Kiwa PI Berlin

Recent Findings on Glass-Breakage

PV ModuleTech Europe – Malaga, Spain

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kiwa

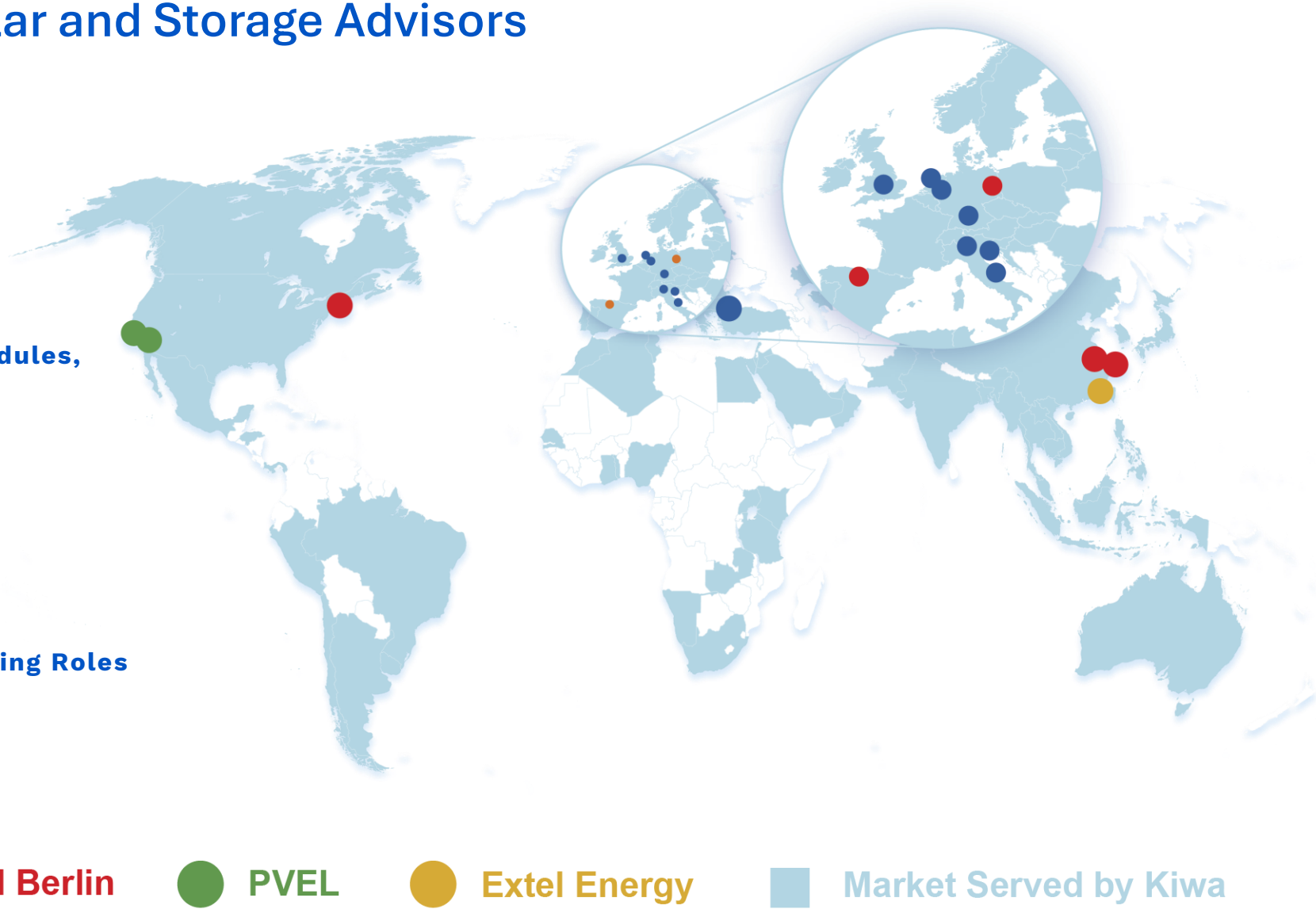
Kiwa PI Berlin: Trusted Solar and Storage Advisors

1,000+
Factory Audits Conducted across PV Modules, BESS, Inverters and Transformers

175+ GW
PV Production Capacity Evaluated

20+ GW
Technical Advisor and Owner's Engineering Roles

3 PV Labs in Key Markets
Germany, China, USA (PVEL)



Agenda

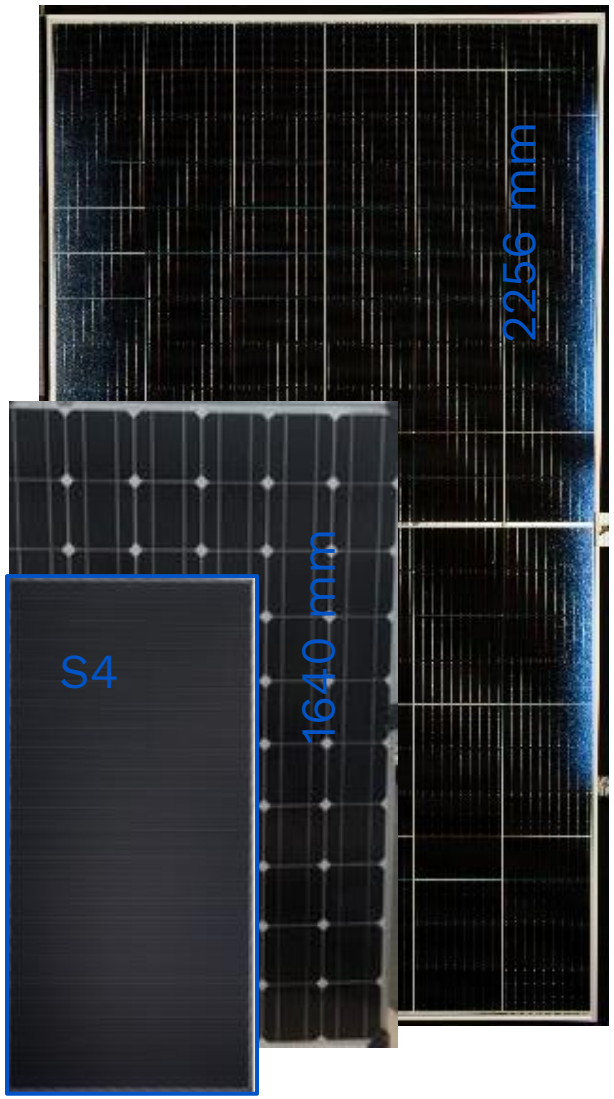
1. Factors leading to more glass breakage
2. Factory findings
3. Lab tests and findings
4. Field findings
5. Summary of potential causes
6. Action plan for the industry

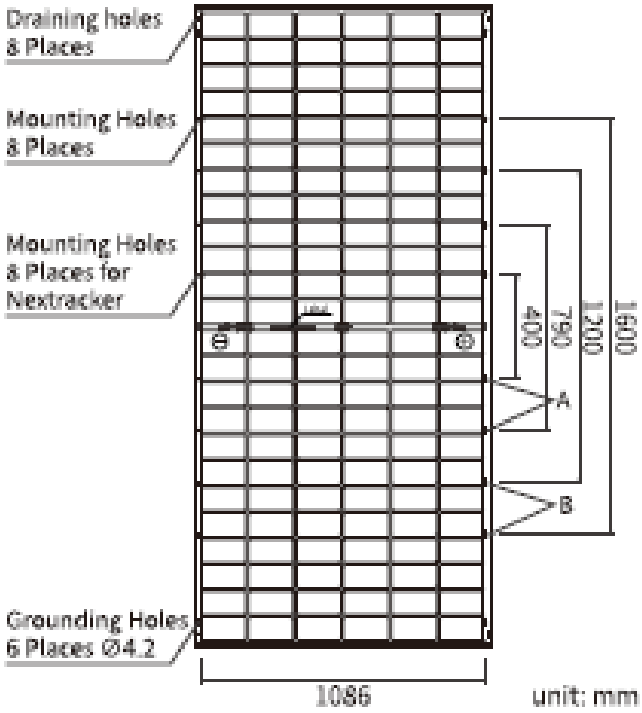
Factors Leading to More Glass Breakage

1. Module Design

- More than 80% of all modules manufactured now are glass/glass
- Module size has more than doubled in last 10 years
- Three junction box holes at module centre, instead of one at the top
- Mounting holes still at same distance leading to higher bending stresses
- Frame width and thickness shrinking

- ➢ Less rigid
- ➢ Load bearing
- ➢ Higher stresses





Factors Leading to More Glass Breakage

2. Glass Quality

- Glass/backsheet modules used 3.2mm fully tempered glass
  - High flexural strength and a larger range of temperature resistance
- Glass/glass modules currently on the market are using 2mm heat strengthened glass
  - 50% lower bending strength and temperature resistance

- ➢ Weaker
- ➢ More sensitive to impact
- ➢ More sensitive to operational loads

Material	Flexural strength	Temperature change resistance
Float glass	45 N/mm²	40 K
Heat strengthened glass	70 N/mm²	100 K
Tempered glass	120 N/mm²	200 K

Factory Findings

Manufacturing defects can be identified during independent Pre-shipment Inspection (PSI)

- Directly impacting glass breakage risk
  - Glass damage
  - Frame assembly
  - Sealant

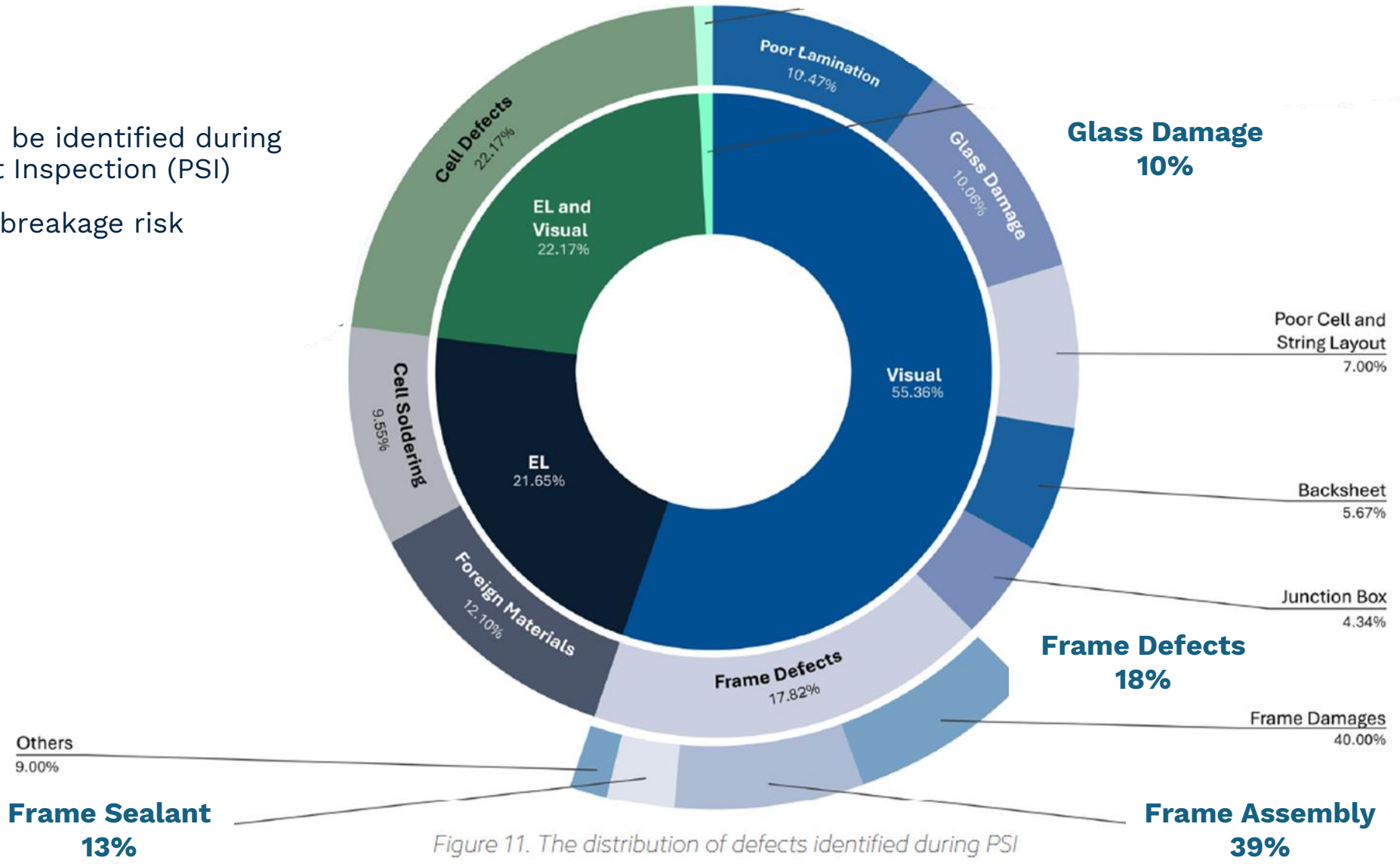


Figure 11. The distribution of defects identified during PSI

www.kiwa.com/pvqualityreport

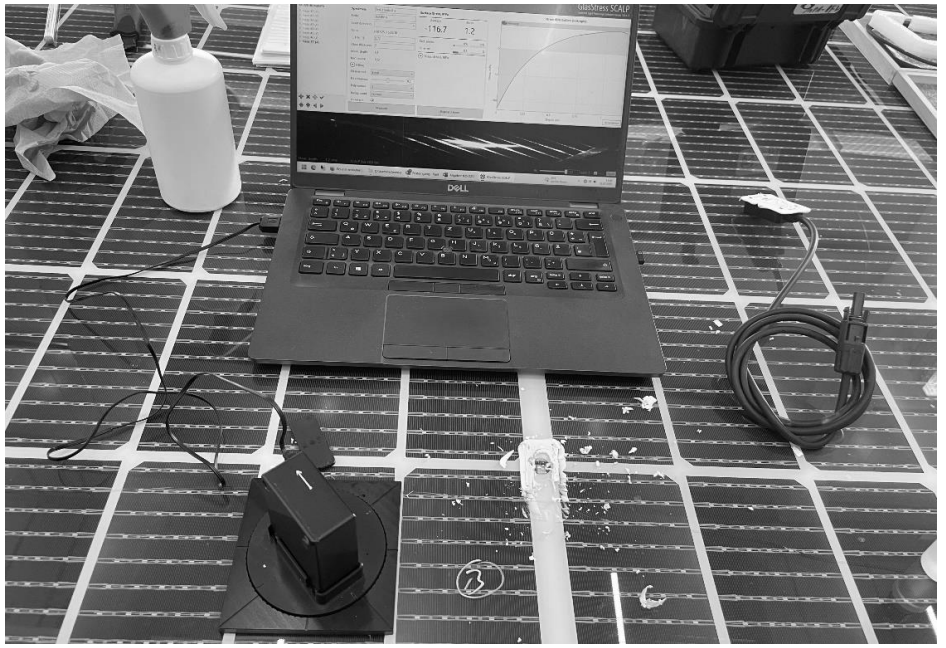
Lab Tests and Findings

Thickness

- Glass thickness not as expected:
  - tolerance of **+/-0.2 mm** is too large
  - should be tightened to **-0**/+0.2 mm

Inhomogeneity of Surface Compression

- Surface compression on 2 mm rear side glass:
  -64 to -117 N/mm² determined over four modules
- SCALP, ASTM C1279-13 (2019)
  Standard Test Method for Non-Destructive Photoelastic Measurement [...] in Glass



#1

-72	-76	-86
-111	-80	-89
-80	-64	-91

#2

-111	-82	-119
-111	-110	-105
-108	-117	-103

#3

-81	-70	-117
-100	-117	-80
-93	-106	-76

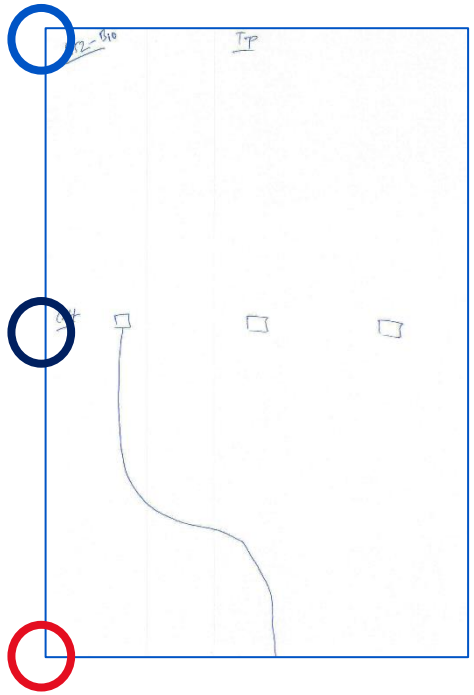
#4

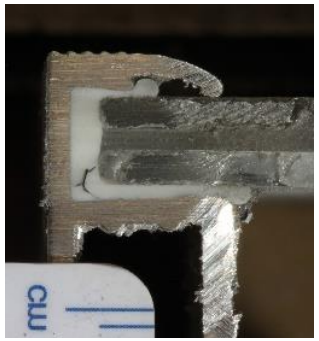
-74	-70	-87
-84	-94	-79
-73	-88	-73

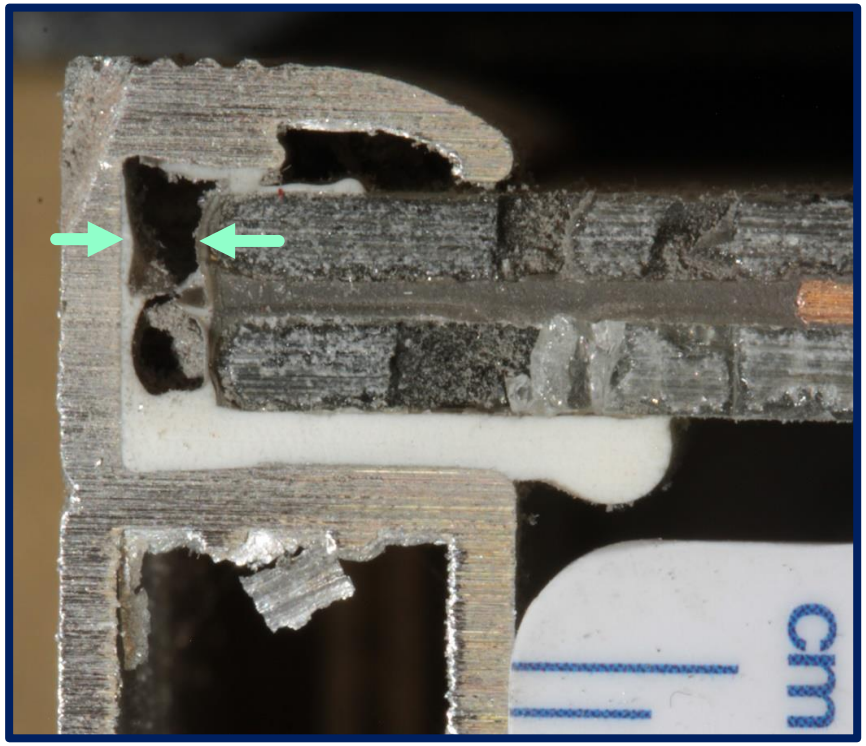
Lab Tests and Findings

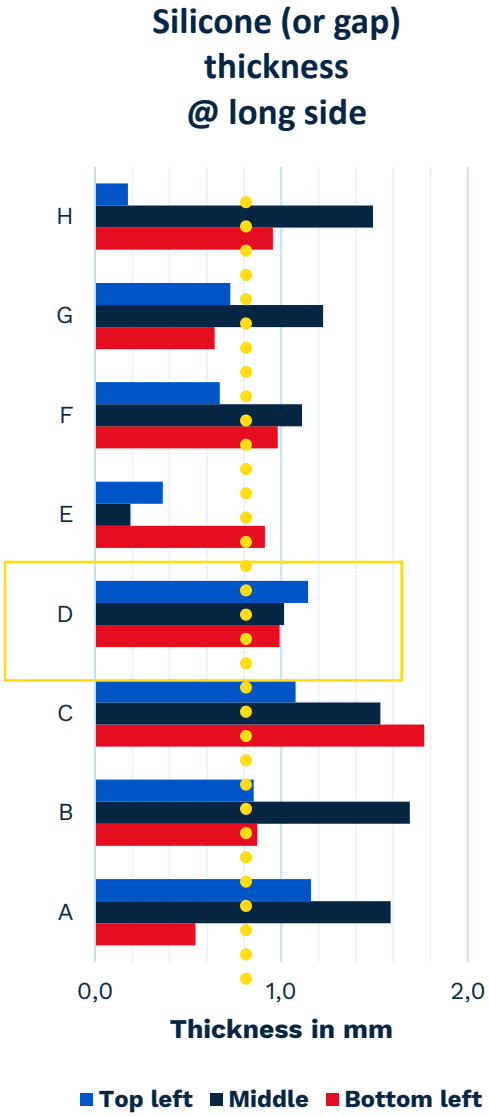
Cross-section-cut analysis

- Glass thickness measurement
- Sealant quality
- Even distribution of sealant





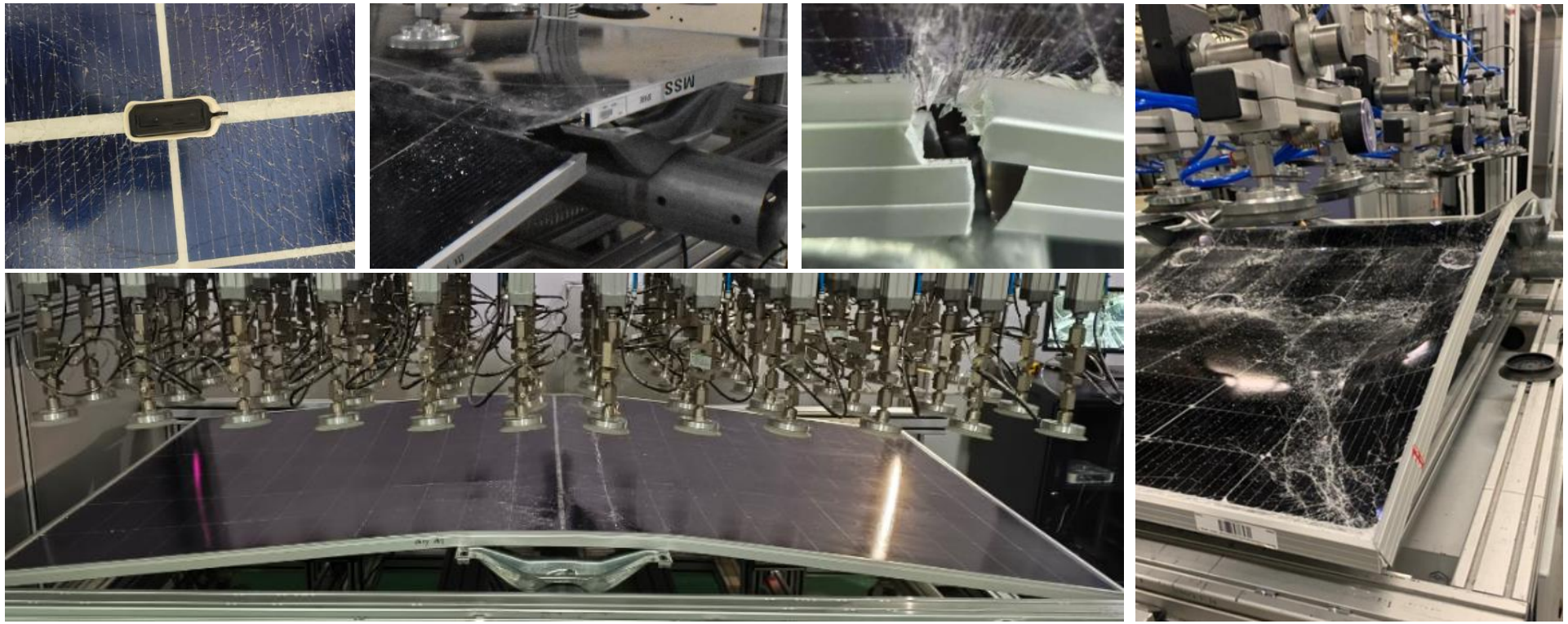




Lab Tests and Findings

Static and dynamic mechanichal load testing

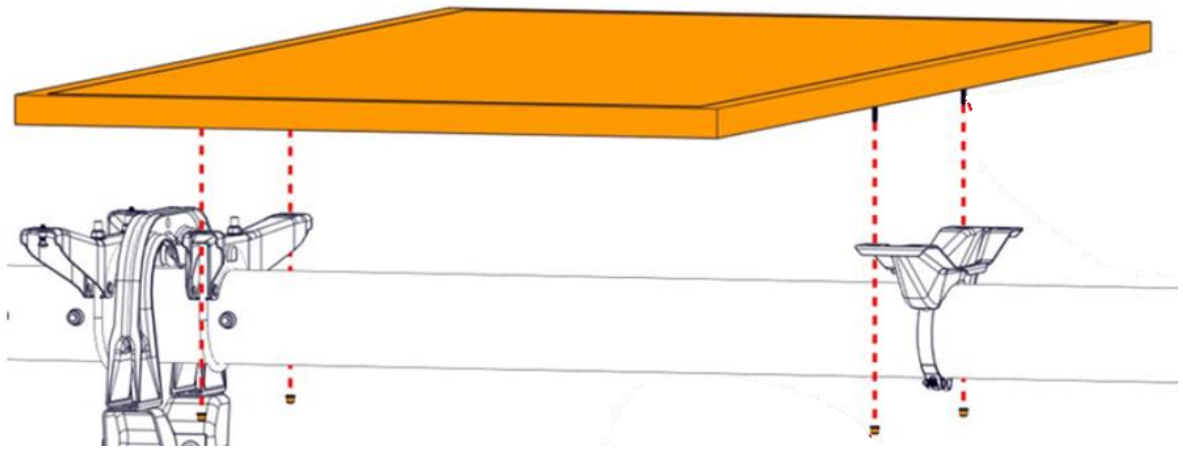
- 2025 PV Module Reliability Scorecard (www.scorecard.pvel.com) results showed:
  - 20% of BOMs undergoing the PQP's Mechanical Stress Sequence (MSS) experience broken glass or frames
  - 40% of manufacturers experienced at least one failure during MSS testing

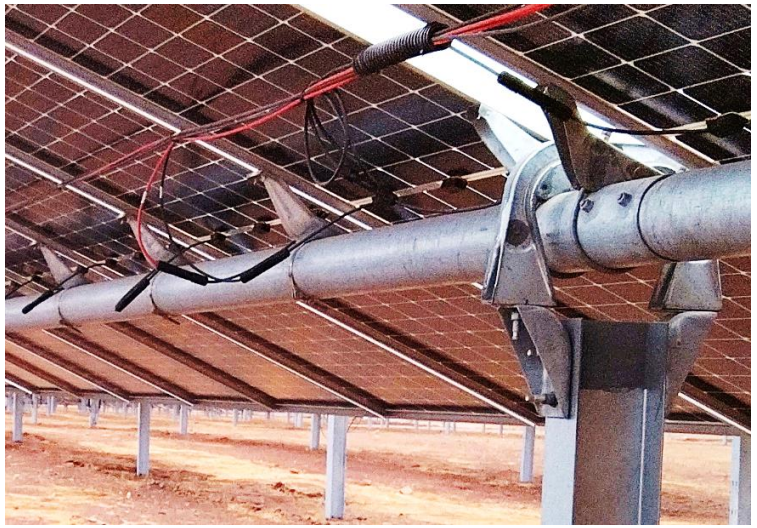


Field Findings

Incompatibility Between Module and/ or Mounting Support

- On-site inspection:
  - Incorrect module mounting holes used
  - Torque level too high or too low
  - Unstable foundations

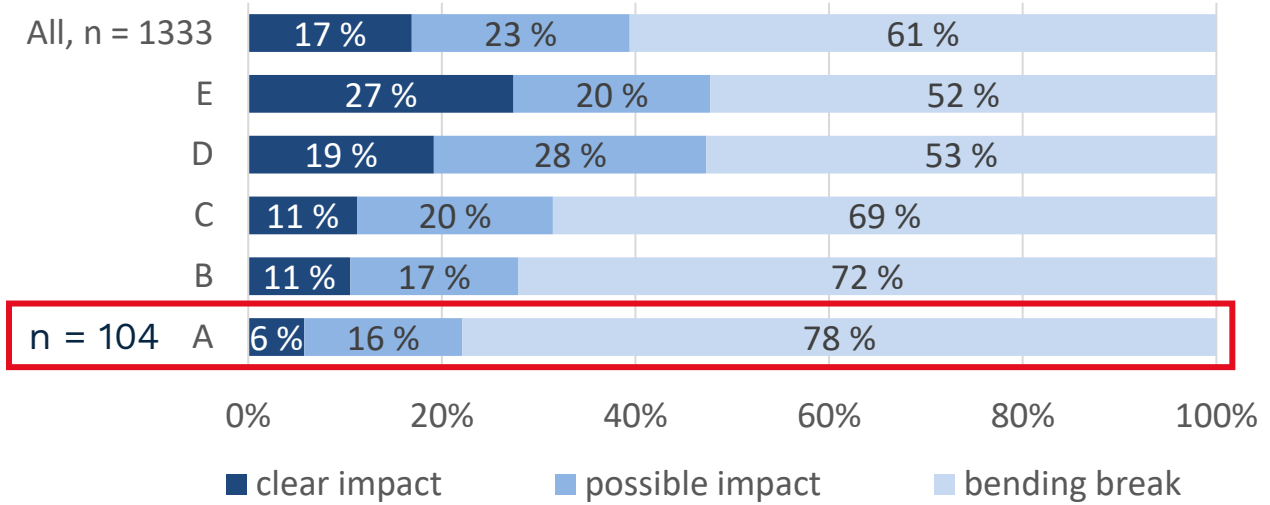


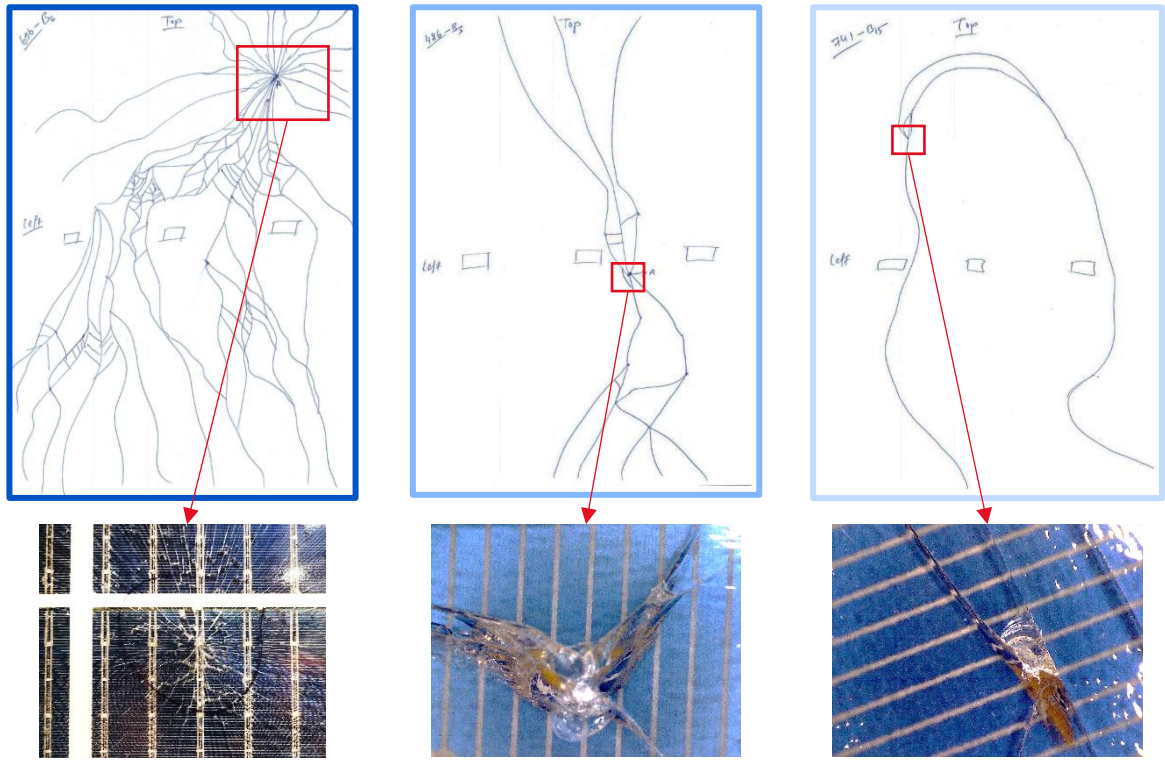


Field Findings

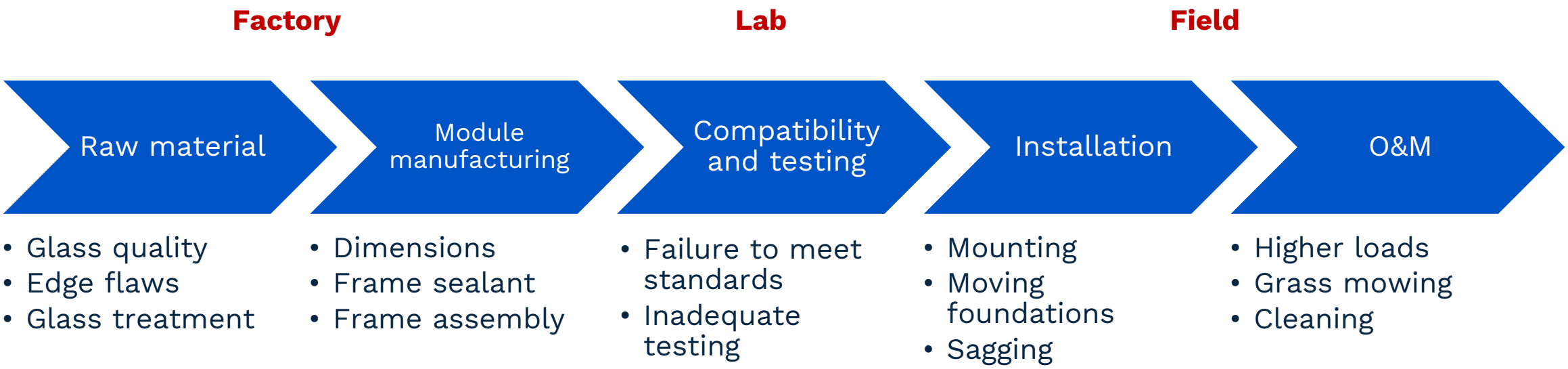
Impact from flying objects

- 6 to 27% of the broken modules show **clear signs of impact**, but many others not obvious
- Some evidence of thrown stones and mud, one case (E) clearly from cleaning device
- Microscopic validation of impact is important





Summary of Potential Causes



Failures are usually due to combination of causes and unlikely due to just one

Action Plan for the Industry

1. Prevention before Production

- Glass specifications (e.g. positive tolerance)
- Quality requirements in MSA and during audit
- Extended reliability testing
- Verifying operational loading vs. test loading

2. Control during Production

- Incoming goods verifying specs and quality
- Production oversight (e.g. framing, sealant, dimensions, glass cutting)
- Lab testing samples (e.g. frame cutting, SCALP, dimensions)

3. Oversight during Construction and Operations

- Inspection of foundation installation
- Verifying of module mounting position and torques
- Improving O&M activities (e.g. grass cutting with cover, limiting vehicle speeds)

4. Near to Mid Term Industry Requirements

- Updated testing standards and protocols (e.g. in-plane forces, rear-side impact test)
- Definition of advanced glass quality specifications (e.g. heat strengthening, impact resistance)
- Specify design loads and safety factors sufficient for operational stresses

Solar glass must be made fit for purpose again

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