

# HOW TO INTRODUCE BIFACIALITY WITHIN MODULE TYPE AND SAFETY TESTING?

Amendmentments & Future Editions of IEC 61215, 61730 Series

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## AIT AUSTRIAN INSTITUTE OF TECHNOLOGY




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# AIT AUSTRIAN INSTITUTE OF TECHNOLOGY



## Services and expertise

- Development support and accredited testing of photovoltaic components for cell and module manufacturers
- Precise characterization of PV technologies
- Independent performance measurements
- Rapid life-cycle test
- Advanced optical characterization
- Periodical round-robin tests with other institutes

## Accreditation and standardisation activities

- Accredited test lab according to EN ISO/IEC 17025
- Member of IECEE CB Scheme
- Member of national and international standardisation committees (IEC/CLC TC82, TC64)

## Product certification

- In cooperation with the Austrian Electro-technical Association (OVE)



### Independent accredited testing

- IEC 61215 (new ed.)
- IEC 61646
- IEC 61730 (new ed.)
- IEC 60904 series

## Services and expertise

- Electrical characterization:
  - I/V measurements (light, dark)
  - Dielectric insulation tests (DC, LI, PD, PID)
- Electro-optical characterization
  - EQE, EL, PL, IR-T, DLIT (indoor and outdoor)
- Optical characterization
  - UV F for indoor and outdoor applications.
  - UV-VIS-FIR FT-spectrometer
- Power rating of thin film devices

## Infrastructure

- Solar simulators (3x3m<sup>2</sup> A+A+A+ pulsed, 3x4m<sup>2</sup> BBB steady state, 0.3x0.3m<sup>2</sup> AAA steady state)
- Module sized QE, EL and PL
- Spectro-radiometer (incl. calibration services)



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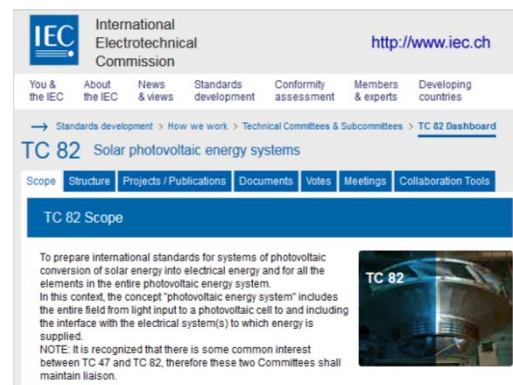
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# INTRO: IEC STANDARDIZATION - TC 82 PV



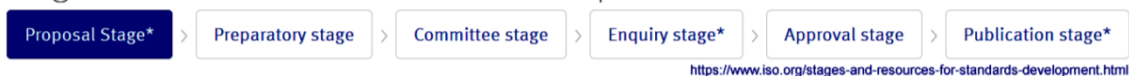
## Experts nominated by countries

- **Expert's meeting 1 expert – 1 vote**
- **European: CEN/CENELEC Economically weighted votes**
- **International: IEC one country – one vote**
  - WG meet ~ 2 x per year
  - Every 1 ½ years (18 month) Plenary Meeting of the TC's (all WG's)
  - Sometimes joined with IEC General Meeting



## Stages and resources for standards development

\* = obligatory stage



<https://www.iso.org/stages-and-resources-for-standards-development.html>

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## INTRO: STANDARD DEVELOPMENT STAGE GATE PROCESS



<https://www.iso.org/stages-and-resources-for-standards-development.html>

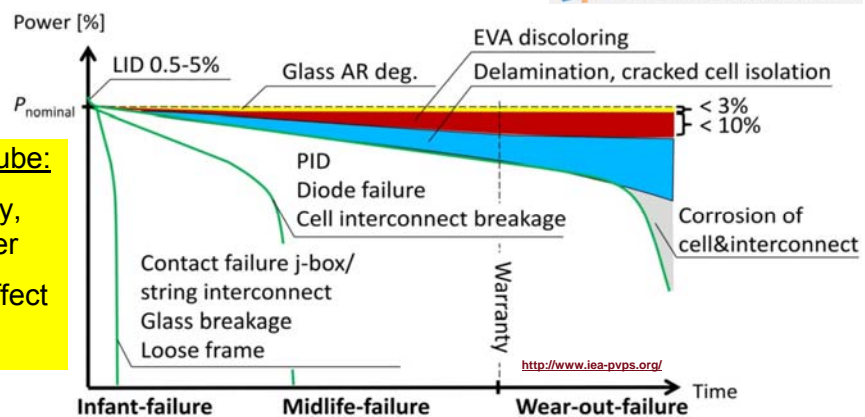
- **New Work Item Proposal (NWIP):** Suggests new Ed. or new standard  
Title and Abstract, circulated in TC/WG
- **Official Country Vote** sent to IEC TC:
  - One ordinary member country (P-member) one vote
  - Shall work start on that? Yes / No / Abstain?
  - Minimum of five countries have nominated volunteers to join the project team?
- **If OK, (>50%)** Project-Team within WG starts drafting, will be presented, circulated and discussed in the WG
- **CD - „Committee Draft“** (consolidated version) gets visible outside the WG, **Comments** collected by national representatives in the TC sent in, must be discussed in the project team, working group
- **CDV „Committee draft for voting“** if „ripe enough“ - (almost) final version (only few comments),
- **FDIS – „Final Draft of International Standard“** if positively voted ...
- **New Ed. bzw. New Standard gets published**, and also the people that developed it are allowed to buy it ...

**IEC TC 82: PV**  
Organized in Working groups:  
WG2 Modules, WG3 Systems,  
WG6 Inverter, WG7 concentrating PV,  
WG8 Cells, JWG ...

## INTRO: BASIC IDEA OF TYPE AND SAFETY QUALIFICATION

### MODULE FAILURE MODES

From IEA PVPS T13-01:2014 Report, <http://iea-pvps.org/>



The reversed bath-tube:  
Question of durability, performance & power  
Failures may also affect safety

## INTRO: BASIC IDEA OF TYPE AND SAFETY QUALIFICATION

### Test design:

- Specific for a failure mode
- Depending on design & cell-type
- Not all failures are covered
- Failure modes not always identical in tests and outdoors ...

Question 1: Modifications necessary for bifacials?

Question 2: Additional failure modes to tackle?

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### SEQUENTIAL TESTING LEADING TO COMMON FAILURE MODES

June 3rd, 2014 SOPHIA workshop EDF LAB Les Renardières Mike Van Iseghem, EDF R&D

failure mode   standard test	TC	DH	HF	UV	static mech	dynamic mech	hail	bypass diode thermal test	salt spray
delamination		X	X	X					
encaps adhesion & elasticity		X		X					
JBox adhesion	X	X	X						
broken cells c-Si	X				X	X	X		
broken interconnections, ribbons	X				X	X			
broken glass					X	X	X		
module OC potential of arcing	X								
electrical bond failure (soldering)	X				X	X			
corrosion (all technos)		X							X
electrochem corrosion of TCO (TF)		X							
inadeq edge deletion (TF)		X	X						
de-coloration encaps / backsheet				X					
ground fault due to backsheet degrad				X					
structural failures					X				
bypass diode failure								X	
bypass overheating causing degrad of encaps, backsheet or jbox								X	
specif corrosion salt water mist, also de-icing, de-snow									X

## ACTUAL MODULE TYPE AND SAFETY TEST PROC.

1/5

### IEC 61215 - PV MODULE DESIGN QUALIFICATION AND TYPE APPROVAL

2016, after several years of discussions:

IEC 61215-Series with **new structure**, integrating crystalline and TF based modules in one series

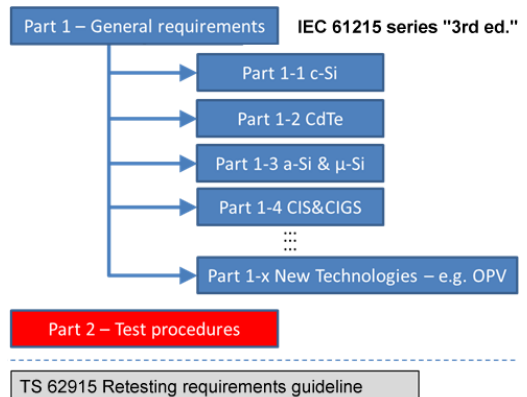
- Part 1 General requirements
- Parts 1-n (Cell) Technology specific requirements
- Part 2 Test procedure descriptions

**Testsequences** & requirements shall sort out bad design (basically infant mortality only)

**Stresstests** to apply, check if / how much the **power** degrades, visible and other **defects**?

Bengt Jäckel, SOPHIA Workshop PV-Module Reliability, June 2014, Fraunhofer ISE, Freiburg.  
John Wohlgemuth: History of IEC Qualification Standards. PV Module QA Forum 2011, <http://www.nrel.gov/docs/fy11osti/52246.pdf>

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## ACTUAL MODULE TYPE TEST PROC.

2/5

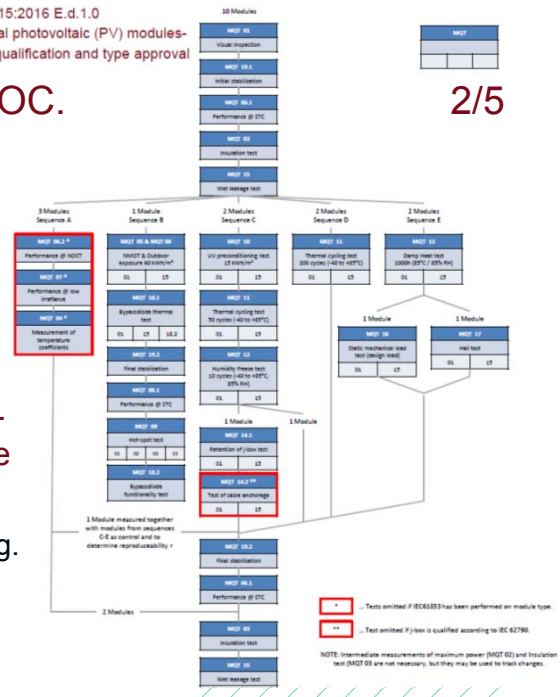
### IEC 61215 – TEST SEQUENCES

New: Verification of rated label values

- Gate #1: Comparison of stabilized power with specs from manufacturer (data sheet, nameplate)

Focus on restructuring, technical content  
~ unchanged → *Amendment(s)*, and *Retesting Guideline* (TS, 2018?) planned to resolve

Connex to real outdoor **Lifetime** still weak and site climatic and application depending.  
„Type Approval“ for „moderate climate“ without harsh operating conditions only



## MODULE TYPE TEST PROC. – NEW ED.

3/5

### IEC 61215 – PLANNED TEST SEQUENCE MODIFICATIONS

First „Applicant“ for new 61215-1-5: Requirements for flexible PV Modules - **BUT**

- Parts 1-n Are *cell technology* specific req., flexibles with different Si & TF cell types exist
- Similar situation for bifacial modules

Would require another layer (matrix) of standards, therefore

#### Proposed Amendment AM1:

These (additional) requirements shall – among with a long list of other unsolved issues in the 2016 Edition - be directly integrated into existing parts of the 61215 series

Decision 2017: To much and substantial changes by AM1

- **NEW EDITION** of the 61215 Series instead of Amendment required

## MODULE TYPE TEST PROC. – NEW ED

4/5

### IEC 61215 – PLANNED TEST SEQUENCE MODIFICATIONS

#### Part 1: Test Requirements:

- i. Add *Cyclic (dynamic) MLT* from IEC TS 62782 into Table 1 and Figure 1.
- ii. Add *PID* test taken from IEC TS 62804-1 into Table 1 and Figure 1.
- iii. **Definitions, references and instructions on how to perform the IEC 61215 design qualification and type approval on bifacial PV modules.**
- iv. Definition, changes to the test methods and pass/fail criteria to perform IEC 61215 design qualification and type approval for *flexible PV modules*.
- v. Clarification of the requirements related to power output measurements.

AND: Refer to the new IEC TS 60904-1-2 bifacial measurement standard

## ACTUAL STATUS IN IEC TC 82 WG2

5/5

### IEC 61215 – PLANNED TEST SEQUENCE MODIFICATIONS

#### Part 2: Test Methods

- i. *Cyclic (dynamic) mechanical load* testing (MQT 20).
- ii. Detection of *potential-induced degradation* in Crystalline silicon modules (MQT 21)
- iii. **Changes to the test methods required for *bifacial PV modules*.**
- iv. Changes to the test methods required for *flexible modules*. This includes the addition of the Bending Test (MQT 22)
- v. Revision of *simulator requirements* to ensure uncertainty is both well-defined and minimized.
- vi. *Correction to the hot spot endurance test*, where the procedure for monolithically integrated (MLI) thin film technologies (MQT 09.2) previously included one section describing the procedure for silicon modules.



# ACTUAL MODULE SAFETY QUALIFICATION

X/N

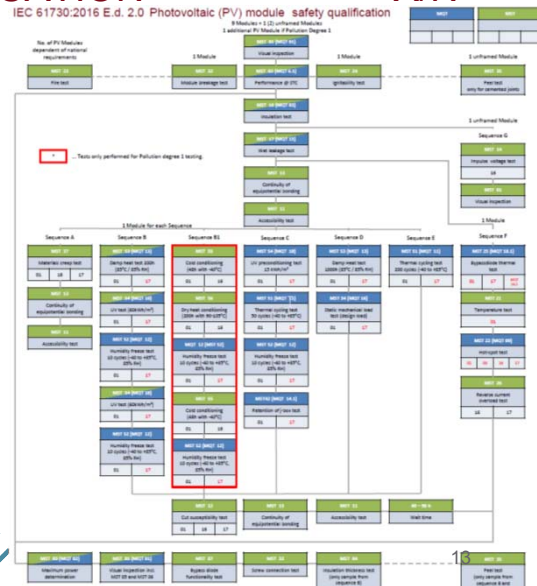
## IEC 61730 - Series

**New Edition 2016:** Harmonizing with „horizontal Standards“ (e.g. insulation coordination):

**Teil 1 Requirements for Construction**

**Teil 2 Requirements for Testing**

- **Primary goal: safe operation and safe state also under failure conditions**
- Requirements partly more strict than in Ed.1
- Tests on **component** (e.g. J-box, connectors) as well as **coupons** (e.g. adhesion) and full size **modules**
- **Material-Prequalification** intended to go in by an Amendment: (AM1 zu 61730-1 und -2 is prepared as NWIP in IEC TC82 WG2)



# PROPOSED CHANGES IN 61215-1 NEW ED. 2

## 2. Normative references - add

- IEC 60904-1-2: Photovoltaic devices – Part 1-2: Measurement of current-voltage characteristics of bifacial photovoltaic (PV) devices

## 3. Terms, definitions and abbreviations - add

- Definition bifacial modules,
- Bifaciality coefficients  $\phi_{ISC}$ ,  $\phi_{VOC}$  and  $\phi_{Pmax}$ .

## 5 Marking and documentation, (h, i) in Clause 5.1

- For bifacial modules, report  $I_{sc}$ ,  $P_{max}$  at two front-side irradiance levels:  $1000 \text{ Wm}^{-2}$ , and equivalent irradiance  $G_E$ , as defined in IEC 60904-1-2, rear irradiance of  $G_R$  that is the largest of either  $200 \text{ Wm}^{-2}$ , or the largest rear incident irradiance claimed by the manufacturer on the datasheet or nameplate. ...

**Question:** What if manufacturer. claims very high output – how to measure at e.g.  $1500 \text{ W/m}^2$ ?



## PROPOSED CHANGES IN 61215-1 NEW ED. 2

### 5 Marking and documentation, (5.1, continued), new j)

- Short-circuit current, open-circuit voltage, maximum power bifaciality coefficients  $\phi_{I_{SC}}$ ,  $\phi_{V_{OC}}$ ,  $\phi_{P_{max}}$ , *including tolerances*, at STC as defined in IEC 60904-1-2 clause 6.2.
- For items (a) through (i) all electrical data shall be shown as relative to STC (1 000 W/m<sup>2</sup>, 25 °C, AM 1,5 according to IEC TS 61836), except for bifacial modules where two irradiance levels are required, as defined in clause 5.1 (h).

### 5.2.2 Information to be given in the documentation:

- all information required under 5.1 e) to i), and in addition j) for bifacial modules

### 6 Testing, add at the end

- NOTE: For bifacial modules Sequence A cannot be omitted until IEC 61853-1 has been amended to take bifacial modules into account.

**The 61853-1 to -4 Energy Rating is under development for 19 (!) years now, with parts 1 and 2 published, and 3 and 4 almost finalized. Bifacials considered in European project follow up of PHOTOCCLASS?**

## PROPOSED CHANGES IN 61215-1 NEW ED. 2

### 7 Pass criteria - 7.2.1 Verification of rated label values → Gate No. 1 - and also for the other PASS/FAIL conditions after the test sequences (7.2.2)

- For bifacial modules, the power shall be measured three times. The first measurement is at STC with only front irradiation. The second measurement is at 25 °C with only backside irradiation using the manufacturers highest rated bifaciality for setting the back irradiation level (for example if the manufacturer advertises the product as having a 30 % bifacial gain, then the back side irradiance shall be 300 W/m<sup>2</sup>). The third test is again at 25 °C with only front side irradiation, set at a level that results in the same  $I_{sc}$  as the sum of the measured  $I_{sc}$ 's in the first 2 measurements. This third measurement is then used in the equations for  $P_{max}$ ,  $V_{oc}$  and  $I_{sc}$  to assess pass/fail for Gate No 1.
- A systematic variation to either higher or lower output power or power bifaciality coefficient

**How changes in bifaciality change power (and energy) output depends on the application ... Fair to have only a note?**



## PROPOSED CHANGES IN 61215-1 NEW ED. 2

### 9 Report, add the following to replace item e).

- e) description and identification of the item tested, including indication if it has been evaluated for bifaciality and/or whether it is has been evaluated as a flexible module;
- k) measurements, examinations and derived results supported by tables, graphs, sketches and photographs as appropriate including: ...
  - change in power bifaciality coefficient observed after each test.

### 11 Test flow and procedures

Use current based on what the manufacturer claims for the bifacial gain for BDT test

MQT 02	10.2	Maximum Power Determination	See IEC 60904-1 for monofacial modules and IEC TS 60904-1-2 for bifacial modules
MQT 18	10.18	Bypass diode thermal test	MQT 18.1: Bypass diode thermal test: 1 h at Isc and 75 °C 1 h at 1,25 times Isc and 75 °C MQT 18.2: Bypass diode functionality test At 25 °C perform voltage and current measurements For bifacial modules, Isc at the highest irradiance from MQT 02 is utilized

## PROPOSED CHANGES IN 61215-2 NEW ED. 2

### 1 Scope.

iii) Changes to the test methods required for bifacial PV modules. For bifacial modules, *multiple irradiances are required in MQT 02, higher currents are required in MQT 11* (as specified by technology-specific parts) and in MQT 18, and UV exposure is performed on *both sides* in MQT 10.

#### 4.2 Maximum power determination (MQT 02)

- Follow procedures in 60904-1-2 I-V measurement standard, adjustable simulator

#### 4.4 Measurement of temperature coefficients (MQT 04)

- For bifacial modules determine the temperature coefficients utilizing the same procedure, but insuring no backside irradiation. The backside shall be covered such that the contribution from the non-exposed side of the module is limited to or below the levels specified for “non-irradiated background” in 60904 1-2

## PROPOSED CHANGES IN 61215-2 NEW ED. 2

### 1 Scope.

As current path and recombination differ (or may differ) somehow for the front and rear side of the cells, AND the loss mechanisms are temperature dependent -> different temperature coefficients may be derived for front and back side? Add a NOTE that e.g. the power bifaciality coefficient may be LOWER at HIGHER TEMPERATURES?  
 Impact on IEC 60891 (2009) Irrad. & temp. corr. too?

### 4.4 Measurement of temperature coefficients (MQT 04)

- For bifacial modules determine the temperature coefficients utilizing the same procedure, but insuring no backside irradiation. The backside shall be covered such that the contribution from the non-exposed side of the module is limited to or below the levels specified for "non-irradiated background" in 60904 1-2

## PROPOSED CHANGES IN 61215-2 NEW ED. 2

### 4.6 - Performance at STC and NMOT (MQT 06), add the following paragraph after the last paragraph of 4.6.3.2:

- For bifacial modules take measurements utilizing the two front-side irradiance levels specified in 61215 1, clause 5.1 (h). Both of these measurements shall be used to evaluate performance for Gates No 1 and 2.

NMOT resp. coefficients for the irradiance and wind depending temperature differences – "No abnormal high albedo" vs. optimized albedo for bifacials ...  
 BUT: If not extreme enhanced irradiation is concentrated on the module, and because more energy is converted into electricity, the operating temperature is in the same range or only slightly higher than for monofacial ones.

## PROPOSED CHANGES IN 61215-2 NEW ED. 2

### 4.7 Performance at low irradiance (MQT 07) in 4.7.3:

- For bifacial modules make two single-sided measurements at 200 W/m<sup>2</sup>, one on the front-side and one on the rear-side using the aperture and back-cover screen. Calculate the bifaciality coefficients at low irradiance.

### 4.8 Outdoor exposure test (MQT 08), add note at the end of 4.8.3

- NOTE: For bifacial modules it is recommended that the standard procedure in IEC 61853-2 be used with the bifacial modules mounted under *conditions as close as possible to those expected in the application*.

Problematic: One Module type may be used for very different Bifi applications  
 e.g. opt. tilt, south vs. east-west;  
 Model for wind chill originates from single sided, south, tilt ...

## PROPOSED CHANGES IN 61215-2 NEW ED. 2

### 4.9.4 & .5 Hot Spot endurance test (MQT 09) apparatus, procedure

- For bi-facial modules, use an aperture around the modules edges, and a *non-reflective cover blocking the irradiance to the back of the module* → test reproducibly with front-side illumination only. Then same procedure than monofacial

Question: Worst case or exist other, also reproducible configurations?

### 4.18 Bypass diode testing (MQT 18)

- For bifacial modules, the applicable current is 1.25 times short-circuit current at the higher irradiance level specified in 61215-1 clause 5.1(h).

Also: Manuf's spec. gain to set test current

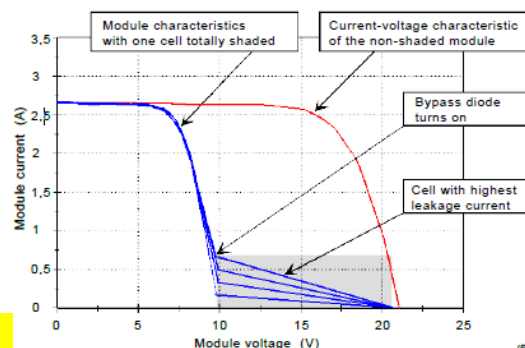


Figure 4 – Module I-V characteristics with different cells totally shadowed

## PROPOSED CHANGES IN 61215-1-1 NEW ED. 2

### Part 1-1: Special requirements for testing of crystalline silicon Modules

#### 11.11 Thermal cycling test (MQT 11)

- For monofacial modules, the technology specific current which needs to be applied according to test MQT 11 of IEC 61215-2:2016, shall be equal to the STC peak power current. *For bifacial modules, the technology specific current which needs to be applied according to test MQT 11 of IEC 61215-2:2016, shall be equal to the peak power current at the higher irradiance level specified in 61215-1 clause 5.1(h).*

**Question: Similar Approach for other cell technologies?  
(With the lower currents like for the monofacial ones)**

## PROPOSED CHANGES IN 61730 SERIES AM1

**For the safety tests, similar approach can be used for testing under higher load conditions because of bifacial gains ...**

- Fire hazard tests

Table 4 – Fire hazard tests

Test	Title	Referenced standards	Based on
			IEC 61215-2
MST 21	Temperature test	ANSI/UL 1703:2015	–
MST 22	Hot-spot endurance test	–	<b>MQT 09</b>
MST 23*	Fire test	–	National/Local code
MST 24	Ignitability test	ISO 11925-2	–
MST 25	Bypass diode thermal test	–	<b>MQT 18</b>
MST 26	Reverse current overload test	ANSI/UL 1703:2015	–

\* Fire tests are locally regulated and typically only required for building integrated or building added products, typically to verify their ability to resist fire from external sources.

**Question: Other effects on performance and/or safety – related to bifaciality – existing that would require to test for? E.g. hotter surrounding for J-box, diodes?**

## IEC IEC 62788-SERIES, MEASUREMENT PROCEDURES FOR MATERIALS IN MODULES, AND OTHER DEGRADATION RELATED ISSUES

- Higher UV dose for materials to apply (2000h → X000 h Xe Lamp)?
- Also for J-box, cables, connectors?
- All depending on application – south tilt vs. East/west ...

### Micro-inverters and power optimizers

- Operating under higher load
- High irradiation on casing
- Actual draft for module related power electronics:  
No tests with load + environmental stress

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## STANDARDS ON THE SYSTEM SIDE

- IEC 61724 Series: Monitoring, yield and degradation
- IEC 62446 Series: Plant commissioning, documentation, inspections

### **Conclusions:**

- Actual draft for I-V measurement TS 60904-1-2 is essential 1st step
- Some roadmap to deal with bifacial in 61215 and 61730 next editions exist  
BUT still lots of open questions  
AND almost no comments on these proposed changes up to now ...

### **What would be urgently needed on the road from kWp to kWh & LCOE:**

- AN IMPROVED ENERGY RATING STANDARD, CONSIDERING BIFI !

**PLEASE COMMENT ON THE DRAFT STANDARDS!**



Many thanks to all the people involved  
in standardization projects! And ...

## THANK YOU!

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