



Scaling-Up Solar PV Deployment: Implementing Projects with Assured Quality

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In recent history we have advised in hundreds of projects, significantly reducing the investors' risk position

OUR EXPERIENCE IN THE RECENT YEARS



>30 GW
installed capacity in
onshore and offshore
wind energy



>25 GW
Over 5,500 successful solar projects



>5 GW
installed capacity in
thermal power
production



>40 projects
involving energy
storage



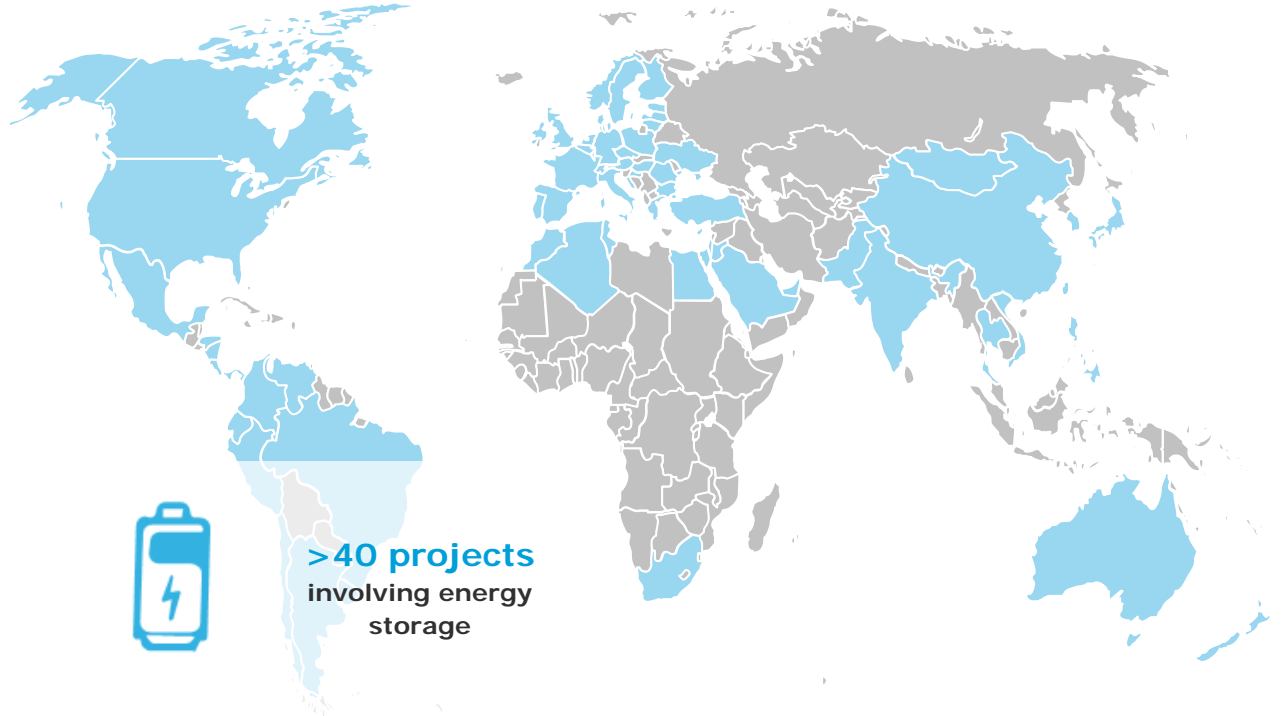
>250,000 km
of transmission and
distribution cables and
overhead lines



>100,000 km
of gas transmission
and distribution
pipelines



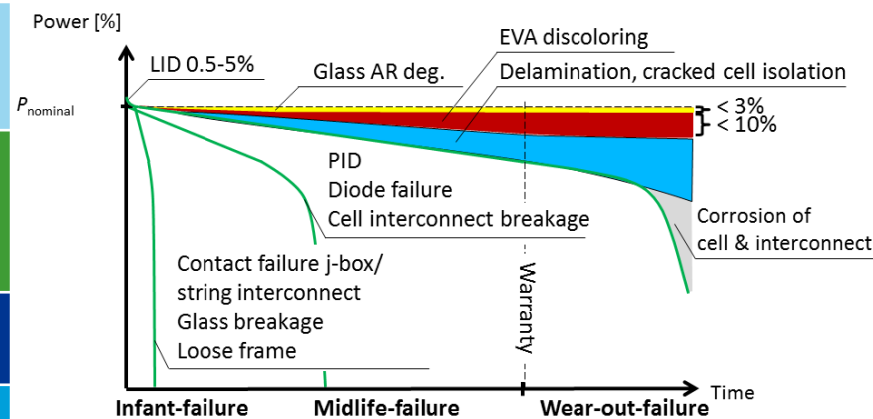
>5,000 km
of heat transmission
and distribution
pipelines



Module defects and Product Qualification Program (PQP)

Failure categorizations (Source: DuPont)

77.7%	No defect detected	Not Applicable
12%	Cell/ Interconnect	Corrosion, hot spot, broken interconnect, snail trails, cracks, burn marks
9.5%	Backsheet	Cracking, yellowing, delamination
1.3%	Encapsulant	Discoloration or delamination
0.4%	Other	Broken, etched, hazed glass, etc.



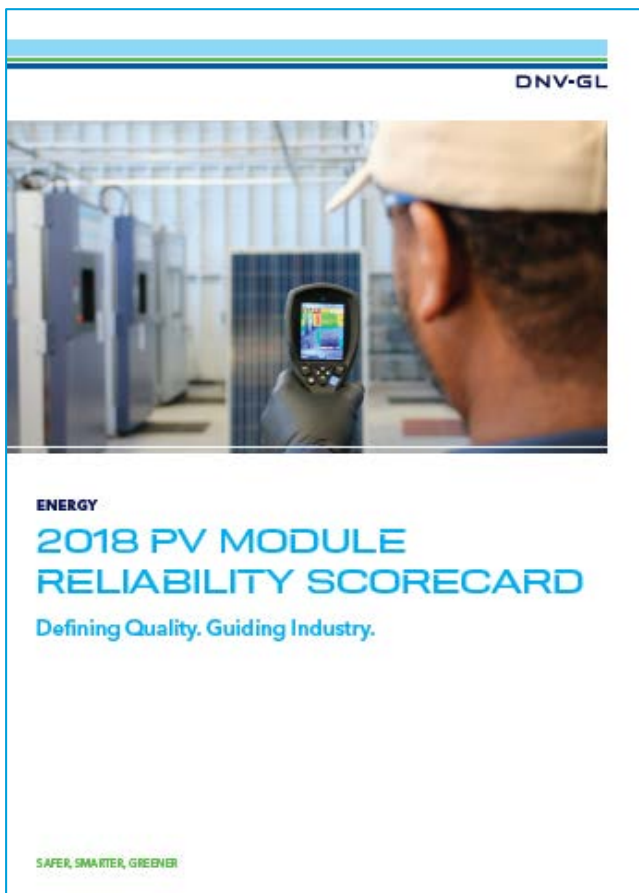
Source: Review of Failures of Photovoltaic Modules, IEA PVPS 2014

- In 2012, DNV GL developed PV modules **PQP** with two aims:

1. Provide buyers with independent reliability data at no cost
2. Provide independent recognition to manufacturers who focus on quality

DNV GL has tested over 300 BOMs from over 50 module manufacturers!

PV Module Reliability Scorecard



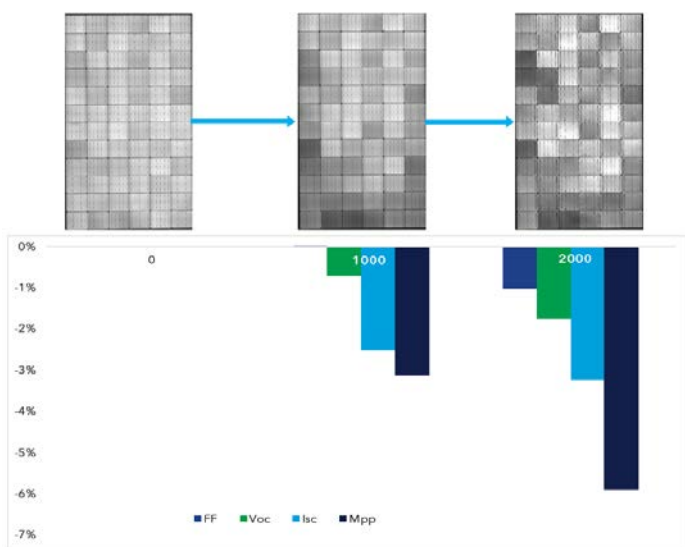
- Updated every 1-2 years
- Summarizes the last 18 months of PQP testing results
- For a specific data on module test result, refer to PQP as downstream partner.

Reliability Tests	Duration	Top Result	Bottom Result (%)	Median Result (%)
Damp Heat	2000 hours	No Measurable Degradation	-8.1	-2.5
Thermal Cycling	600 Cycles	No Measurable Degradation	-8.8	-1.6
Dynamic Mechanical Load	1000 Cycles + TC50 + HF10	No Measurable Degradation	-3.1	-1.2
Potential Induced Degradation	192 Hours	No Measurable Degradation	-7.4	-1.4

The 2018 PV Module Reliability Scorecard is available as a [free download](#).

2018 results – Damp heat

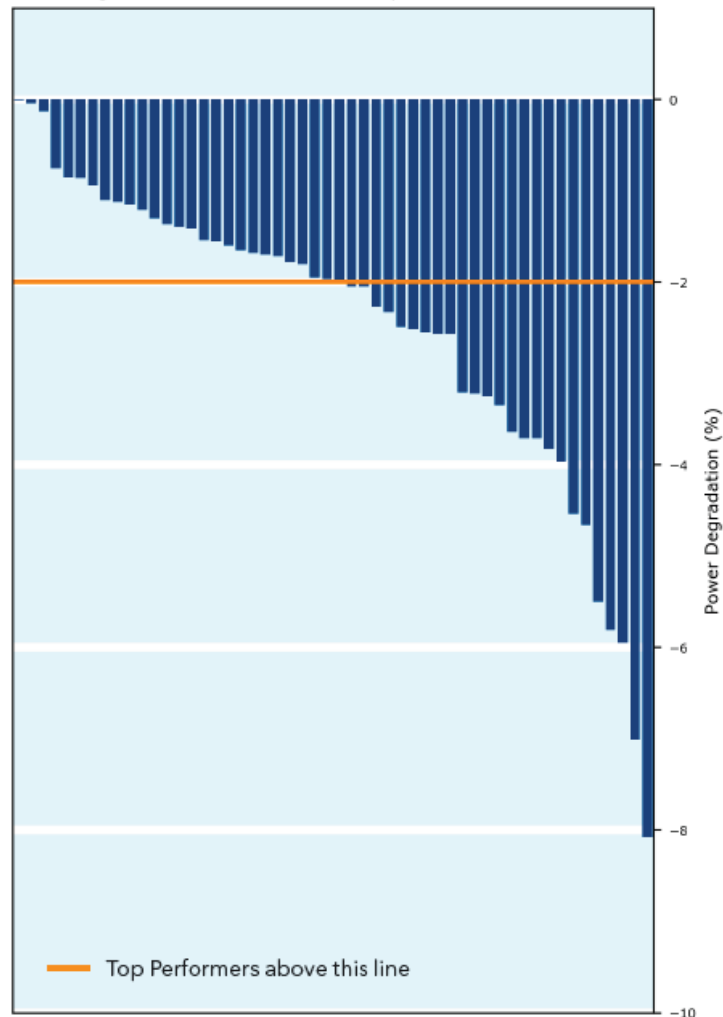
- DNV GL evaluated failures from three viewpoints: BOM, model type and manufacturer.
- Broadly categorized into:
 1. Visual failure
 2. Safety failure
 3. >5% power loss



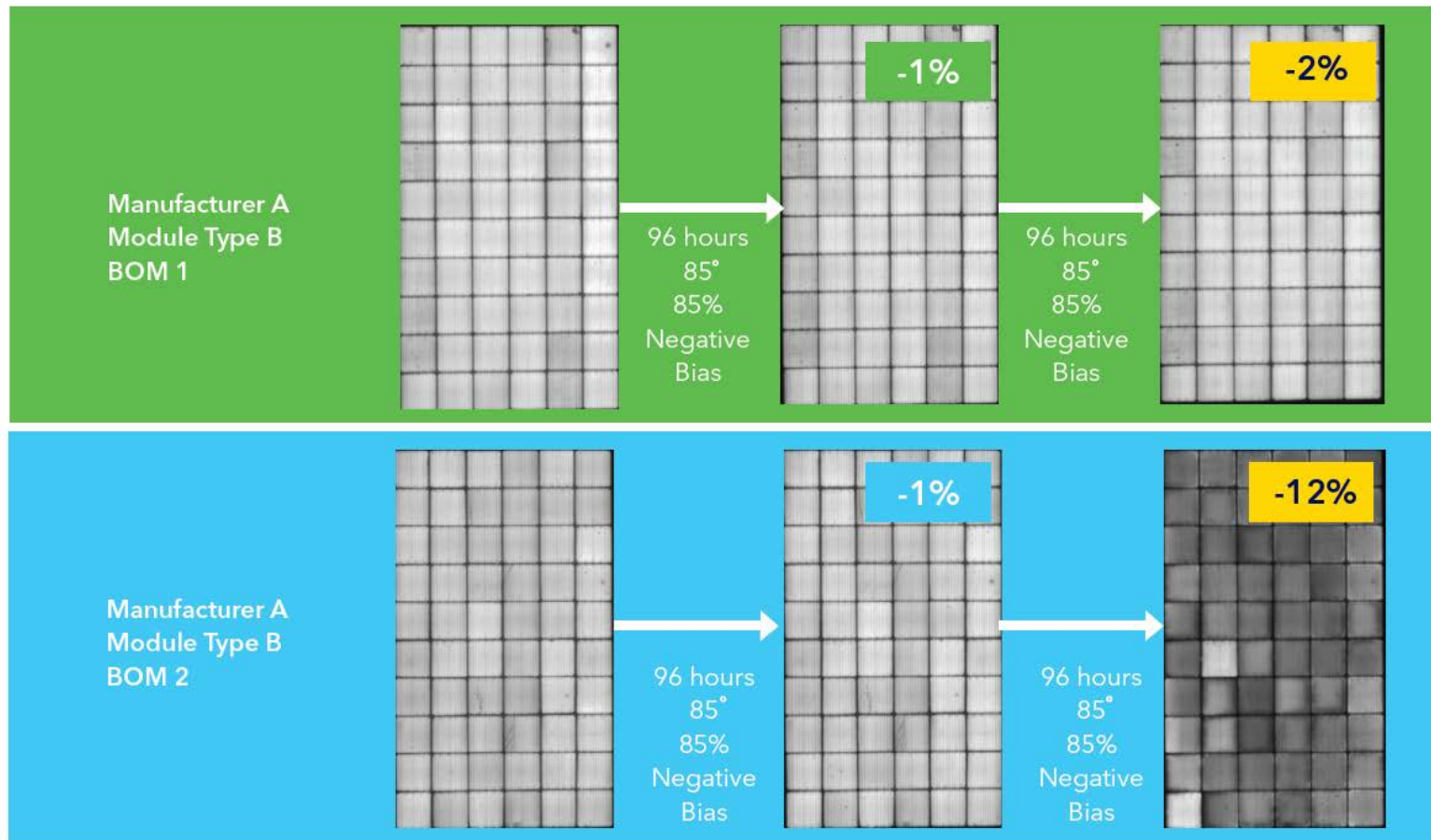
Module Model

CHSM6612M/HV-xxx
 CHSM6612P/HV-xxx
 BYDxxxP6C-36
 BYDxxxP6K-36
 FXS-xxxBB-SAB1W
 FXS-xxxBC-SAD1W
 GCL-P6/72xxx
 Q.PLUS BFR-G4.1 xxx
 HT60-156P-xxx
 HT72-156P-xxx
 JKMSxxxPP-60
 JKMxxxPP-72
 JKMxxxPP-72-V
 LR6-60PB-xxxM
 LR6-72PH-xxxM
 D6PxxxE3A
 RECxxxTP2
 SPR-P19-xxx-COM
 STPxxx-20/Wem
 TSM-xxxDD05A.18(II)
 TSM-xxxDD14A.18(II)
 TSM-xxxPD14
 TSM-xxxPE14A
 YLxxxD-36b

Power Degradation from DH 2000 Test Sequence for Each Module Model



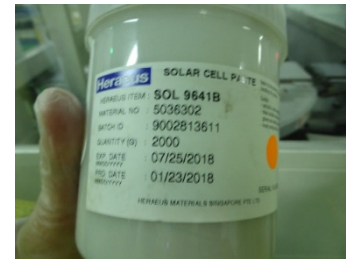
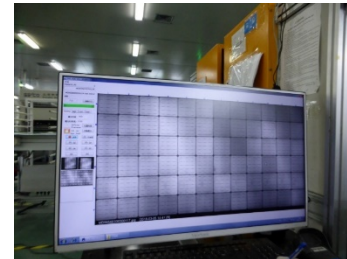
Case Study– PID performance



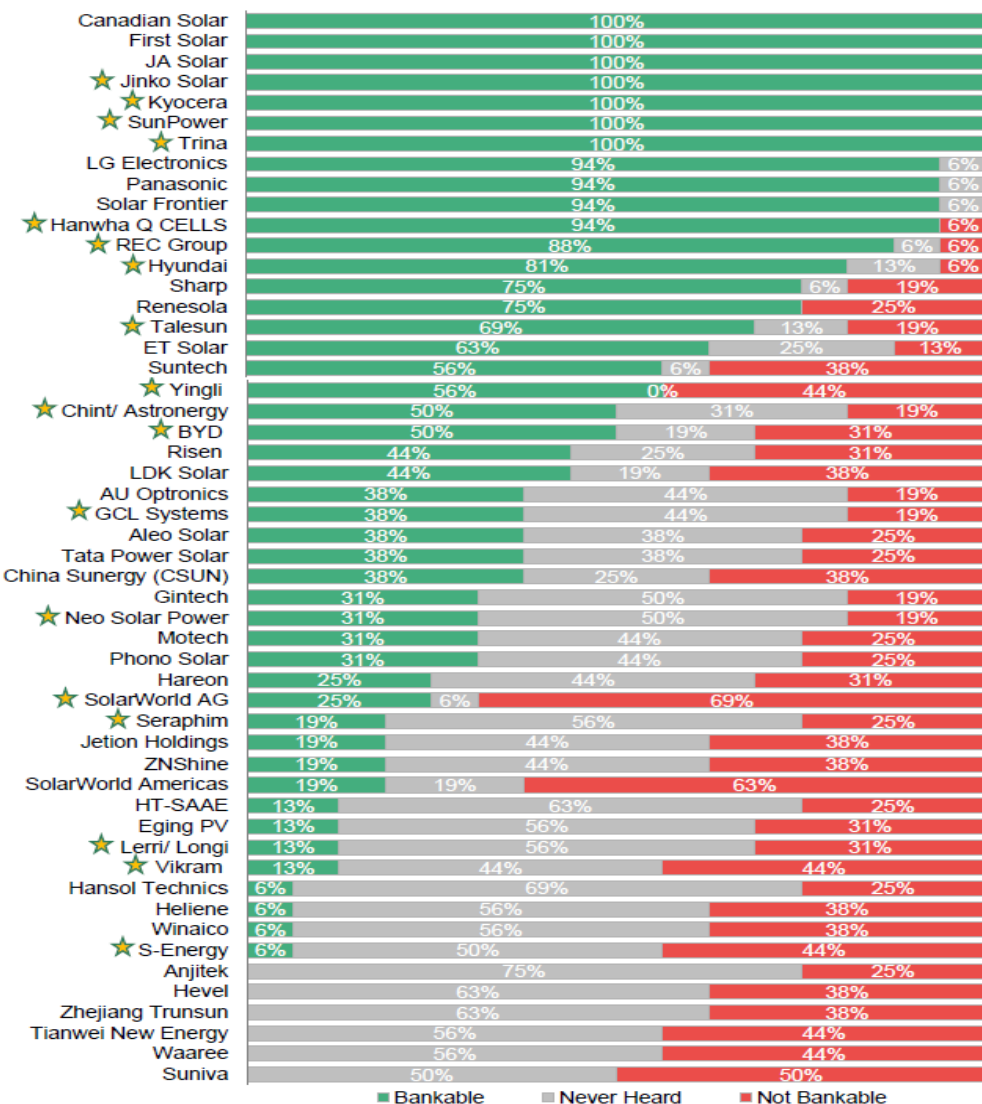
Same Manufacturer. Same Model Number. **Different Performance.**

Witness test

- Control of the provenance (temper-proof sealing tape)
- Systematic factory witness
 - Avoids golden samples
 - Control of BOM
 - 122 elements constitute a BOM
 - Sneak-peek in the factory
- Factory location is part of the BOM description
- Re-test guidelines for factories
 - Ask for the factory location to be **DNV GL “qualified”**
- **Witness report** is an integral part of the PQP
 - Ask for it!



BNEF's PV bankability survey results (with 2017 PQP)



- Stars indicate the 'top performers' within DNV GL's 2017 PV Module Reliability Scorecard Report.
- DNV GL did not test all of the manufacturers listed, so a missing star is not indicative of poor quality.

Source: Bloomberg New Energy Finance

Historical Scorecard



- Top Performers are module types that degraded less than 2% for the entirety of the test sequence.

	2018	2017	2016	2014
Jinko Solar	✓	✓	✓	✓
Trina Solar	✓	✓	✓	✓
Yingli Solar	✓	✓	✓	✓
Astronergy Solar	✓	✓		✓
Hanwha Q CELLS Co., Ltd	✓	✓	✓	
JA Solar Holdings	✓		✓	✓
REC Solar	✓	✓	✓	
BYD Co, Ltd	✓	✓		
Flex Ltd	✓	✓		
GCL Solar Energy, Inc.	✓	✓		
LONGi Solar Technology Co, Ltd	✓	✓		
Neo Solar Power Corporation (NSP)	✓	✓		
Phono Solar Technology Co, Ltd	✓		✓	
Solaria Corporation	✓	✓		
SunPower Corporation	✓	✓		
SunSpark Technology, Inc	✓	✓		
Suntech Power	✓			✓
Adani (Mundra Solar PV Ltd)	✓			
First Solar, Inc.	✓			
HT-SAAE	✓			
LG Electronics, Inc.	✓			
Panasonic	✓			

Thank you

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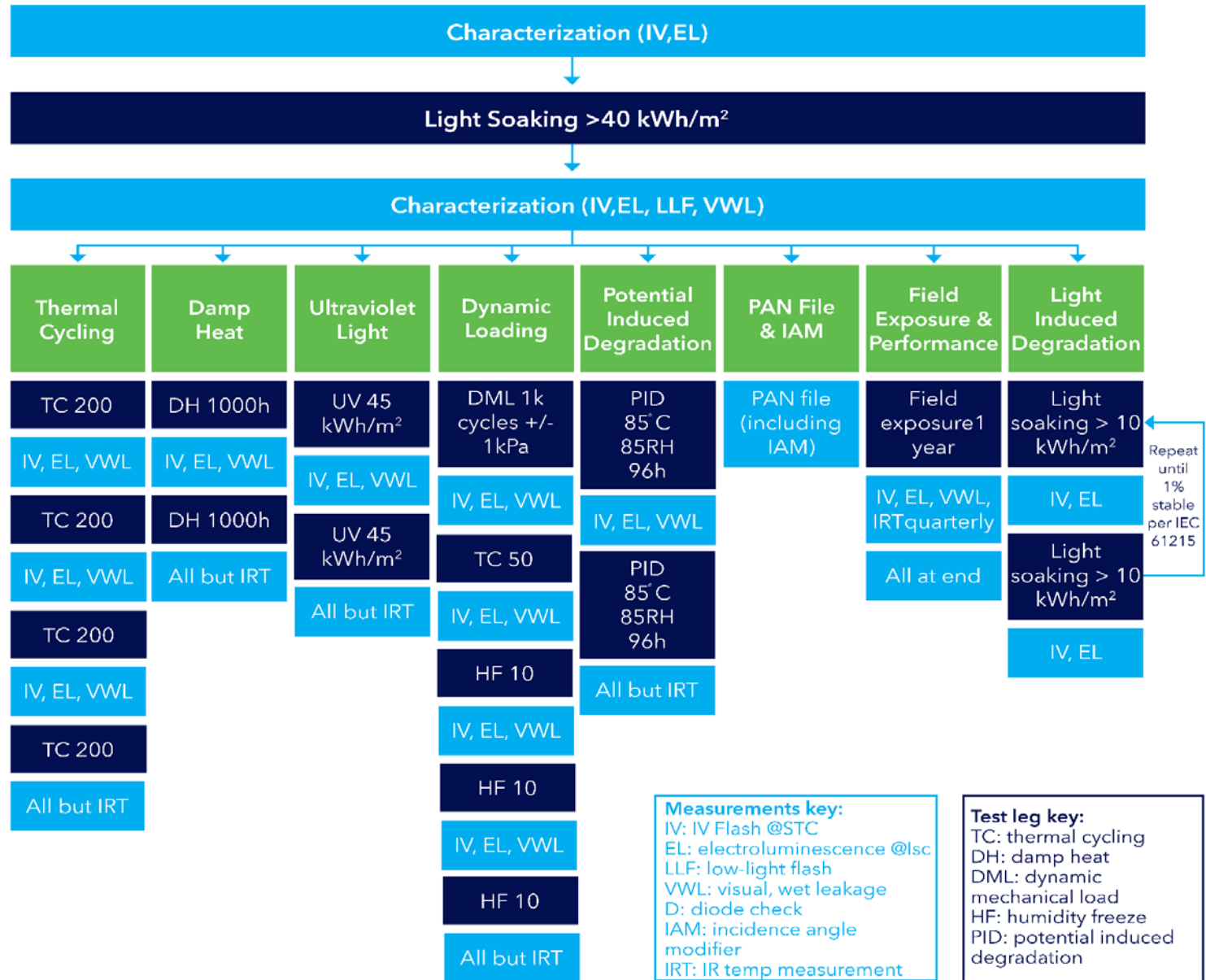
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PQP Test Sequences



The trouble with warranties

- Measuring power degradation in the field is extraordinarily difficult due to the uncertainty of measurement tools and sensors.
- Additionally, an allowance for uncertainty, typically according to EN 50380, is applied for warranty enforcement which effectively lowers the guaranteed level by a further amount (on the order of 3%).
- This results in most PV module warranty claims being limited to excessive underperformance, defects seen visually, or complete failure.
- Most module warranties only cover the replacement module costs and not the associated labor.

