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

Deep Dive Workshop, ACEF, Manila 4-8 June, 2018

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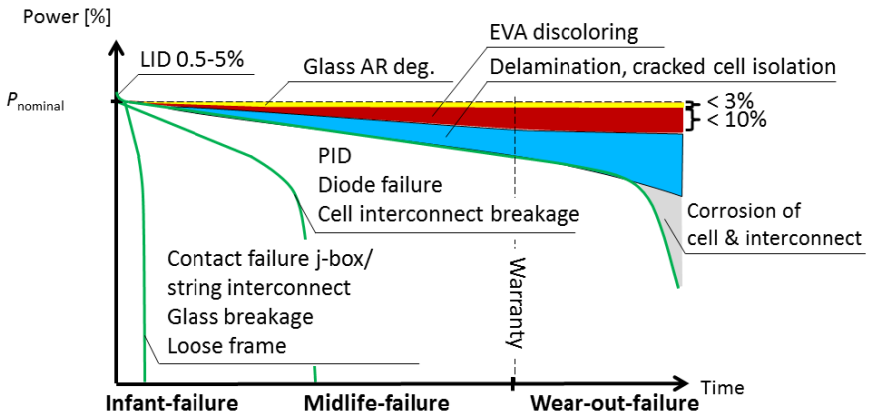
Module defects and Product Qualification Program (PQP)

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.

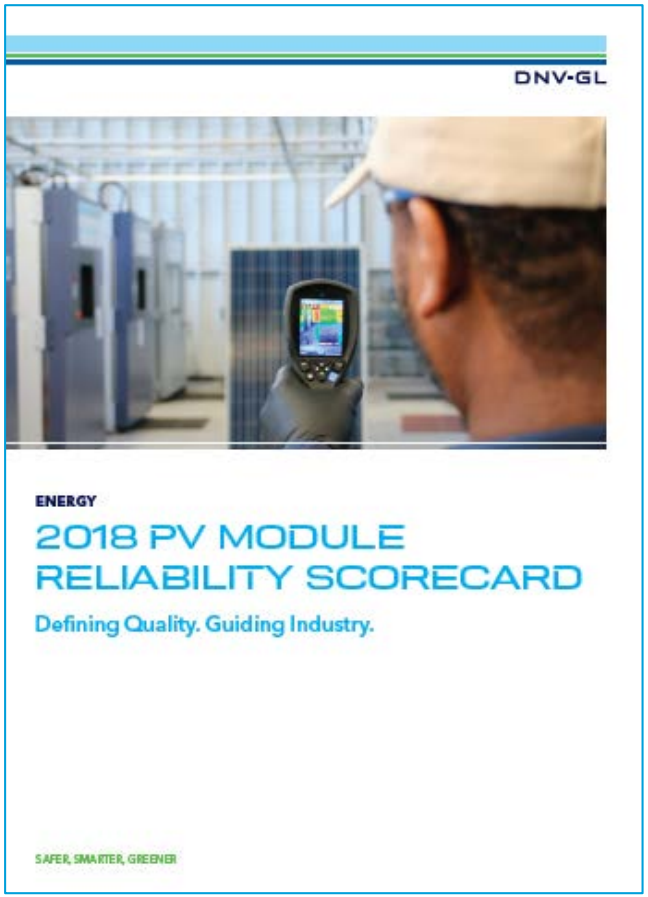


Source: Review of Failures of Photovoltaic Modules, IEA PVPS 2014

- 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



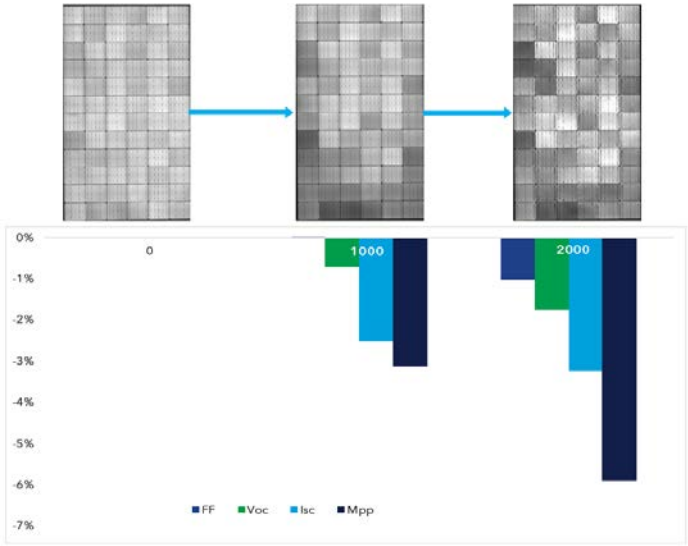
- Updated every 1-2 years
- Summarizes the last 18 months of PQP testing results
- For a specific data on module test result, refer to PQP as downstream partner.

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

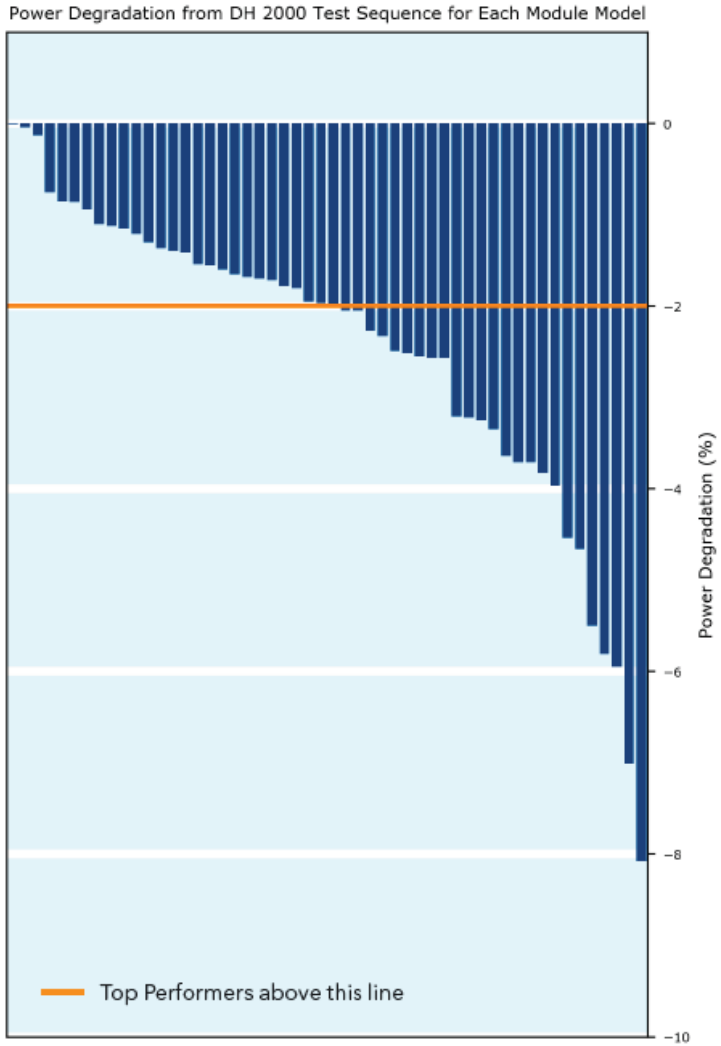
The 2018 PV Module Reliability Scorecard is available as a free download.

2018 results – Damp heat

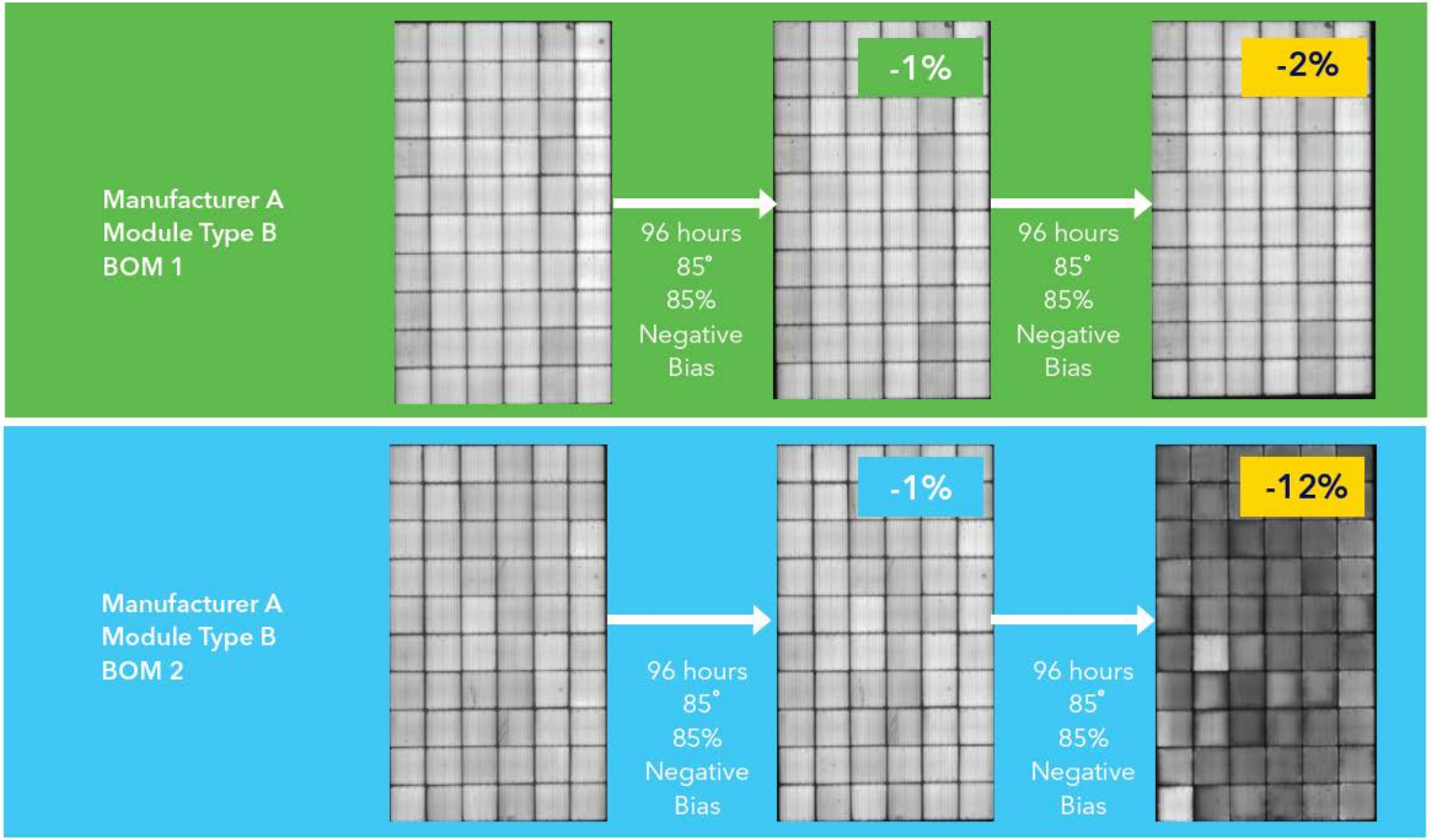
- DNV GL evaluated failures from three viewpoints: BOM, model type and manufacturer.
- Broadly categorized into:
  1. Visual failure
  2. Safety failure
  3. >5% power loss



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



Case Study– PID performance

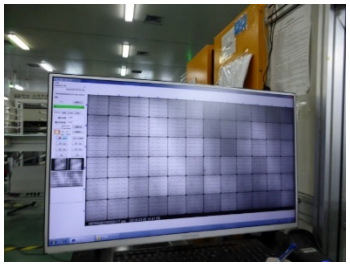


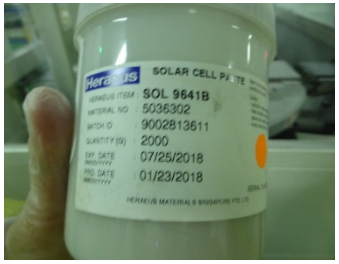
Same Manufacturer. Same Model Number. Different Performance.

Witness test

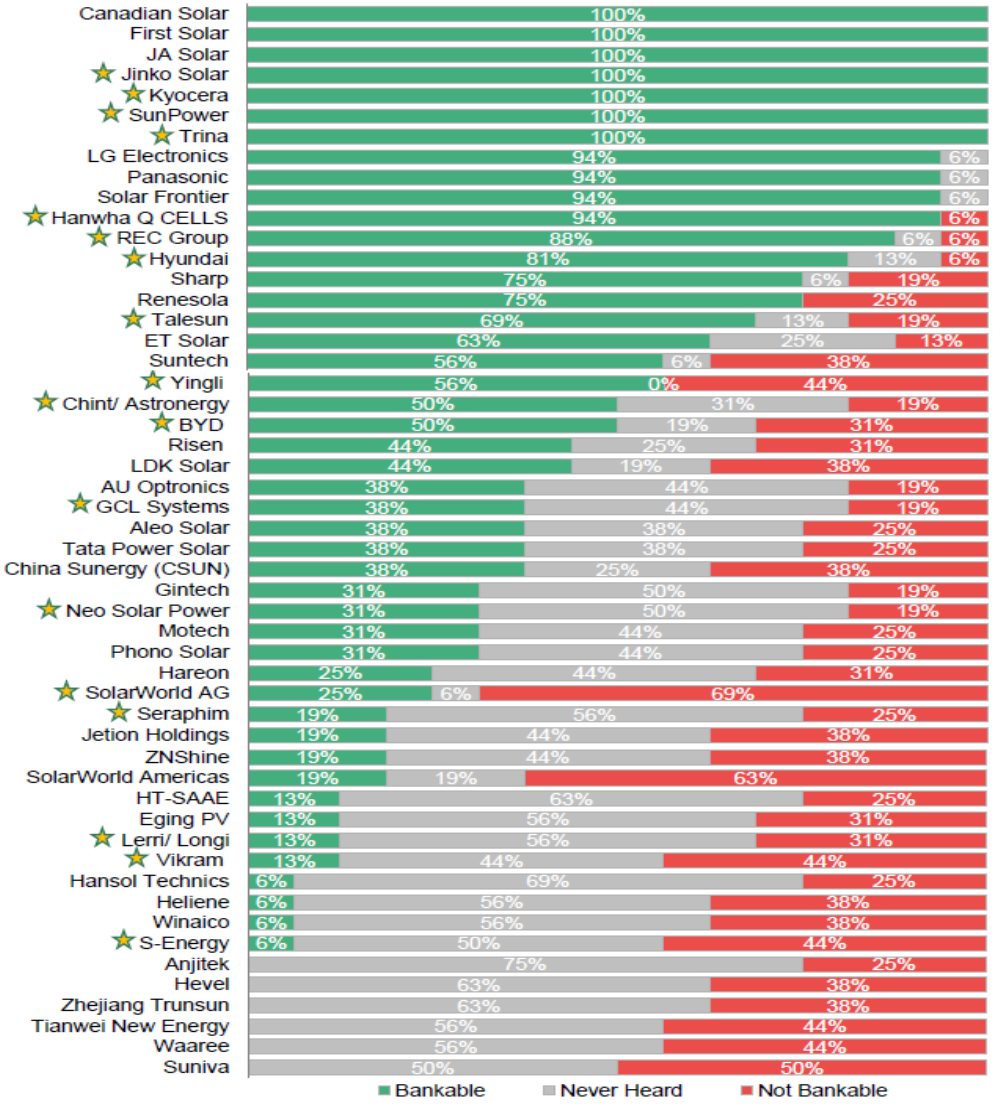
- Control of the provenance (temper-proof sealing tape)
- Systematic factory witness
  - Avoids golden samples
  - Control of BOM
    - 122 elements constitute a BOM
  - Sneak-peek in the factory
- Factory location is part of the BOM description
- Re-test guidelines for factories
  - Ask for the factory 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.

	TOP PERFORMER 2018 DNV·GL PV MODULE RELIABILITY SCORECARD	TOP PERFORMER 2017 DNV·GL PV MODULE RELIABILITY SCORECARD	TOP PERFORMER 2016 DNV·GL PV MODULE RELIABILITY SCORECARD	TOP PERFORMER 2014 DNV·GL PV MODULE RELIABILITY SCORECARD
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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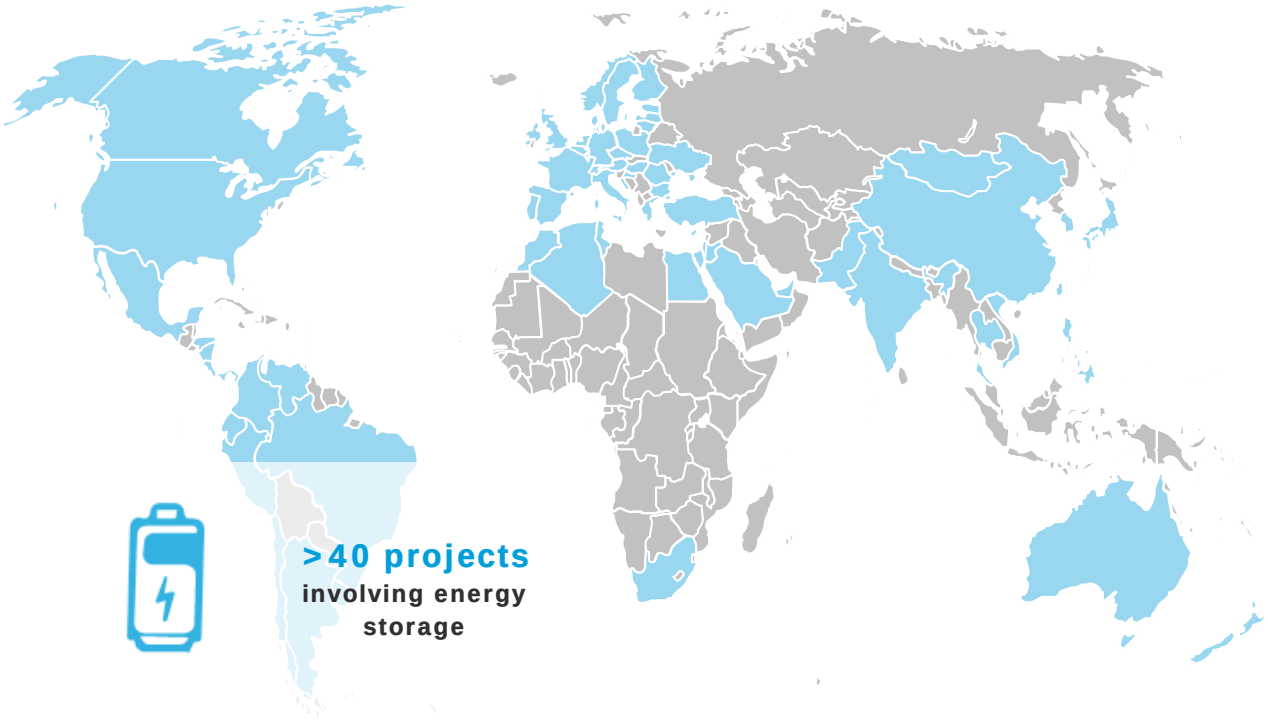
In recent history we have advised in hundreds of projects, significantly reducing the investors' risk position

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



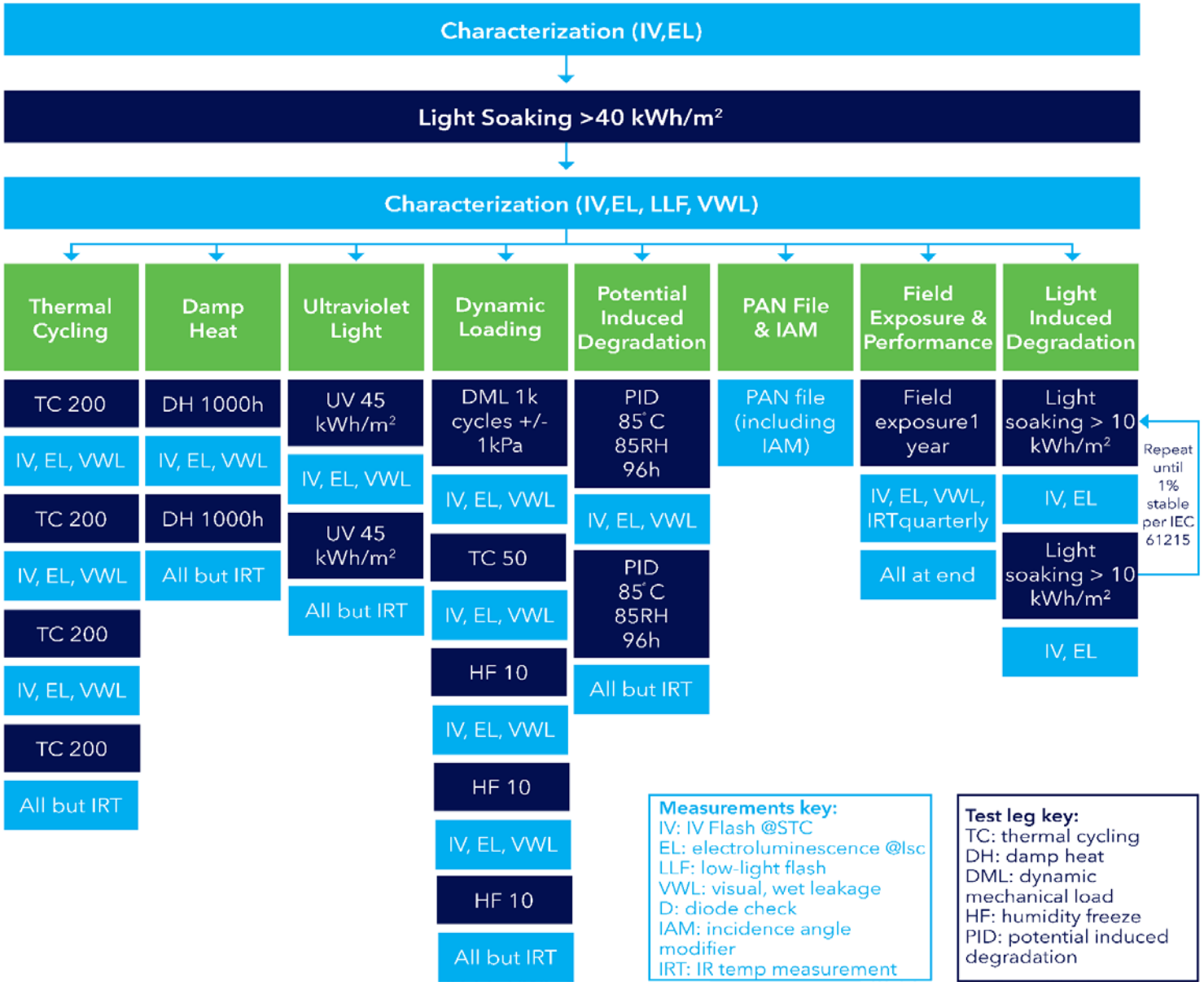
>40 projects
involving energy storage

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

>100,000 km
of gas transmission and distribution pipelines

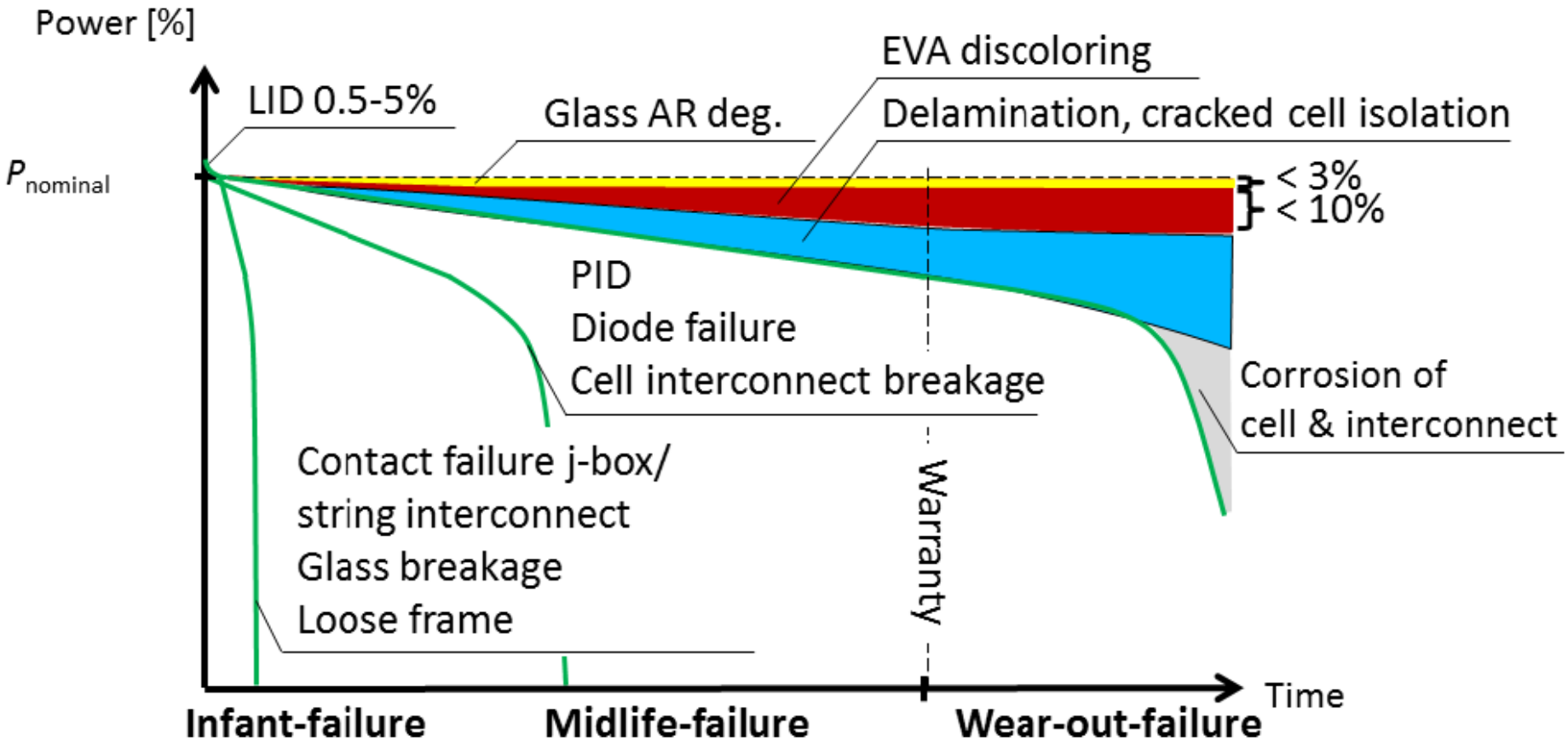
>5,000 km
of heat transmission and distribution pipelines

PQP Test Sequences



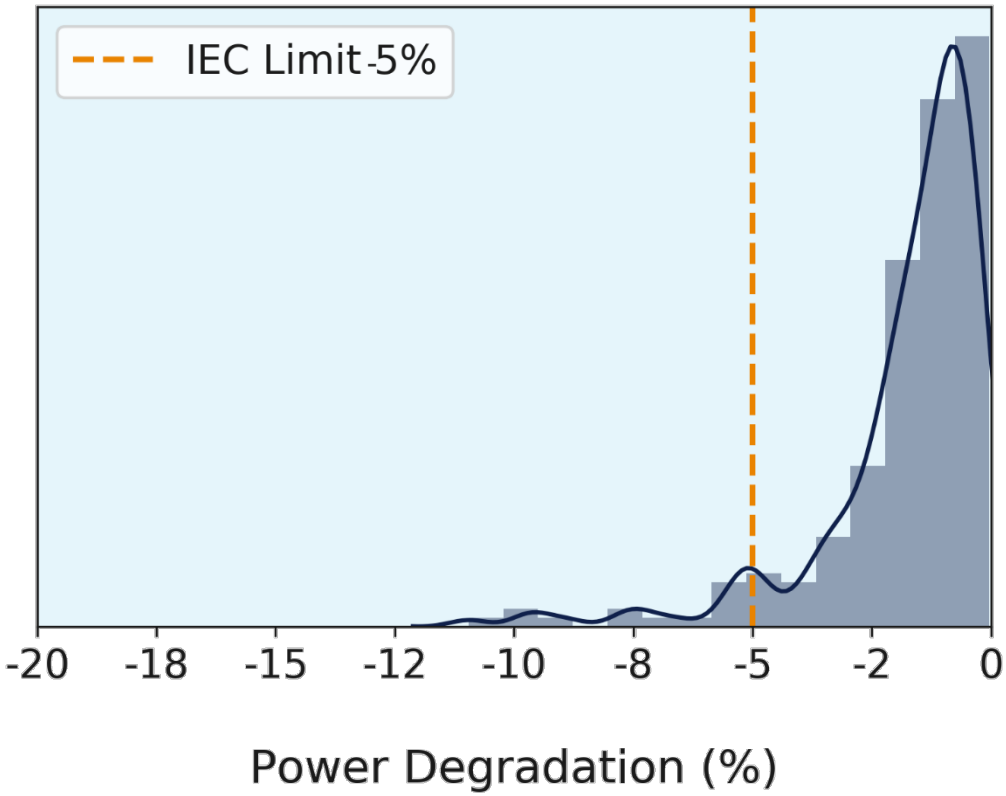
Module degradation mechanisms

- *Review of Failures of Photovoltaic Modules*, IEA PVPS 2014



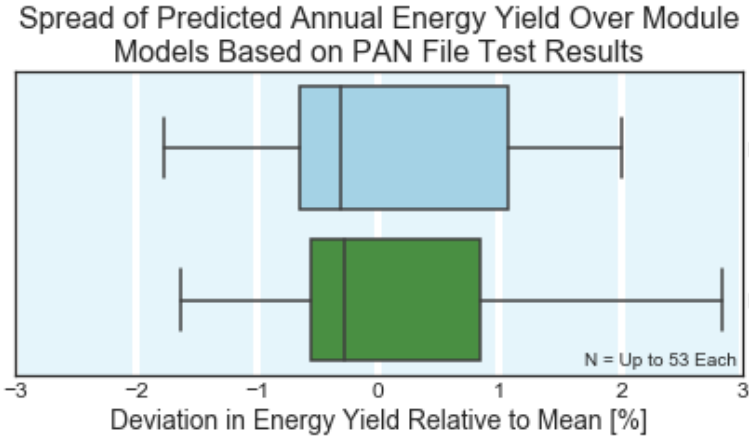
FAILING IEC TESTING

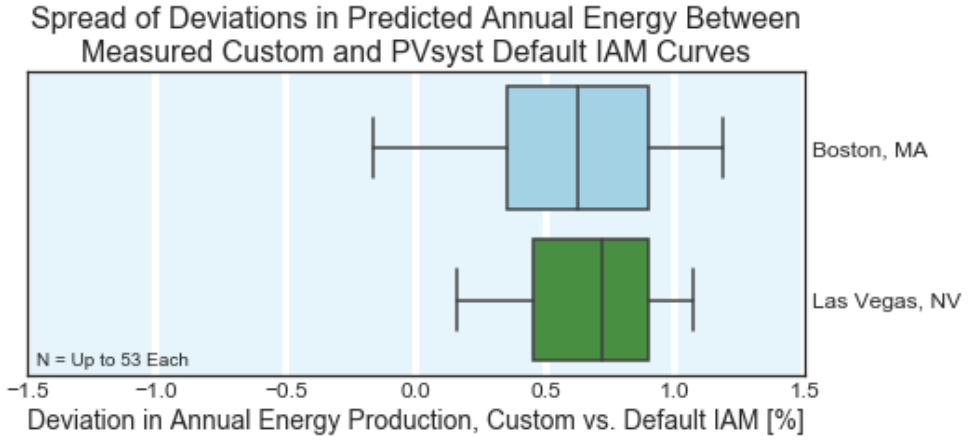
- Based on DNV GL's experience and data, at least 7% of commercial PV modules do not pass the IEC 61215 humidity freeze test. This 7% figure pulls from the historical dataset that has grown from tens to hundreds of modules



Case study– PAN and IAM differences

- Compared to default PVsyst simulations, PAN files and IAM data from DNV GL can provide more accurate performance predictions for the measured modules.
- Module selection can result in a 4-5% production difference when all other parameters are fixed.
- The IAM profile of the module can represent a 1-2% difference in predicted production.



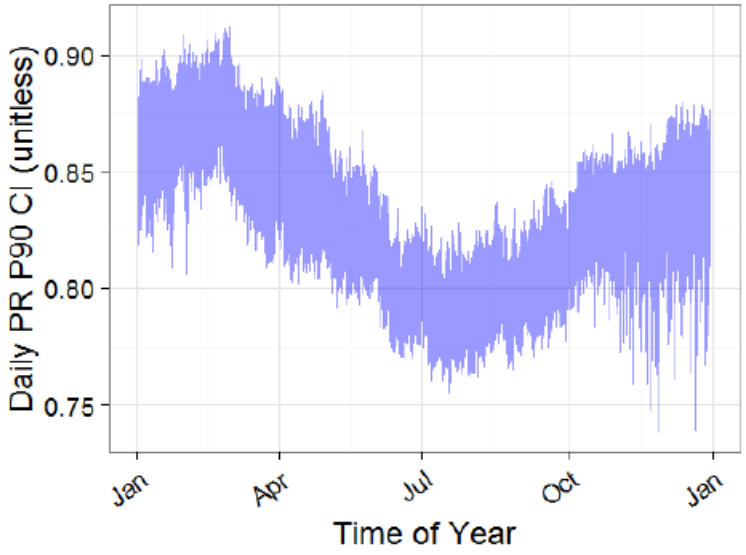


PQP – Test Failures

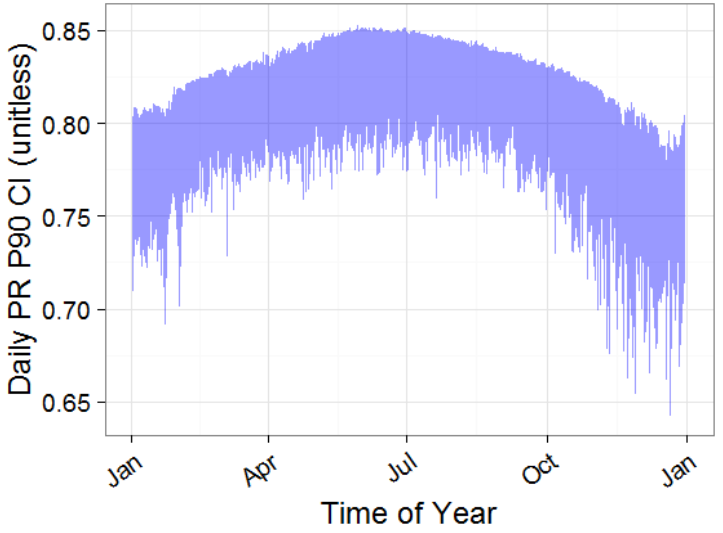
- During each test sequence, modules are characterized before and after each test interval. This is when module safety and performance are assessed under several criteria before continuing in the test sequence.
- For the 2018 Scorecard, DNV GL evaluated failures from three viewpoints: BOM, model type and manufacturer.
  - 9% of tested BOMs failed at least one of the evaluation criteria.
  - 12% when viewed at a model-type level.
  - 22% of all manufacturers who tested in the PQP in the past 18 months had at least one failure.

Limitation of PR – annual average ≠ daily value

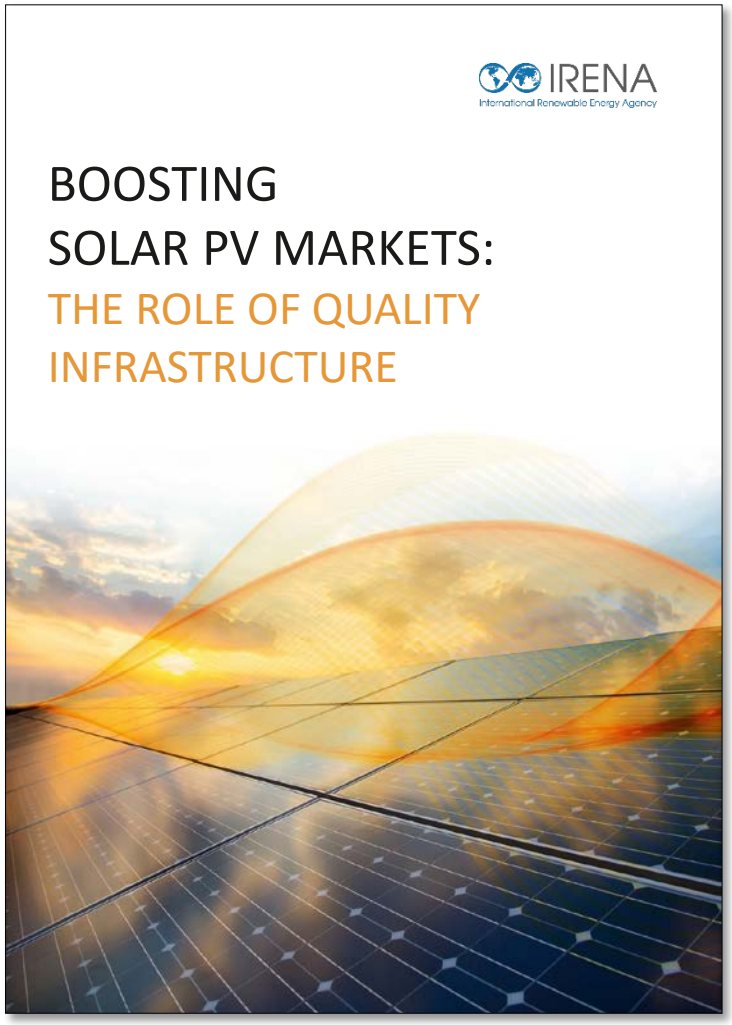
- Typical PR seasonal variation, *high uncertainty to be used for daily measurement*



- Typical temperature corrected PR seasonal variation, *only slightly better*



Technology bankability



DNV GL helped IRENA with this publication on the push for quality infrastructure in PV development.

- Involved many relevant stakeholders
- Complete list of standards and certifications available
- Components
- Cost breakdowns, uncertainties, trends
- Typical failure modes
- Economics of cleaning PV modules

http://www.irena.org/publications/2017/Sep/Boosting-solar-PV-markets-The-role-of-quality-infrastructure

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.