standard reporting conditions (SRC) were developed:

Cell temperature: 25 °C

Illumination power: 1000 W/m²

Spectral irradiance distribution: AM1.5 global (Standard [ASTM G173](#))

Procedure efficiency measurement at SRC

Required:

- Solar simulator, preferably Class A (usually Xe-lamp with AM1.5 filter)
- Calibrated reference cell to adjust the intensity of the simulator

Errors are introduced:

- Mismatch simulator spectrum and AM1.5 GN reference spectrum (ASTM G173)
- Deviations of Spectral Response (SR) test cell and reference cell
- For novel type of solar cells: no stable reference cell with same SR and geometrical design is available

This error can be expressed as spectral mismatch correction factor (M):

$$M = \frac{\int E_R(\lambda)S_R(\lambda)d\lambda}{\int E_S(\lambda)S_R(\lambda)d\lambda} * \frac{\int E_S(\lambda)S_T(\lambda)d\lambda}{\int E_R(\lambda)S_T(\lambda)d\lambda}$$

In which:

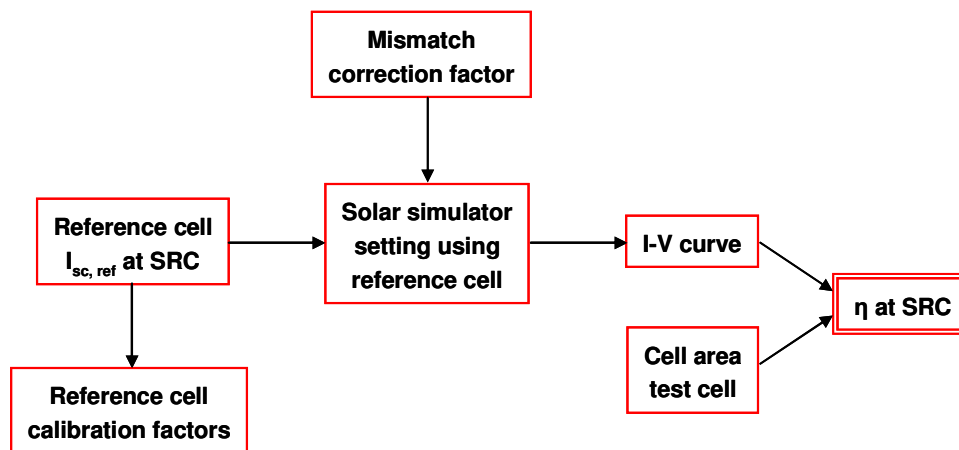
$E_R(\lambda)$:reference spectral irradiance

$E_S(\lambda)$: source spectral irradiance

$S_R(\lambda)$:spectral response of the reference cell

$S_T(\lambda)$:spectral response of the test device

Schematically, the procedure for efficiency measurements at SRC is as follows:



Organic Thin Film Transistors and Integrated Circuits

Published standards

- i) IEEE Std 1620™-2004 “IEEE Standard Test Methods for the Characterization of Organic Transistors and Materials” (ISBN: 978-0-7381-5011-6)
<http://grouper.ieee.org/groups/1620/>
- ii) IEEE Std 1620.1™-2006 “IEEE Standard for Test Methods for the Characterization of Organic Transistor-Based Ring Oscillators” (ISBN: 978-0-7381-3993-7)
<http://grouper.ieee.org/groups/1620/1/>

Draft standards

- iii) IEEE Std 1620.2 DRAFT “IEEE Draft Standard Methods for the Characterization of Printed and Organic Diode Bridge Structures for RF Devices”
<http://grouper.ieee.org/groups/1620/2/>

Within the FP6-project PolyApply a [standardization report](#) was compiled in 2004 giving an overview of the standardization efforts in all global regions (EU, US/Americas, Asia) related to RFID technology. The information was collected from the different standardization organizations, e.g. ISO, DIN, ETSI. Updates of these reports were done in [2005](#) and [2006](#).

Ongoing work towards forming standards or measurement protocols

- i) Within the Organic Electronics Association (OE-A) a working group exists which heads for developing a “Guideline for Measurement and Characterization of organic FETs”. The results of this working work are foreseen to be published in the future on the oe-a homepage (<http://www.oe-a.de/>).
- ii) No other activities were identified so far. Please let us know, if there are activities going on, which we might have overlooked.

OLED/Lighting

End customers are putting their focus on several key parameters such as efficiency, lifetime and colour quality and are keen to describe the properties of a new light source by just a few key figures. This is sufficient to emphasise the need of standardisation in the field of measuring important light parameters for OLEDs as a new technology. Whilst conventional lamp technologies have already derived standards on the measurement of lighting efficiency, the field is still open for OLED light sources. Many definitions can be used to describe various efficiency or efficacy parameters and at least the same amount of measurement setups.

Within the FP6-project OLLA, the white paper "[Luminous Efficacy Measurement Standardisation of OLED Light Sources](#)" gives indications on the important parameters that should be addressed in a standardised procedure.

The FP7-project [OLED100.eu](#) aims at reaching a common understanding on OLED specific parameters. In a second stage, measurement setups will be worked out which quantify these parameters in an adequate way. The OLED100.eu consortium has identified seven single or grouped parameters, which are very specific for flat area light sources like OLEDs. These parameters are – in order of prioritisation of experimental procedures:

1. Homogeneity of luminance and CIE colour coordinates
2. Angular dependence of luminance and CIE colour coordinates
3. Lifetime
4. Efficacy / Efficiency
5. Standard electro-optical parameter set: IVL and spectrum
6. Colour Rendering Indices and CRI
7. In case of modular assemblies: Tile to Tile variations which could make binning necessary.