Helmholtz Institute Erlangen-Nürnberg

General Introduction to Standardisation and Activities of TC113 - Nanotechnology for electrotechnical products and systems

Viperlab Standardization Workshop

17.1.2024 ||| Dr. Jens Hauch ||| High Throughput Methods in Photovoltaics

part of Forschungszentrum Jülich

in cooperation with Friedrich-Alexander Universität Erlangen-Nürnberg, Helmholtz Zentrum Berlin

Why Standardize?

To avoid this!

National and International Standardization

	National z.B. Deutschland	Regional z.B. Europa	International
General	DIN	CEN	ISO
Electrical Engineering	DKE VDE DIN	CENELEC	IEC
Telecom-munications	DKE VDE DIN	ETSI	ITU

What is the IEC (International Electrotechnical Commission)?

Wikipedia:
„The International Electrotechnical Commission (IEC) is an **international standards organization that prepares and publishes international standards** for all electrical, electronic and related technologies – collectively known as "electrotechnology".

IEC standards cover a vast range of technologies from **power generation, transmission** and distribution to home appliances and office equipment, **semiconductors,** fibre optics, batteries, **solar energy, nanotechnology** and marine energy as well as many others.

The IEC also manages four global conformity assessment systems that certify whether equipment, system or components conform to its international standards."

What is the IEC (International Electrotechnical Commission)?

170+
countries

A global network that covers 99% of the world population and offers a free programme to developing countries

10 000+
standards

Develops international standards that represent a global concensus of state-of-the-art know-how

1M+
certificates

Four Conformity Assessment Systems that cover the breadth of electrical and electronic technologies

20 000
experts

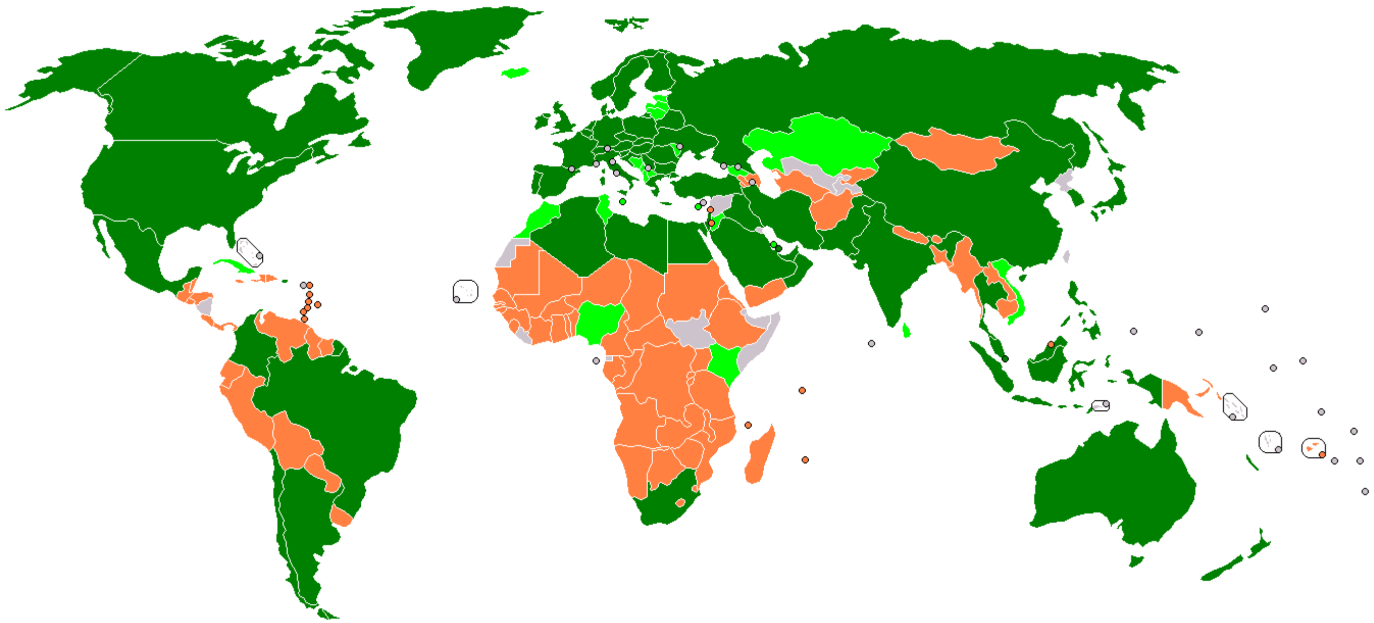
Over 20 000 experts and more than 100 years expertise

Who is in it?

Wikipedia:
“The IEC is made up of **members, called national committees**, and each NC represents its nation's electrotechnical interests in the IEC.

This includes manufacturers, providers, distributors and vendors, consumers and users, all levels of governmental agencies, professional societies and trade associations as well as standards developers from national standards bodies.

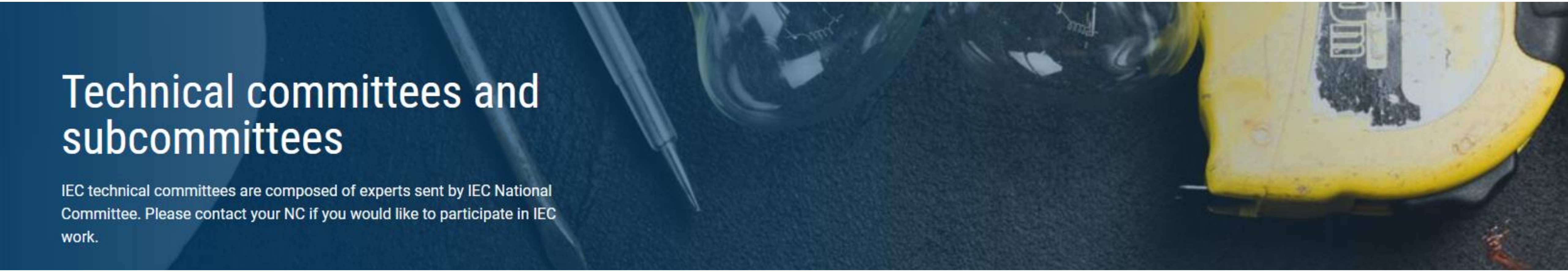
National committees are constituted in different ways. Some NCs are public sector only, some are a combination of public and private sector, and some are private sector only. **About 90% of those who prepare IEC standards work in industry.**



A map of IEC membership as of April 2012 Full members Associate members Affiliates

60 Full members – Voting rights + access to managing functions
23 Associate members – Limited voting rights
87 Affiliates – access to standards for national adoption

How is it organized?



Facts & figures

IEC TCs/SCs

Technical Committees	115
Subcommittees	102
Total	217

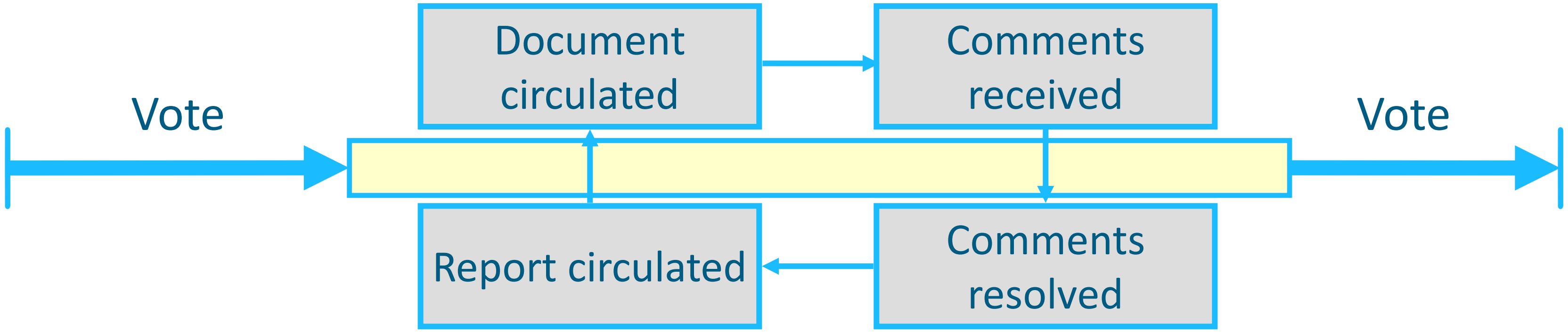
WGs

Working Groups	771
Project Teams	195
Maintenance Teams	671
Total	1637

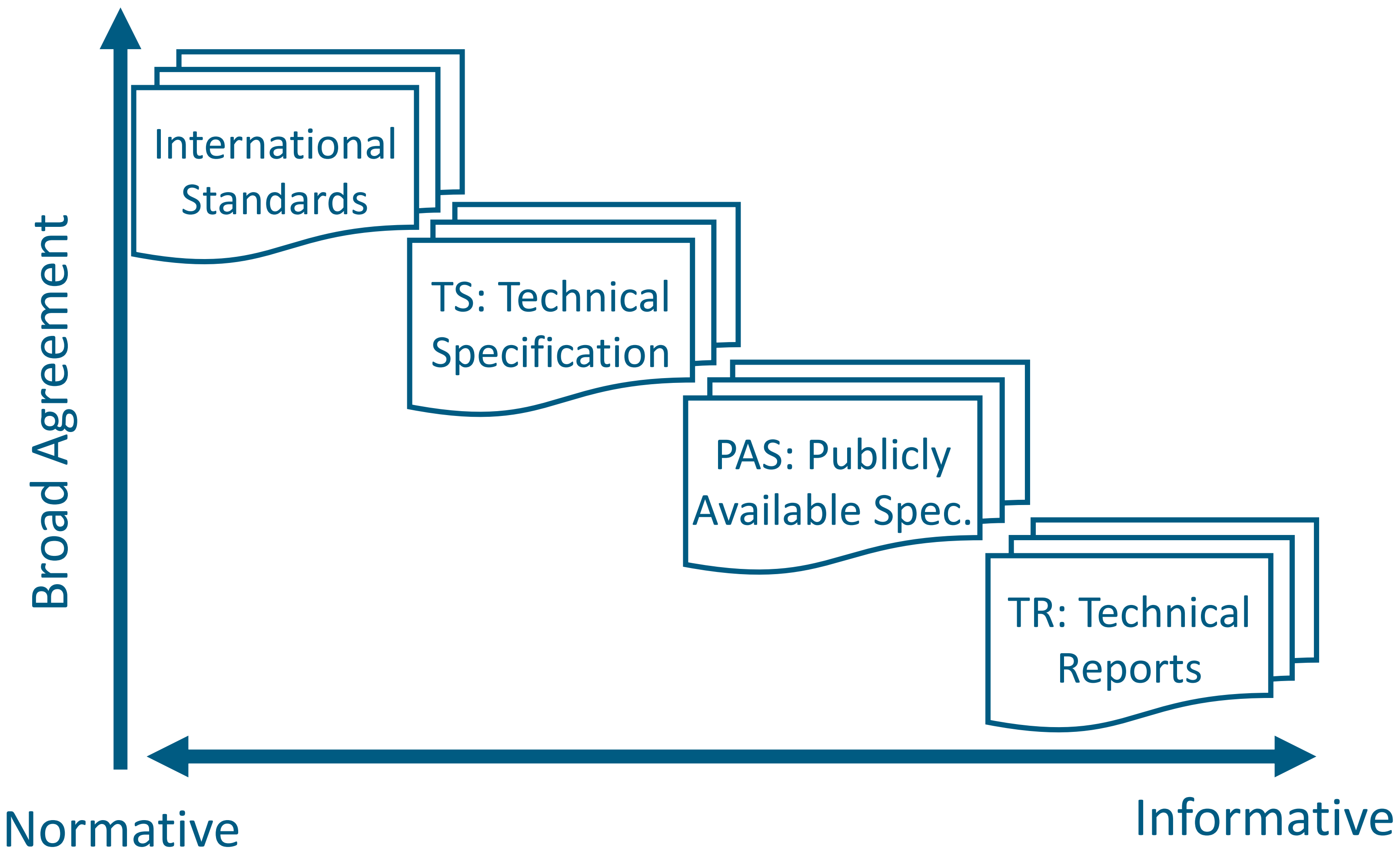
- **National experts** are chosen by their National Committee (NC) as delegates to share their technical expertise and represent the national requirements in **Technical Committees (TCs).**
- Each TC defines its scope and area of activity.
- A TC can form one or more **Subcommittees** depending on the extent of its work programme. Each SC defines its scope and reports directly to the parent TC.
- TCs & SCs form **working groups** to prepare standards in a process of consensus.

Stages of the Standardization Process

Project Stage	Associated Document Name	Abbreviation
0 Preliminary Stage	Preliminary work item	PWI
1 Proposal Stage	New work item proposal	NP
2 Preparatory Stage	Working draft(s)	WD
3 Committee Stage	Committee draft(s)	CD
4 Enquiry Stage	Enquiry draft (Committee draft for vote)	CDV
5 Approval Stage	Final draft international standard	FDIS
6 Publication Stage	International standard	IEC



Products of the IEC



Relevant subcommittees of the IEC

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

IEC subcommittees

TC82 – Solar photovoltaic energy systems

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. In this context, the concept "photovoltaic energy system" includes the entire field from light input to a photovoltaic cell to and including the interface with the electrical system(s) to which energy is supplied.

TC113 – Nanotechnology standardization for electrical and electronic products and systems

Standardization of the technologies relevant to electrotechnical products and systems in the field of nanotechnology in close cooperation with other committees of IEC and ISO

TC119 – Printed Electronics

Standardization of terminology, materials, processes, equipment, products and health / safety / sustainability in the field of printed electronics

Relevant subcommittees of the IEC (my personal interpretation)

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

IEC subcommittees

TC82 – Solar photovoltaic energy systems

→ **Product oriented standards**

TC113 – Nanotechnology standardization for electrical and electronic products and systems

→ **Technology oriented standards**

TC119 – Printed Electronics

→ **Process/Device oriented standards**

TC113 – Nanotechnology for electrotechnical products and systems

Scope: Standardization of the technologies relevant to electrotechnical products and systems in the field of nanotechnology in close cooperation with other committees of IEC and ISO

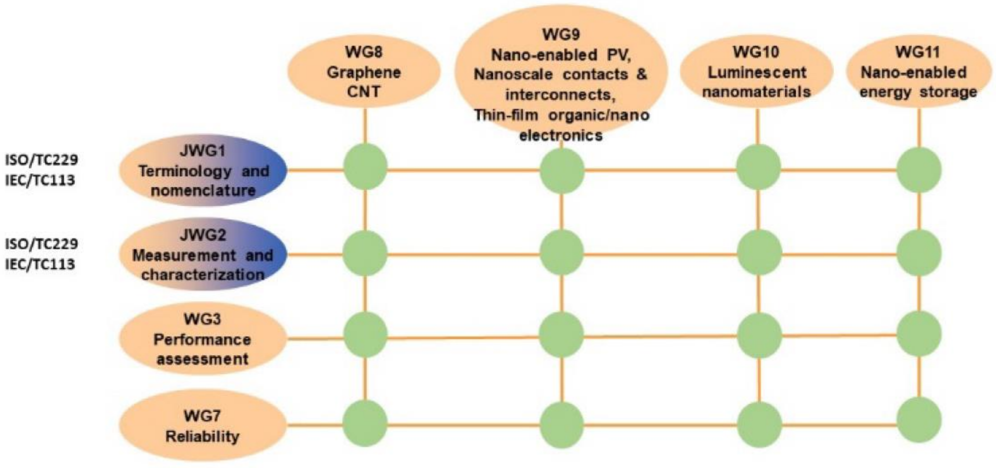


Figure 1 Matrix Organization Structure of TC 113

WG 7: Reliability

To develop standards for the assessment of reliability in the field of nano electro technology. The focus is on failure mechanisms and failure modes related to the use of nanomaterials, nanostructures, material interfaces and nanoscale contacts with consideration of size dependent effects. Standards to be developed include test methods to identify failure mechanisms, analyse failure effects and estimate the reliability (i.e. the early fail rate, measure in units of parts per million in the first 1000h of operation) and the durability of nano-enabled products, i.e. the fit rate (1 fit = 1 fail in 10^9 hours of operation).

WG 9: Nano-enabled photovoltaics, Thin-film organic/nano electronics, Nanoscale contacts and interconnects

To develop standards in the area of nano-enabled photovoltaics and organic electronics to facilitate the assurance of quality and reliability of materials and intermediates, subject to the general concepts of blank detail specifications (BDS) and Key Control Characteristics (KCCs). Furthermore the WG is responsible for standardization in the area of nano-scale contacts and interconnects.

IEC TS 62876-2-1:2018

Nanotechnology – Reliability Assessment – Part 2-1:

Nano-enabled photovoltaic devices – Stability test

part of

in cooperation with

HI ERN
Helmholtz Institute Erlangen-Nürnberg

2009 Recommended practices: Organic Photovoltaics Lifetime Assessment

2010

Solar Energy Materials & Solar Cells 95 (2011) 1253–1267

Contents lists available at ScienceDirect

Solar Energy Materials & Solar Cells

journal homepage: www.elsevier.com/locate/solmat

ELSEVIER

Consensus stability testing protocols for organic photovoltaic materials and devices

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Why am I here?

Consensus on ISOS Protocols for Stability Assessment and Reporting for Perovskite Photovoltaics

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IEC TS 62876-2-1:2018

IEC TS 62876-2-1:2018

Nanotechnology - Reliability assessment - Part 2-1: Nano-enabled photovoltaic devices - Stability test

TC 113 | Additional information

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Abstract

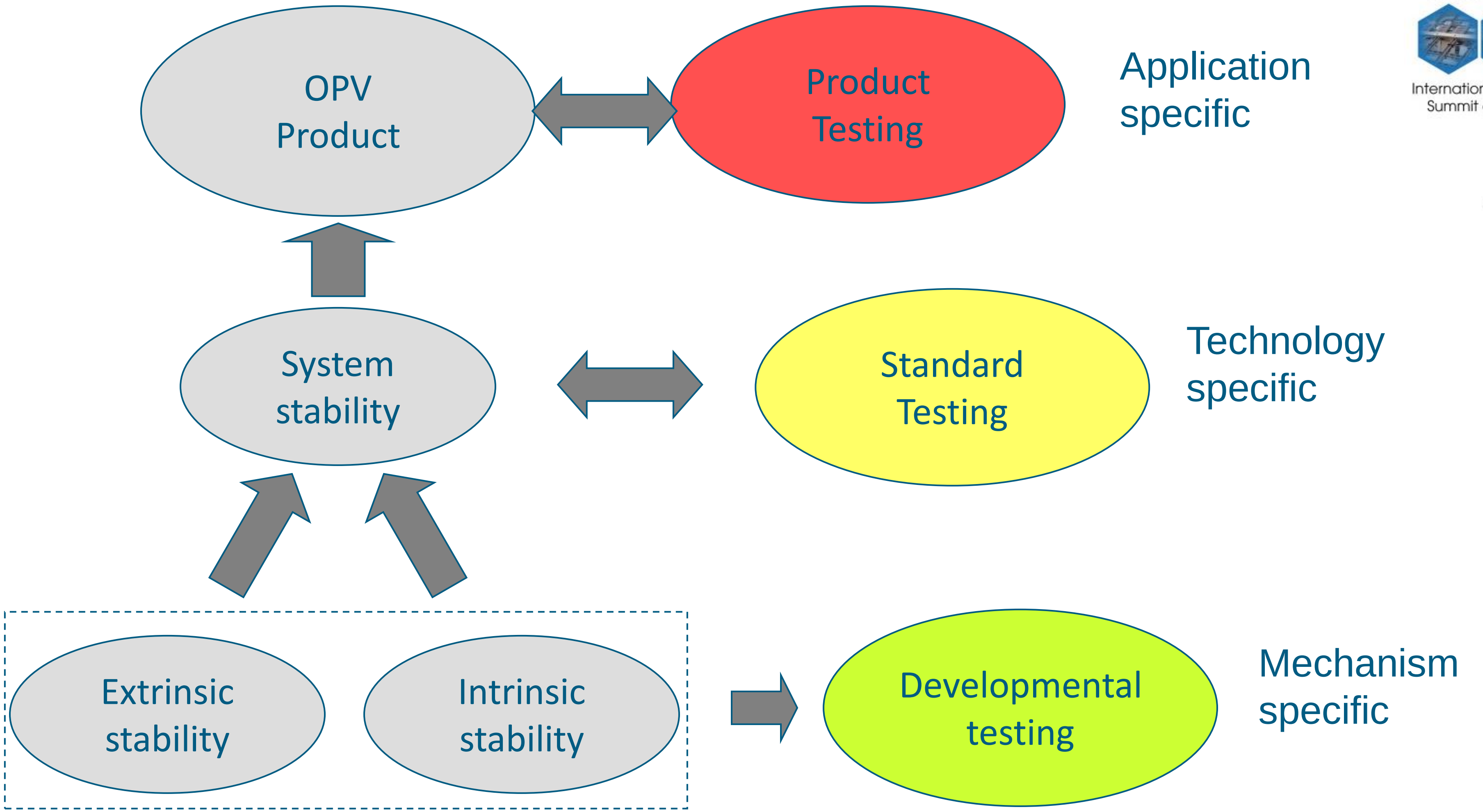
PREVIEW

IEC TS 62876-2-1:2018 establishes a general stability testing programme to verify the stability of the performance of nanomaterials and nano-enabled photovoltaic devices (NePV) devices. These devices are used as subassemblies for the fabrication of photovoltaic modules through a combination with other components. This testing programme defines standardized degradation conditions, methodologies and data assessment for technologies. The results of these tests define a stability under standardized degradation conditions for quantitative evaluation of the stability of a new technology. The procedures outlined in this document were designed for NePV,
Show more »

Look inside

- Table of contents
- Foreword
- Introduction
- Scope
- Normative references

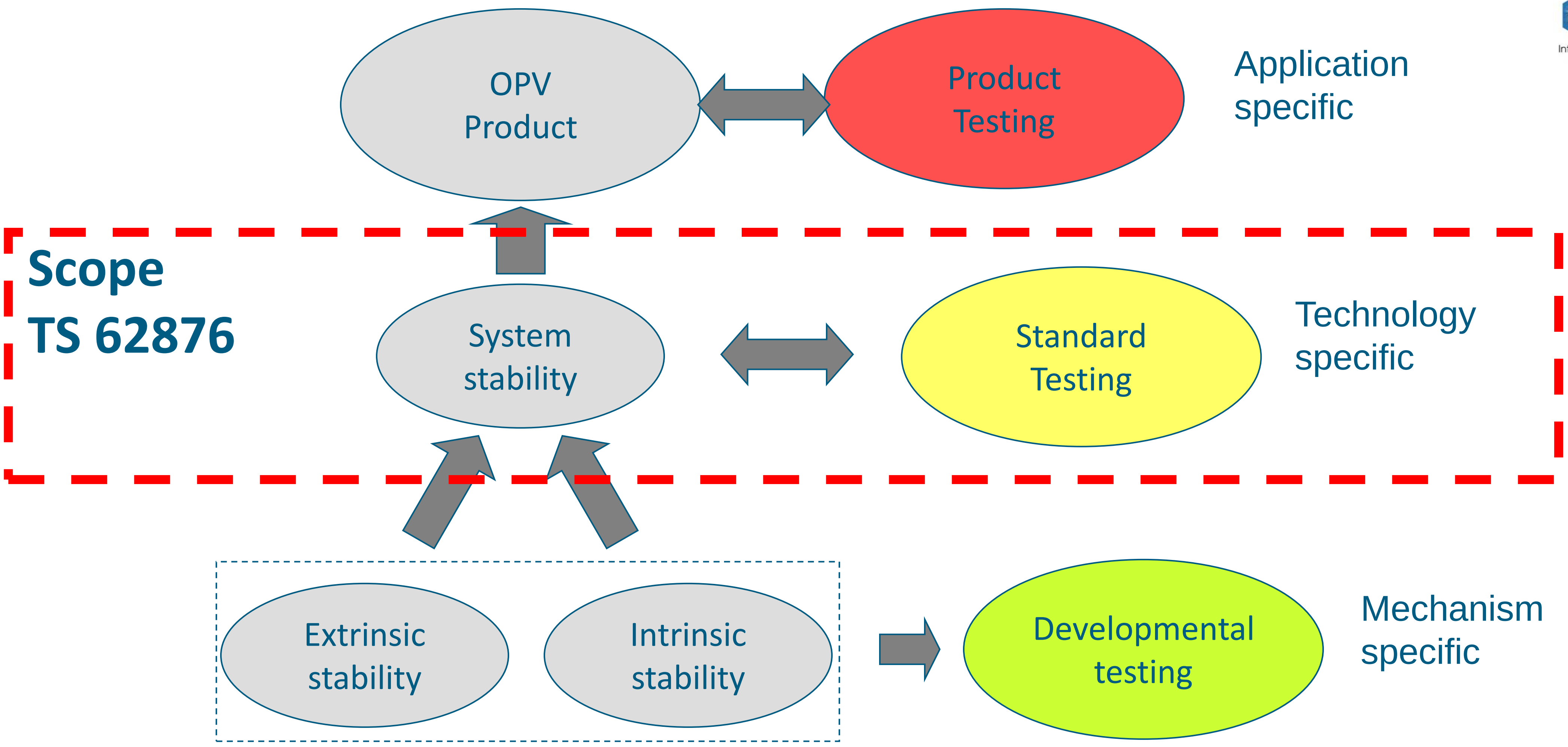
The testing hierarchy



General Philosophy

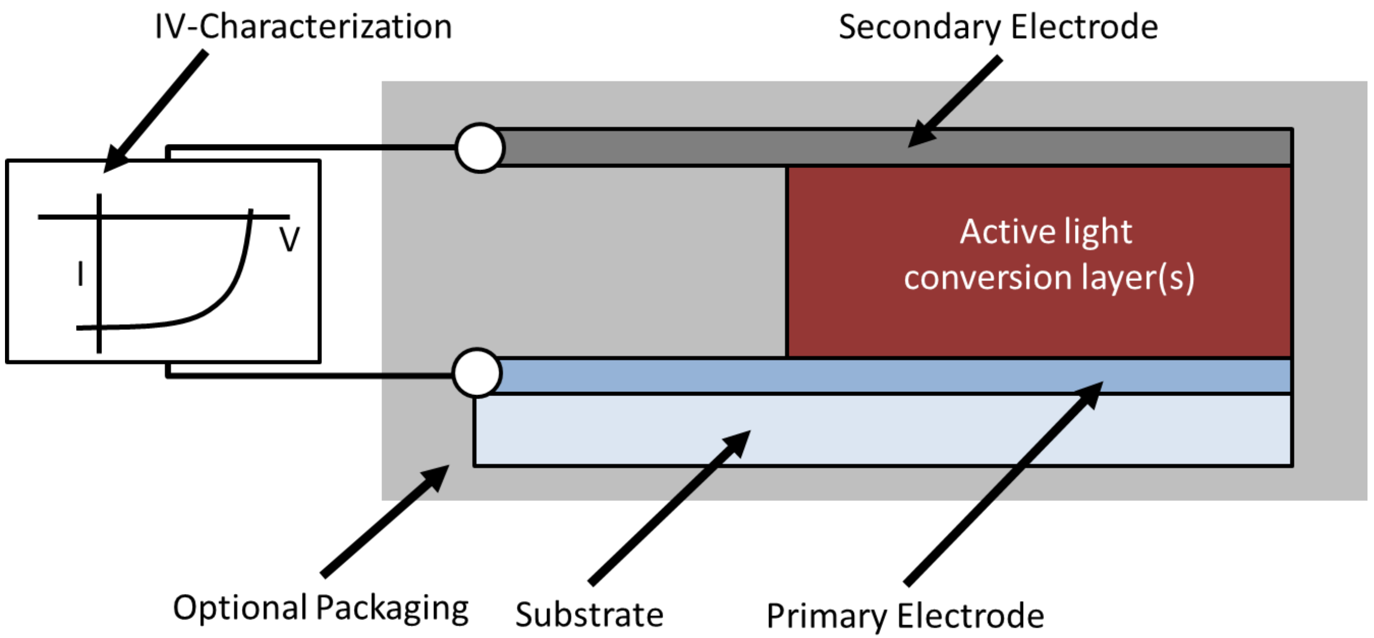
- Original Target „Technical Report“ status
- Provide guidelines for stability testing
- Perform technology testing – NOT product testing
- Define stresses & procedures to establish comparability (=define yardstick for stability)
- Establish procedures that would allow certified laboratories to perform tests and verify performance
- Recommend a sequence of tests that reflects a basic stability testing program for NePV technology
- Establish reporting requirements

The testing hierarchy



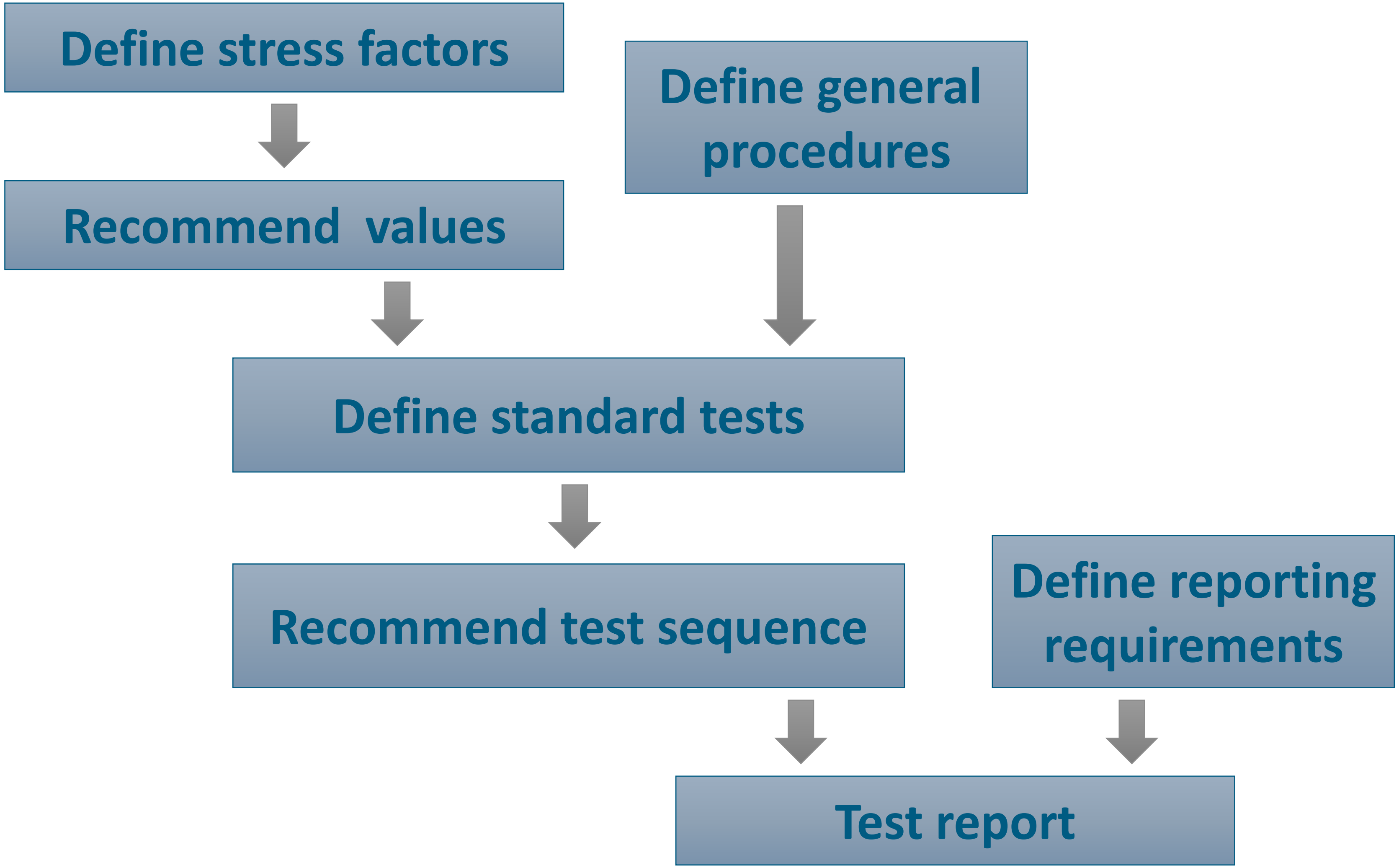
NANOTECHNOLOGY – RELIABILITY ASSESSMENT–

Part 2.1 Nano-enabled photovoltaic devices – Stability test

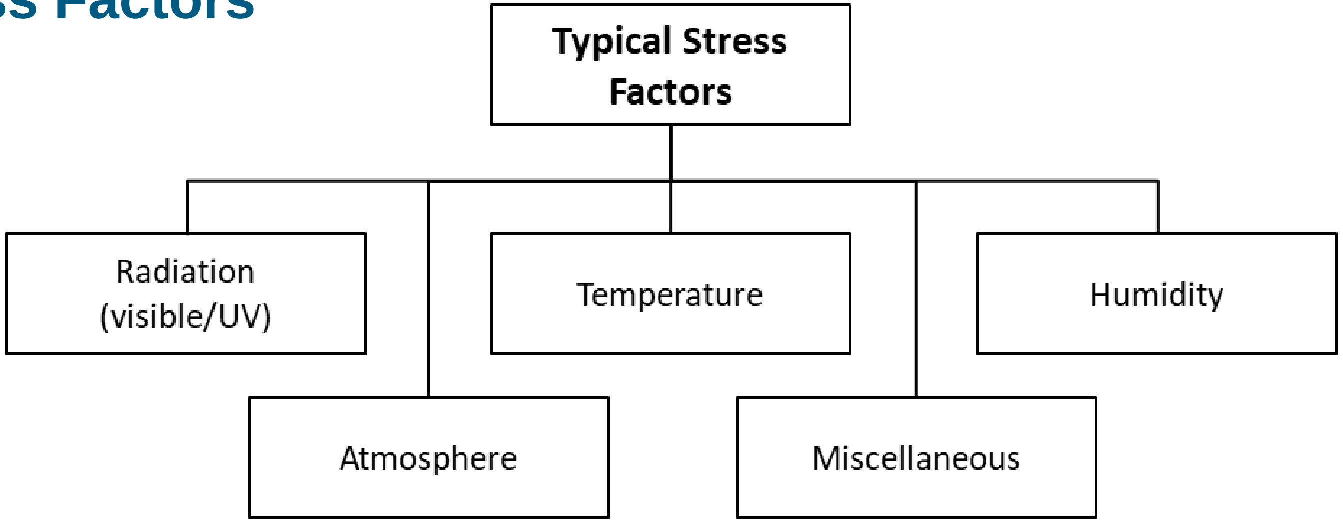


NePV = Nano-enabled photovoltaic devices

Approach

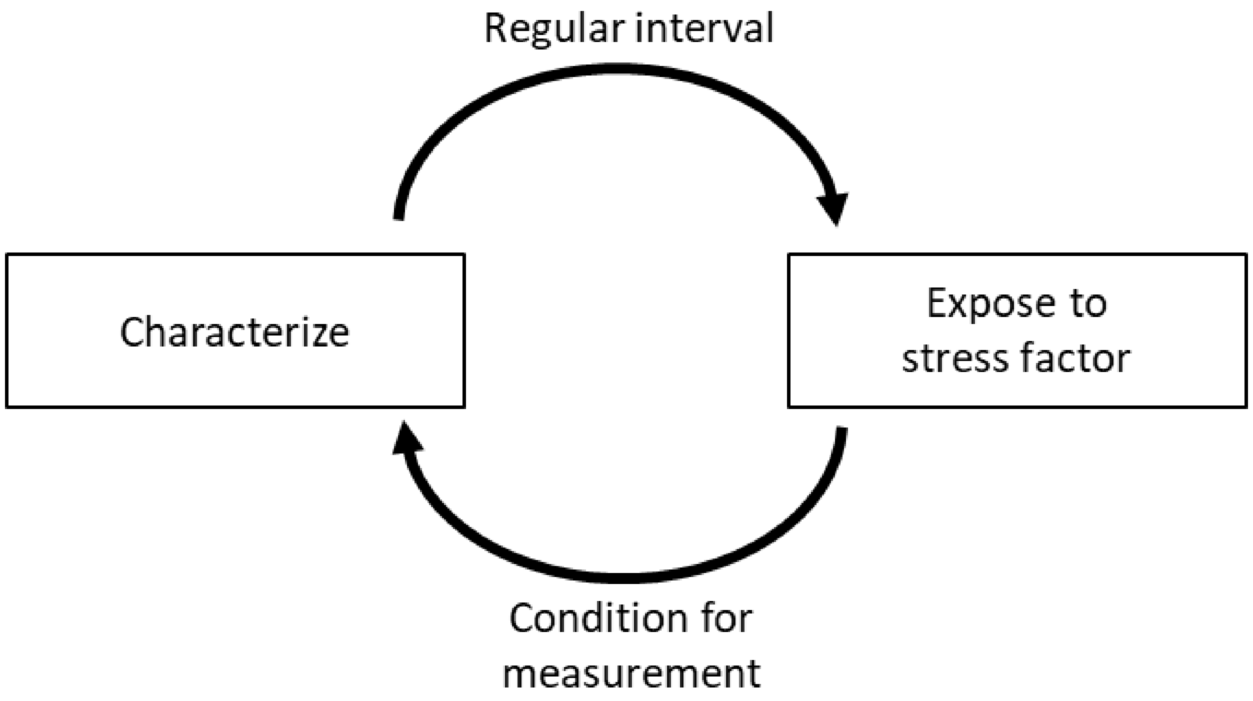

Define stress factors
Define general procedures
Recommend values
Define standard tests
Recommend test sequence
Define reporting requirements
Test report

Definition of Stress Factors

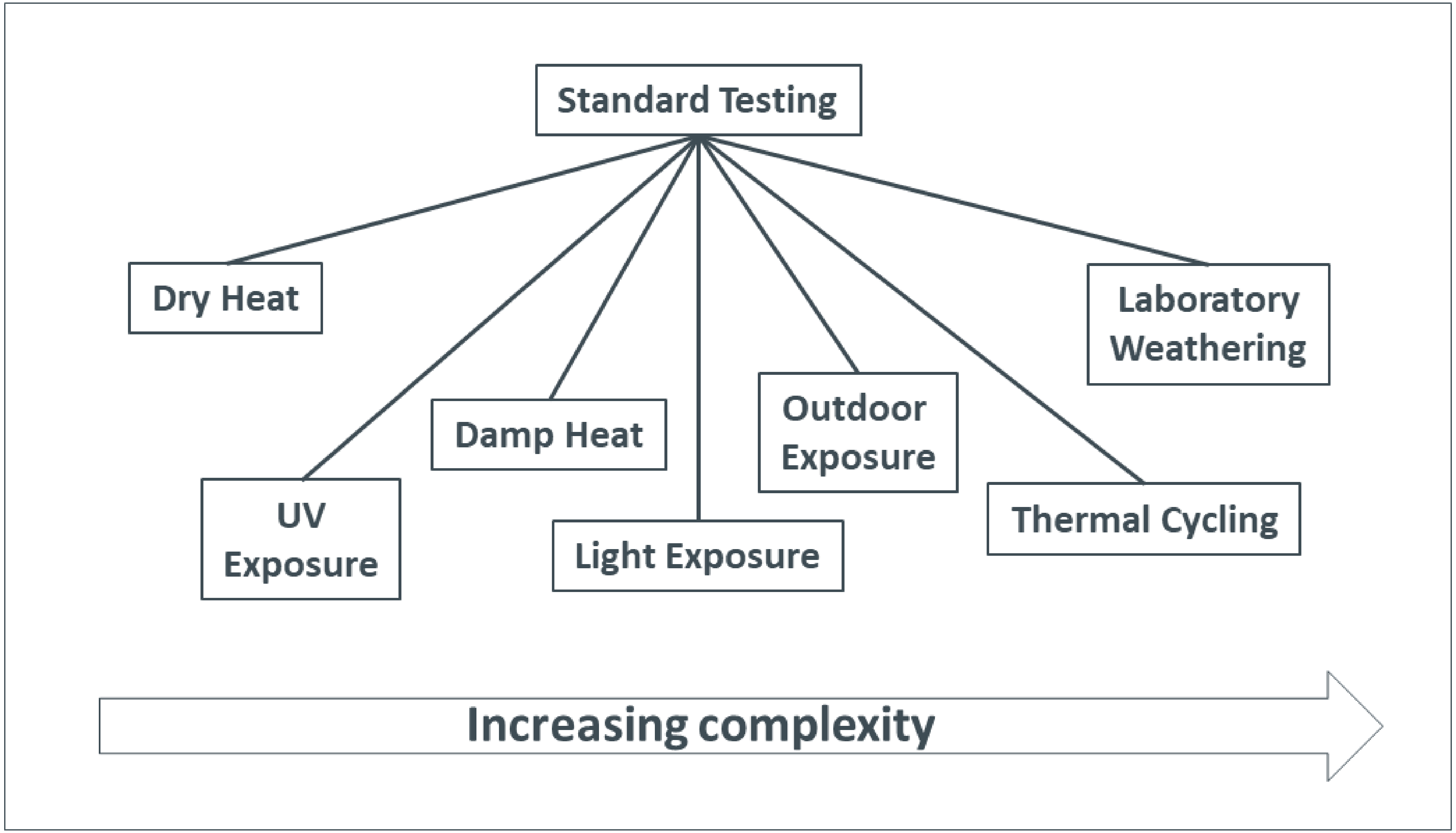


Stress	Typical values				
Temperature (T)	Ambient	45 °C	65 °C	85 °C	Thermal cycle −40 °C to 85 °C
Humidity (H)	Ambient	0 % rh	50 % rh	85 % rh	
Light (L)	No(dark)	Outdoor	Solar simulator (AM1.5, 1000 W/m^2)	Lamp	UV
Misc. (M)	Atmospheric effects	Mechanical (pressure, shear)			

Definition of General Procedure



Overview of Tests



Defined tests

Parameter	Test ID and description						
	ST1 **Dry heat**	**ST2** **UV exposure**	**ST3** **Damp heat**	**ST4** **Light exposure**	**ST5** **Outdoor exposure**	**ST6** **Laboratory weathering**	**ST7** **Thermal cycling**
Light	None	UV	None	Daylight, (600-1 000) W/m^2	Ambient	Daylight, (600-1 000) W/m^2	None
Temperature	45 °C **65 °C** 85 °C	65 °C	45 °C 65 °C **85 °C**	45 °C **65 °C** 85 °C	Ambient	38 °C	−40 °C to +85 °C
Humidity	Ambient	Ambient	85 % rh	Ambient	Ambient	50 % rh/ water spray	Ambient
Environment	Oven	UV chamber	Climate chamber	Light soak chamber	Outdoor	Weathering instrument	Climate chamber
Load	None	None	None	Passive or Active, M_{pp}	Passive or Active, M_{pp}	Passive or Active, M_{pp}	None

Detailed Description of Tests

5.1 ST1- Dry Heat

5.1.1 Purpose

To determine the ability of the DUT to withstand thermal stress.

5.1.2 Temperature/Humidity

The test shall be carried out in accordance with IEC 60068-2-2. Typical temperatures used in this test 65ºC/75°C/ 85°C to test for degradation mechanisms. Recommended is testing at 85°C. Termination of the test is either T_{80} or user defined.

5.1.3 Data Logging

Periodic with an initial interval of 1 measurement per day for the first 5 days, with no more than 6 hours interruption of stress exposure per measurement. Thereafter devices should be measured weekly with no more than 6 hours interruption of stress exposure. The total exposure time in stress test shall be recorded in hours. IV characterization under calibrated solar simulation is necessary. Devices shall be stored under open circuit condition. Allow cells to equilibrate to standard conditions before efficiency measurements.

5.1.4 Output

Conditioned efficiency or maximum power output should be extracted from IV-measurements and plotted over time. Then the burn-in range, the initial conditioned efficiency, the time to T_{80}, and the decay rate of the performance should be extracted from the plot and reported. Visually inspect the device and record any changes.

5.1.5 Required Equipment

a) Calibrated AM1.5 Solar Simulator according to IEC 60904-9 or alternatively a light source calibrated by the DSR(Differential Spectral Resposivity[6)])-method may be used. For IV-Measurement also refer to notes in 3.1.

b) Furnace with a temperature stability +/-2°C, Temperature logger in accordance with IEC 60068-2-2

Reporting Requirements

6 Report

Performance characteristics and details of any failures and re-tests shall be prepared by testing laboratories in accordance with ISO/IEC 17025. Each test report shall include at least the following information.

a) A title.

b) Name and address of the test laboratory and location where the tests were carried out.

c) Unique identification of the report on each page.

d) Name and address of the client, where appropriate.

e) Description and identification of the DUTs and technology tested.

f) Characterization and condition of the test item.

g) Date of receipt of test item and date(s) of test, where appropriate.

h) Identification of test method used.

i) Reference to sampling procedure, where relevant.

j) Number of devices in the test and number of devices that failed during testing.

k) Any deviations from, additions to or exclusions from the test method, and any other information relevant to a specific test, such as environmental conditions.

l) Measurements, examinations and derived results supported by tables, graphs, sketches and photographs as appropriate.

m) A statement of the estimated uncertainty of the test results (where relevant).

n) A signature and title, or equivalent identification of the person(s) accepting responsibility for the content of the report, and the date of issue.

Comparison TS 62876 to ISOS Protocols (1/2)

	Document	Test Name	Light	Temperature	Humidity	Environment	Load
ST1	NePV Stability	ST1 Dry Heat	None	45/65/85 °C	Ambient	Oven	None
	ISOS 2009	T1 Shelf Life B	None	Controlled (elevated)	(Controlled)	Dry oven	None
	ISOS 2011	ISOS-D-2 High temp.	None	65/85 °C	Ambient (low)	Oven	Open Circuit
ST2	NePV Stability	ST2 UV-Exposure	UV	65 °C	Ambient	UV chamber	None
	ISOS 2009	Not described in the document					
	ISOS 2011	Not described in the document					
ST3	NePV Stability	ST3 Damp-Heat	None	45/65/85 °C	85 % rh	Climate chamber	None
	ISOS 2009	T4 Damp-Heat	None	40/65/85 °C	85 % rh	Environm. Chamber	None
	ISOS 2011	ISOS-D-3 Damp Heat	None	65/85 °C	85 % rh	Environm. Chamber	Open Circuit
ST4	NePV Stability	ST4 Light Exposure	Daylight, (600-1 000) W/m2	45/65/85 °C	Ambient	Light soak chamber	Passive or Active, M_{pp}
	ISOS 2009	T2 Light Soak	(0.6 - 1) Sun	(30-50) °C	Ambient	Light Soaking Chamber	Active or Passive
	ISOS 2011	ISOS-L-2 Laboratory Weathering	AM 1.5	65/85 °C	Ambient	Light & Temp.	M_{pp} or Open Circuit

Comparison TS 62876 to ISOS Protocols (2/2)

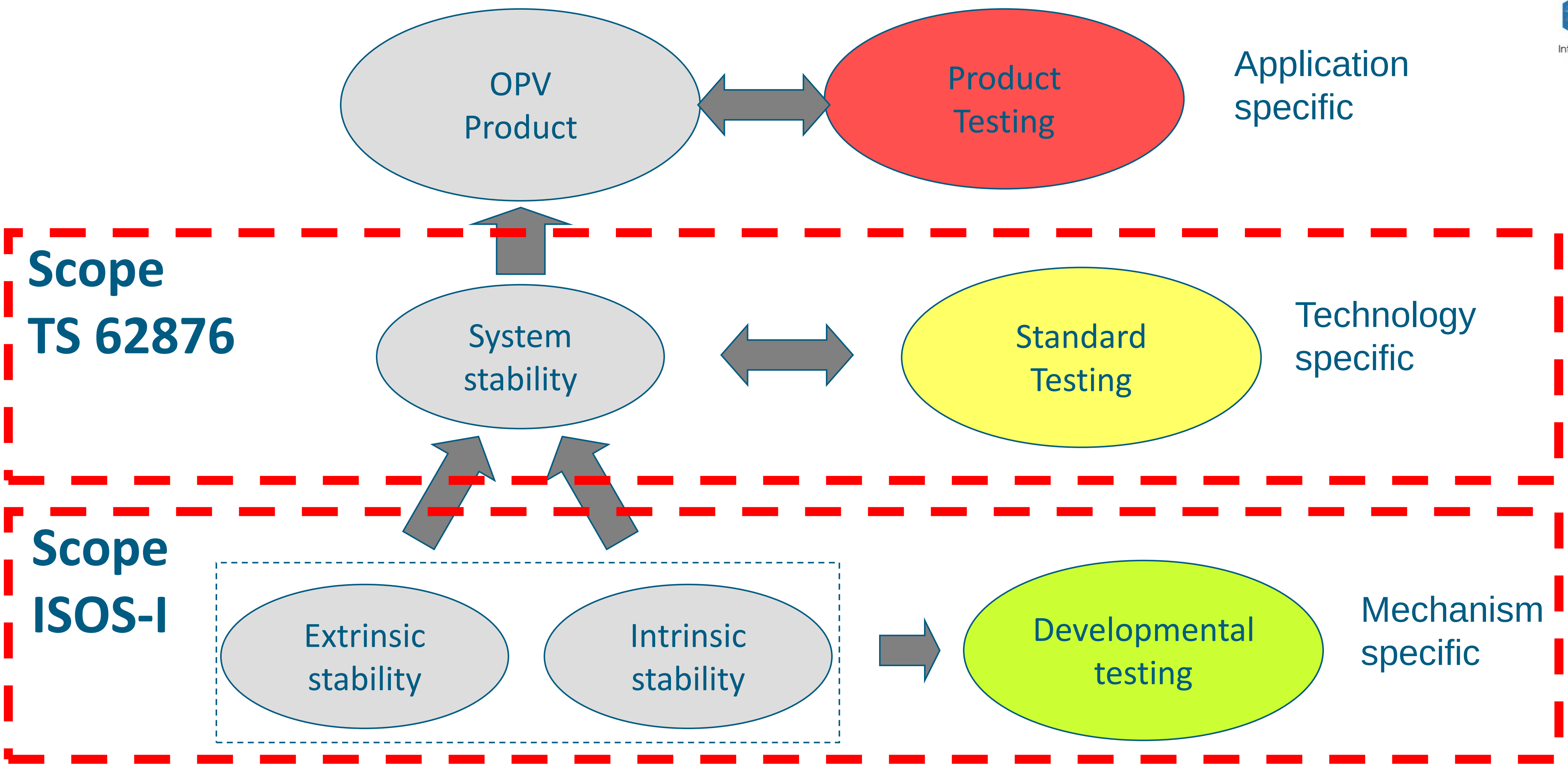
	Document	Test Name	Light	Temperature	Humidity	Environment	Load
ST5	NePV Stability	ST5 Outdoor Exposure	Ambient	Ambient	Ambient	Outdoor	Passive or Active, M_{pp}
ST5	ISOS 2009	T3 Outdoor Exposure	Ambient	Ambient	Ambient	Outside	Active or Passive
ST5	ISOS 2011	ISOS-O-3 Outdoor	Sunlight	Ambient	Ambient	Outdoor	M_{pp}
ST6	NePV Stability	ST6 Laboratory Weathering	Daylight, (600-1 000) W/m2	38 °C	50 % rh/ water spray	Weathering instrument	Passive or Active, M_{pp}
ST6	ISOS 2009	T5 Light/Temp./ Humidity	1 Sun	45/65/85 °C	35 % rh	Weatherometer	None
ST6	ISOS 2011	ISOS-LT-2 solar-thermal-humidity-cycling	Simulator	Linear ramping (5-65) °C	Monitored, controlled at 50 % rh beyond 40 °C	Env. Chamber, with sun simulation	M_{pp} or Open Circuit
ST7	NePV Stability	ST7 Thermal Cycling	None	−40 °C to +85 °C	Ambient	Climate chamber	None
ST7	ISOS 2009	T6 Thermal Cycling	None	−30 °C to +80 °C	Ambient (low)	Environm. Chamber	None
ST7	ISOS 2011	ISOS-T-3 Thermal Cycling	None	−40 °C to +85 °C	Near 55%	Environm. Chamber	Open Circuit

What about the test extensions suggested for Perovskite (ISOS-I)?

Test ID	Short description
ISOS-D-1I	Inert atm.; RT; dark
ISOS-D-2I	Inert atm.; elevated T; dark
ISOS-L-1I	Inert atm.; RT; light
ISOS-L-2I	Inert atm.; elevated T; light
ISOS-V-1I	Inert atm.; RT; dark; electrical bias
ISOS-V-2I	Inert atm.; elevated T; dark; electrical bias
ISOS-LC-1I	Inert atm.; RT; cycled light
ISOS-LC-2-3I	Inert atm.; elevated T; cycled light
ISOS-T-1-3I	Inert atm.; cycled T; dark

- None of these are among the standard recommended tests that are part of TS 62876
- Depending on the stress factor chosen all tests can be described within TS 62876
- However – Should each of the tests be performed as part of technology development?

The testing hierarchy

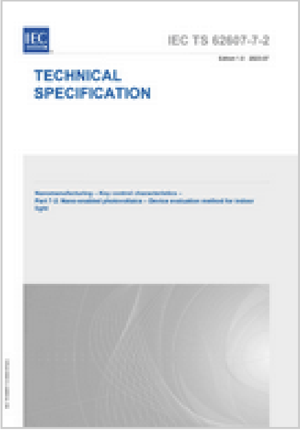


Conclusion

- The Technical Specification IEC TS 62876-2-1:2018 for the stability testing of Nano-enabled PV-Devices has passed all steps of the standardization process and is officially published under the IEC.
- There is a large overlap betwenn the TS 62876 and the ISOS Protocols.
- The TS has significantly higher normative relevance than journal publications.
- The content is the result of a worldwide process of consensus (and time)
- It relies heavily on cross referencing for normative relevance.
- The suggested ISOS-I tests for Perovskites are in agreement, as long as they conform to the stress conditions outlined in the TS and as long as the general protocols are followed.
- When designing future tests it is recommended to stick to the stress factors outlined in the TS.
- Amendments to the TS or new normative documents can be created.

IEC TS 62607-7-2:2023 – Indoor Light Evaluation

HOME / IEC-NORMEN / IEC TS 62607-7-2:2023



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IEC TS 62607-7-2:2023

Nanomanufacturing – Key control characteristics – Part 7-2: Nano-enabled photovoltaics – Device evaluation method for indoor light

Ausgabedatum: **2023-07**

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Inhaltsverzeichnis

Abstract

IEC TS 62607-7-2:2023 specifies the efficiency testing of photovoltaic cells (excluding multi-junction cells) under indoor light. Although it is primarily intended for nano-enabled photovoltaic cells (organic thin-film, dye-sensitized solar cells (DSC), and Perovskite solar cells), it can also be applied to other types of photovoltaic cells, such as Si, CIGS, GaAs cells, and so on.

IEC TS 62607-7-2:2023 – Indoor Light Evaluation - contents

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CONTENTS

FOREWORD ... 4
INTRODUCTION ... 6
1 Scope ... 7
2 Normative references ... 7
3 Terms and definitions ... 7
4 Abbreviated terms ... 9
5 Methods for measuring current-voltage characterization ... 10
5.1 General ... 10
5.2 Requirements ... 10
5.2.1 Device under test (DUT) ... 10
5.2.2 Illumination adjustment ... 10
5.2.3 Measurement procedure ... 11
5.3 Important additional information ... 13
6 Indoor reference photovoltaic cells ... 14
Comparison TS 62876 to ISOS P...
6.1 Requirements ... 14
6.1.1 Selecting indoor reference photovoltaic cells ... 14
6.1.2 Calibrating indoor reference photovoltaic cells ... 14
6.2 Important notes ... 15
7 Standard indoor light – Requirements ... 16
7.1 Standard indoor illuminance ... 16
7.2 Standard indoor light ... 16
7.3 Spectral irradiance of standard indoor light ... 16
8 Traceability ... 19
8.1 Description – General ... 19
8.2 Calibration chain example ... 19
9 Temperature correction ... 20
9.1 Requirements ... 20
9.2 Temperature of the DUT ... 20
10 Spectral-mismatch correction ... 20
10.1 Requirements ... 20
10.1.1 Indoor reference photovoltaic-cell method ... 20
10.1.2 Recording results ... 21
10.2 Important additional information ... 21
11 Spectral responsivity ... 21
11.1 Requirements ... 21
11.1.1 Spectral responsivity, $S(\lambda)$ ... 21
11.1.2 Measurement methods ... 21
11.2 Important notes ... 21
12 Illumination sources ... 22
12.1 Requirements ... 22
12.1.1 Indoor spectral coincidence ... 22
12.1.2 Illuminance non-uniformity ... 22
12.1.3 Temporal stability ... 23
12.1.4 Light source classification ... 23
12.1.5 Indoor standard relative spectral responsivity ... 23
12.2 Illuminance non-uniformity ... 35
13 Nonlinearity ... 35
13.1 Requirements ... 35
13.2 Important notes ... 35
Annex A (informative) Explanations of the provisions, descriptions, and other content in the standard main body of this document ... 36
A.1 Purpose of this document ... 36
A.2 Target of this document ... 36
A.3 Issues discussed during deliberation ... 36
A.3.1 Adjusting light intensity with an illuminometer ... 36
A.3.2 Indoor spectral coincidence ... 36
A.3.3 Stability of a DUT (5.2.2) ... 37
A.3.4 Maximum power (P_{max}) ... 37
A.4 Supplemental remarks on requirements ... 38
A.4.1 Requirements for the DUTs (5.2.1) ... 38
A.4.2 Standard indoor light (Clause 7) ... 38
A.4.3 Methods for adjusting illuminance (5.2.2) ... 39
A.4.4 Quasi-reference photovoltaic cell ... 42
A.4.5 Standard indoor light (7.1, 7.2) ... 42
A.4.6 Spectral responsivity (11.1.2) ... 42
A.4.7 Illumination source and indoor spectral coincidence (12.1.1) ... 43
A.4.8 Illumination sources and non-uniformity of brightness (12.1.2) ... 44
A.4.9 Temporal stability (12.1.3) ... 44
A.4.10 Classification of illumination sources (12.1.5) ... 44
A.4.11 Nonlinearity (13.1) ... 45
A.5 Correspondence between this document and the IEC 60904 series ... 45
Bibliography ... 47

Figure 1 – Spectral irradiance of standard indoor light at 1 000 lx ... 19
Figure 2 – Calibration chain example ... 20
Figure 3 – Standard relative spectral responsivity ... 34
Figure A.1 – Configurations of illuminance adjusting methods described in a) A.4.3.2, b) A.4.3.3 and c) A.4.3.4 ... 39
Figure A.2 – PRISM or spectroradiometer method ... 40
Figure A.3 – Measurement laboratories ... 41
Figure A.4 – Temporal fluctuation of illuminance of a fluorescent lamp ... 44

Table 1 – Standard indoor illuminance ... 12
Table 2 – Result record ... 13
Table 3 – Calibration record ... 15
Table 4 – Spectral irradiance (mW/m^2/nm) of standard indoor light at 1 000 lx ... 16
Table 5 – Light source classification ... 23
Table 6 – Indoor standard relative spectral responsivity (%) ... 24
Table A.1 – Spectral coincidence of F to reference spectrum CIE FL10 ... 42
Table A.2 – Spectral coincidence of L to reference spectrum CIE LED-B4 ... 42
Table A.3 – Correspondence between clauses of this document and IEC 60904 ... 46
Table A.4 – New concepts in this document derived from IEC 60904 ... 46

Standardized Indoor light sources and calibration procedures

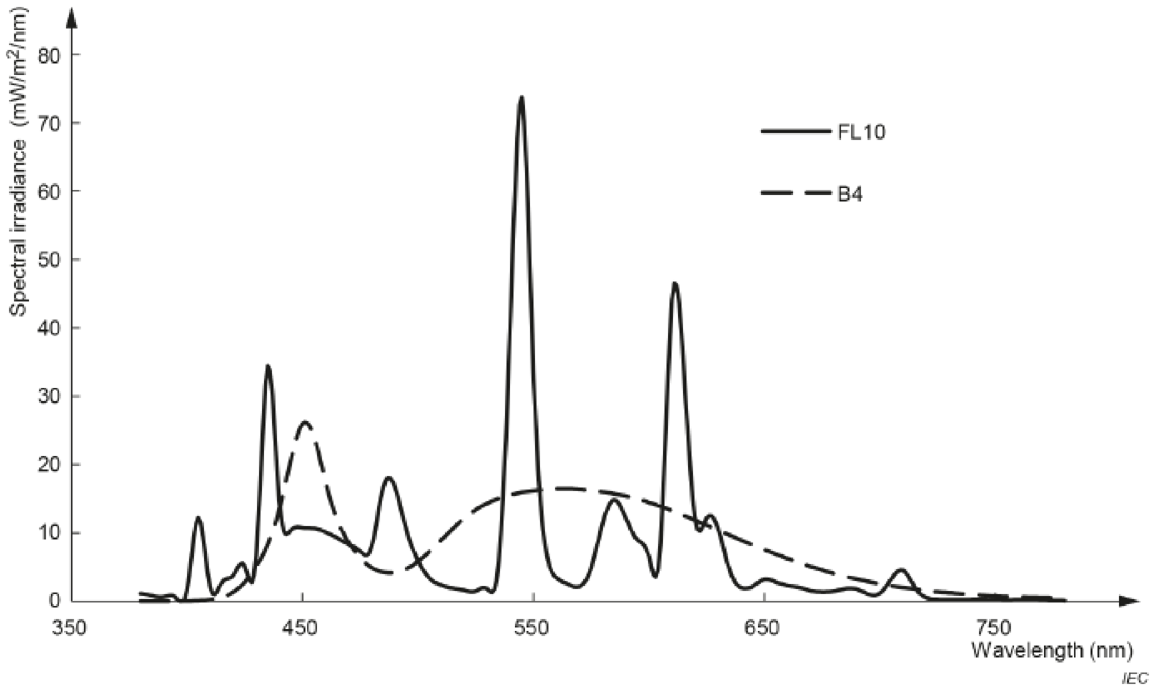

Figure 1 – Spectral irradiance of standard indoor light at 1 000 lx

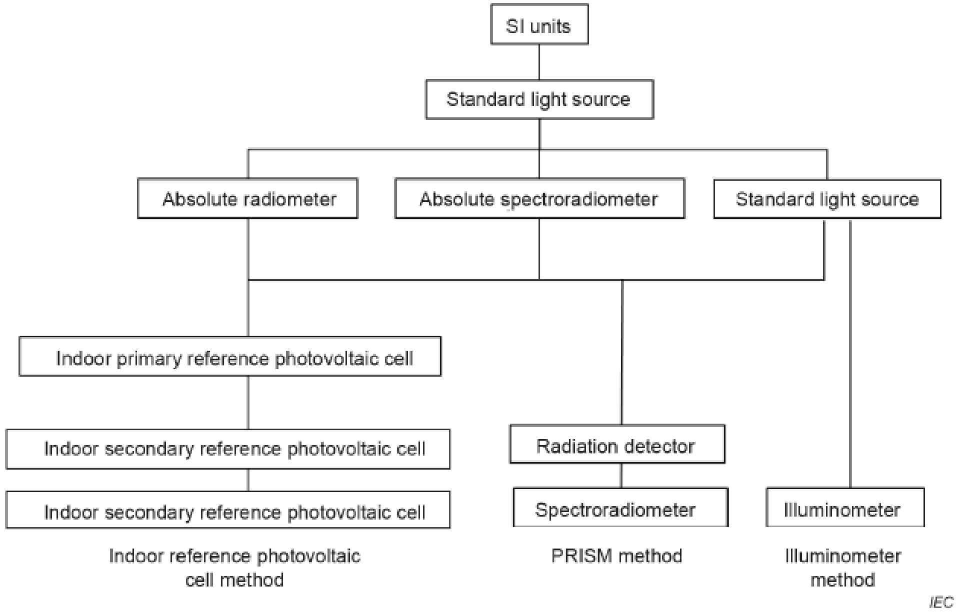

Figure 2 – Calibration chain example

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