



What Solar Module Test Failures Reveal in 2026

Key Takeaways from Kiwa PVEL's PV Module Reliability Scorecard

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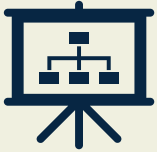
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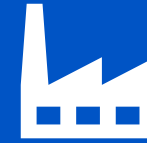
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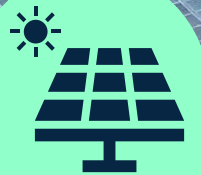
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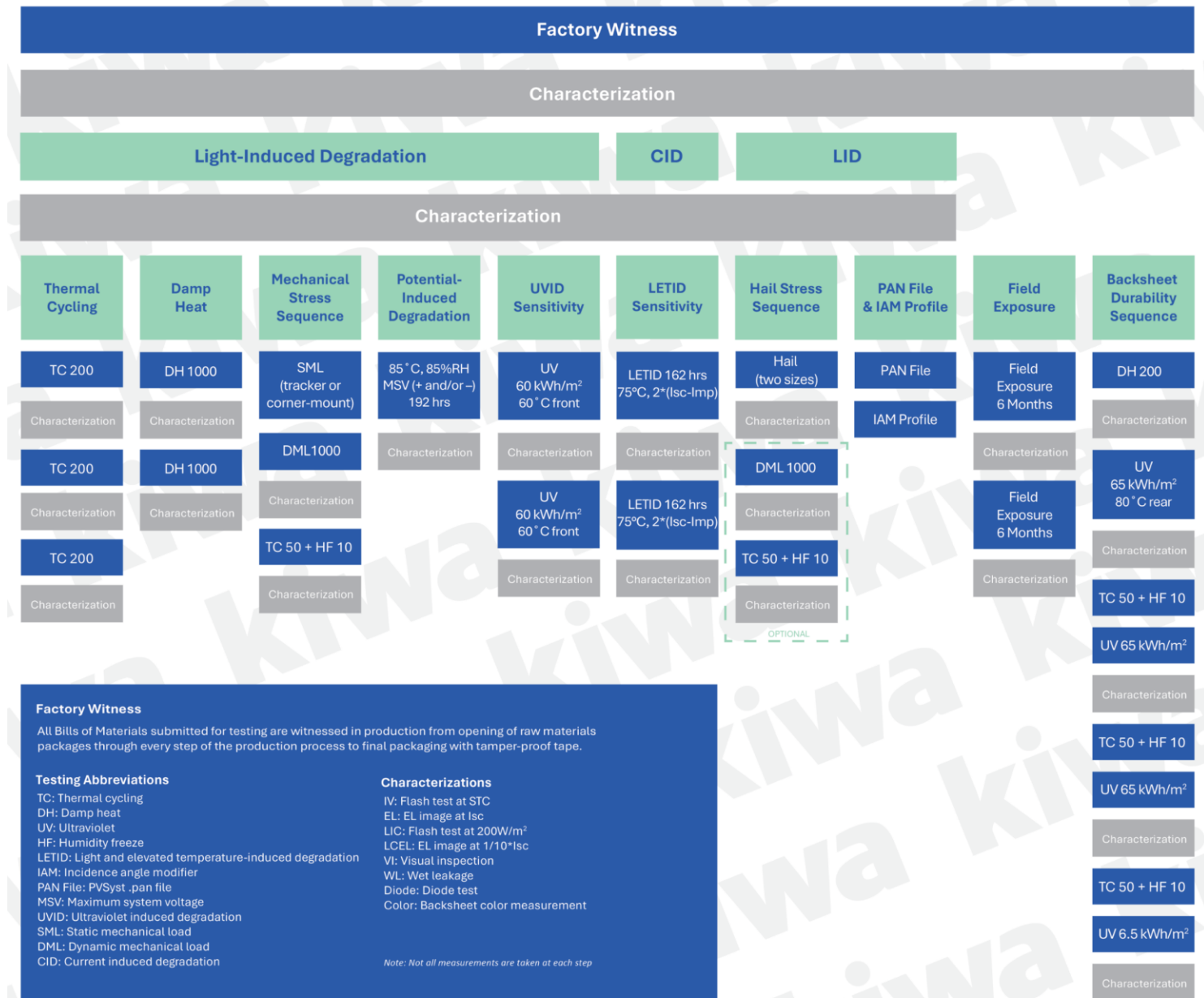
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PQP Test Sequence

The PQP evolves every 2-3 years based on feedback from Kiwa PVEL's downstream partners, module manufacturers, and the industry's collective understanding of module failure modes and test mechanisms.

The previous update, shown here, introduced the UVID test.

The latest update, introduced in April 2026, includes a new test to failure approach for module durability. Learn more about the new version of the PQP test plan at kiwa.com/pvel/pqpv12.



Test Conditions for Select PQP Tests

- **Thermal Cycling (TC):** 600 temperature cycles from -40°C to +85°C.
- **Damp Heat (DH):** +85°C and 85% relative humidity for 2000 hours.
- **Mechanical Stress Sequence (MSS):** Static mechanical load (SML): 3 rounds of downward and upward force at 1800 Pa while tracker or corner mounted. Dynamic mechanical load (DML) test comprises 1000 cycles of loading at ± 1000 Pa using the same mounting as SML. Followed by 50 TC cycles and 10 humidity freeze (HF) cycles from +85°C and 85% relative humidity down to -40°C.
- **Potential Induced Degradation (PID):** +85°C and 85% relative humidity with maximum system voltage applied between the cell circuit and frame for 192 hours.
- **Ultraviolet Induced Degradation (UVID):** Front side UV exposure of 120 kWh/m² of metal halide or 55 kWh/m² of UVF, at short-circuit condition and 60°C.
- **Light Induced Degradation (LID):** >40 kWh/m² of outdoor light soak with Irradiance > 500 W/m²
- **Light and Elevated Temperature Induced Degradation (LETID):** 324 hours of 75 C at $2 \times (I_{sc} - I_{mp})$

PV Module Reliability Scorecard Overview



The annual PV Module Reliability Scorecards lists top performing modules and insights from Kiwa PVEL's PQP.

Each year the Scorecard is accessed by tens of thousands unique visitors from over 150 countries.



- To be eligible for the Scorecard, manufacturers must have:
 - Completed the PQP sample production factory **witness** within 18 months of the Scorecard publication and have new Top Performer results.
 - Submitted at least two factory-witnessed PV module samples to all PQP reliability tests, as per Kiwa PVEL's BOM test requirements.
- To be a **“Top Performer”** in a particular test:
 - TC, DH, MSS, PID, UVID must have < 2% power degradation.
 - LID+LETID must have < 1% combined power degradation.
 - HSS must not experience glass breakage with ≥ 40 mm hail.
 - PAN must place in the top quartile for energy yield.
 - Top Performers must not have experienced a wet leakage failure, ‘major’ defect during visual inspection, or a diode failure for that particular test.
- **“All-Stars”** are top performers in all tests

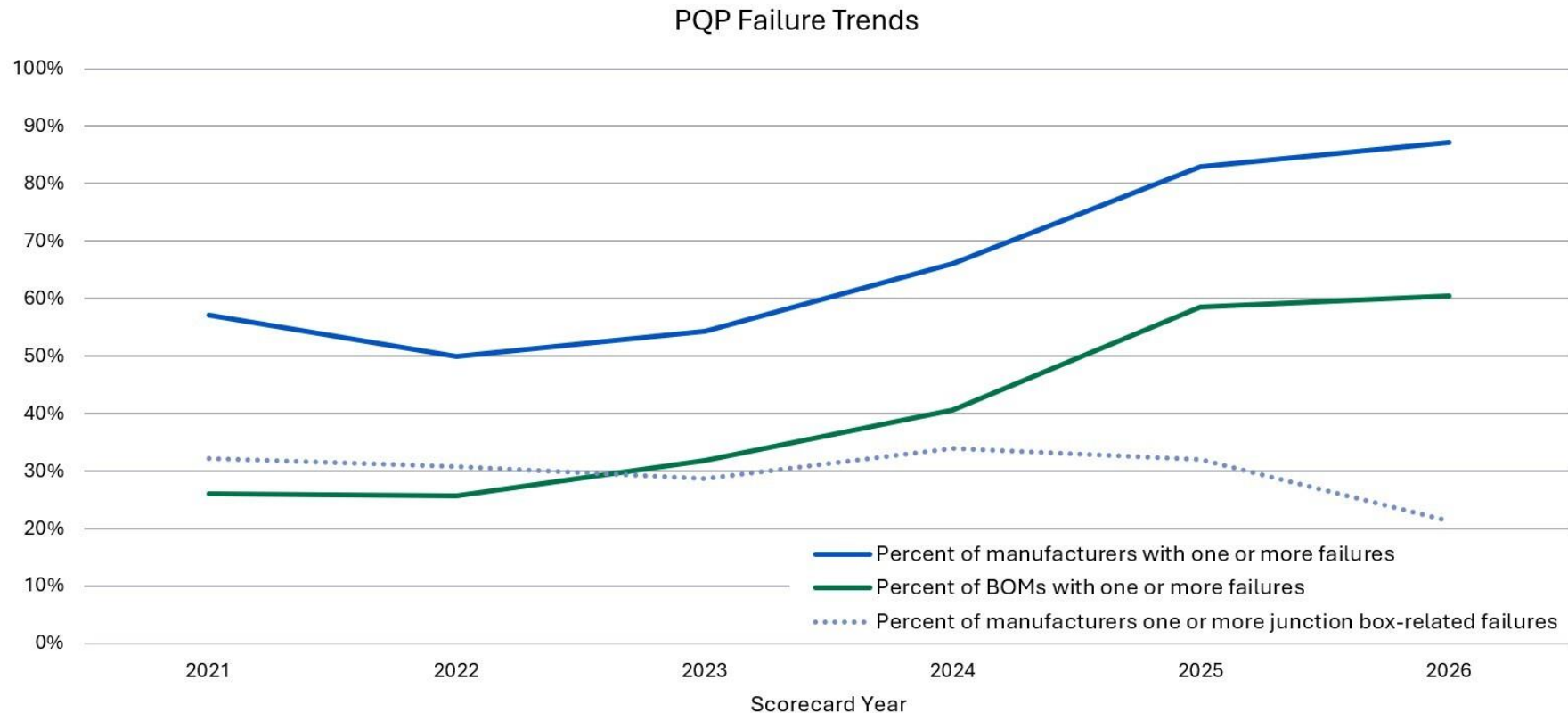
Key Highlights from the 2026 PV Module Reliability Scorecard

- 43 manufacturers have a module achieving Top Performer status in >1 test, including 13 for first time. (Everyone is a winner!)
- **No 'all-stars'**: No single model/BOM was a top performer on all tests – a first for the Scorecard.
- UVID is now a listed Top Performer test category.
- Power loss is decreasing for some tests, but **failure risk is rising**: most notably, degradation due to PID and UVID improved, yet failures reached record highs (87% of manufacturers and 61% of BOMs experienced at least one failure).
- Failure mix is shifting: Module breakage remains the #1 source of failures, but delamination surged sharply with 45% of manufacturers having at least one major delamination defect.

PQP Failures on the Rise

PQP failure rate continues to increase over the past year, with 87% of manufacturers and 61% of BOMs experiencing one or more failures.

Module breakage during MSS and HSS (hail) testing continued to be the top failure mode, but a sharp increase in **delamination** defects made it a close second in failure occurrences.



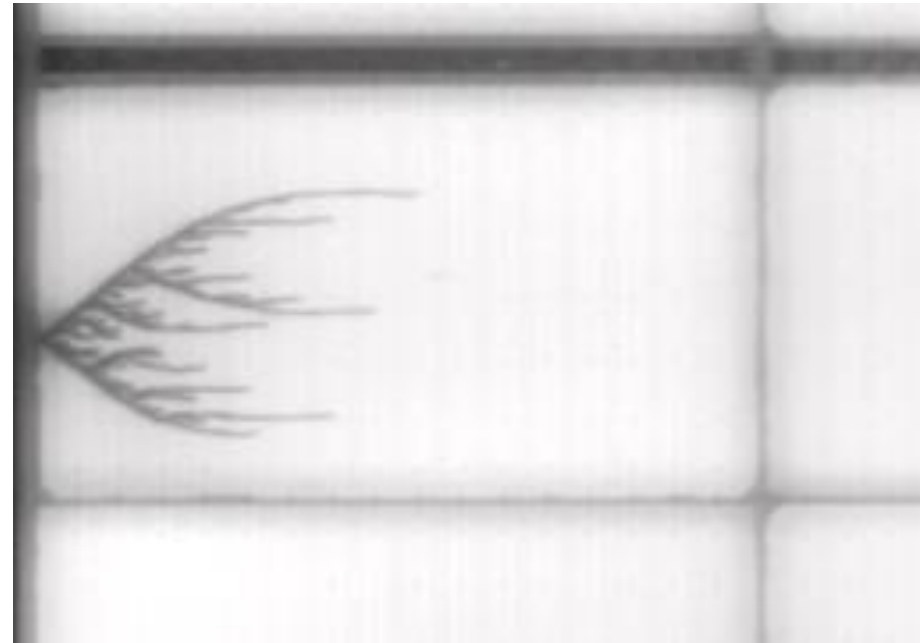
Module Breakage

26% of BOMs undergoing MSS testing had at least one (of two) broken modules.

62% of broken modules in MSS showed evidence of pinched glass via front glass breakage.
Example:



Module-1 broke during testing, showing a clear point of breakage due to edge pinch.



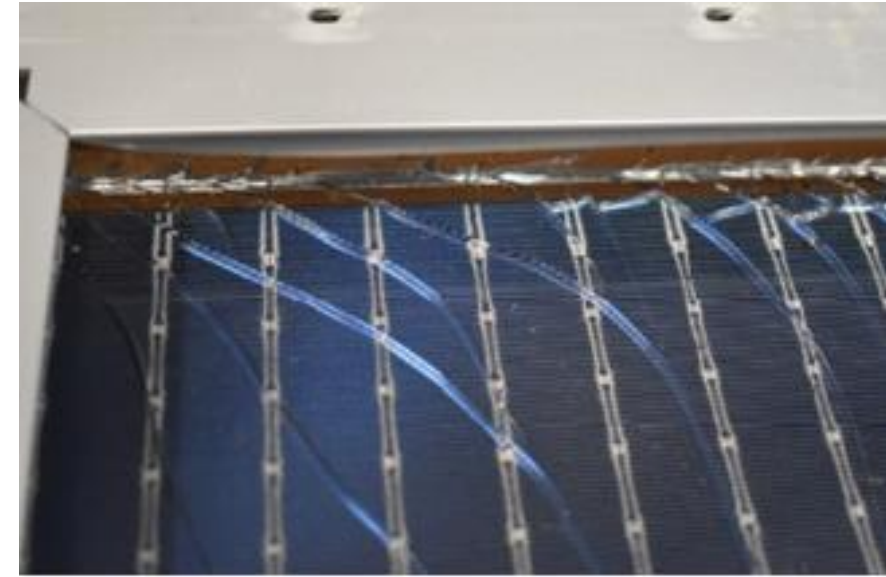
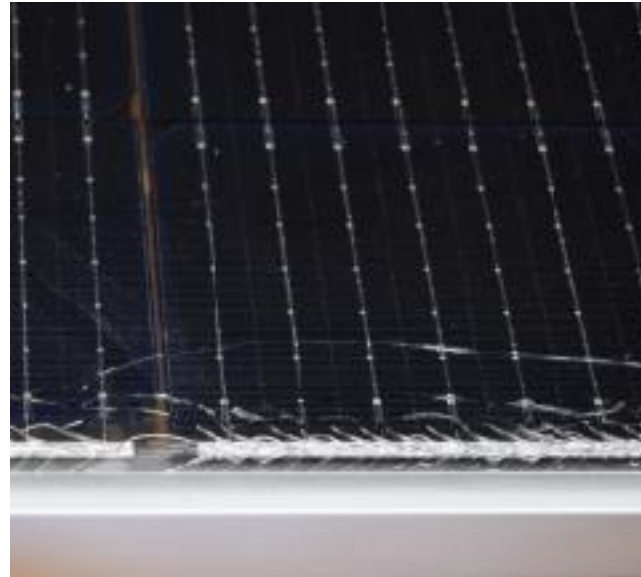
Module-2 did not break, but edge pinching on one cell can be seen in the EL image.

Spontaneous Glass Breakage

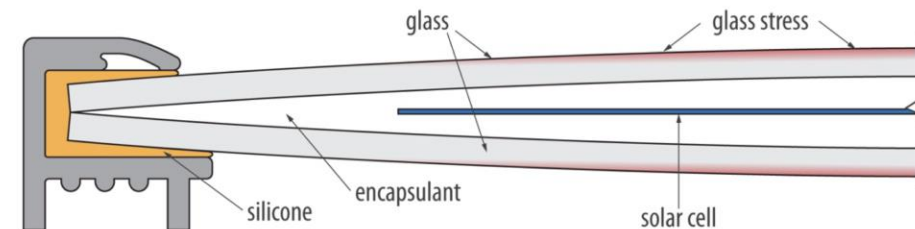
Glass//glass modules experiencing **spontaneous glass breakage** is the most significant reliability issue affecting today's PV modules.

Kiwa PVEL recently observed six of 20 modules from one BOM with broken glass after weeks of outdoor exposure.

The cracks along the busbars indicate a lack of encapsulant along the laminate edges, leading to edge-pinch induced stress concentration points between the metal busbar and the glass surface.



Glass cracking stemming from the module busbars in glass//glass modules can be prevented with thicker encapsulant and/or changes to lamination recipe.

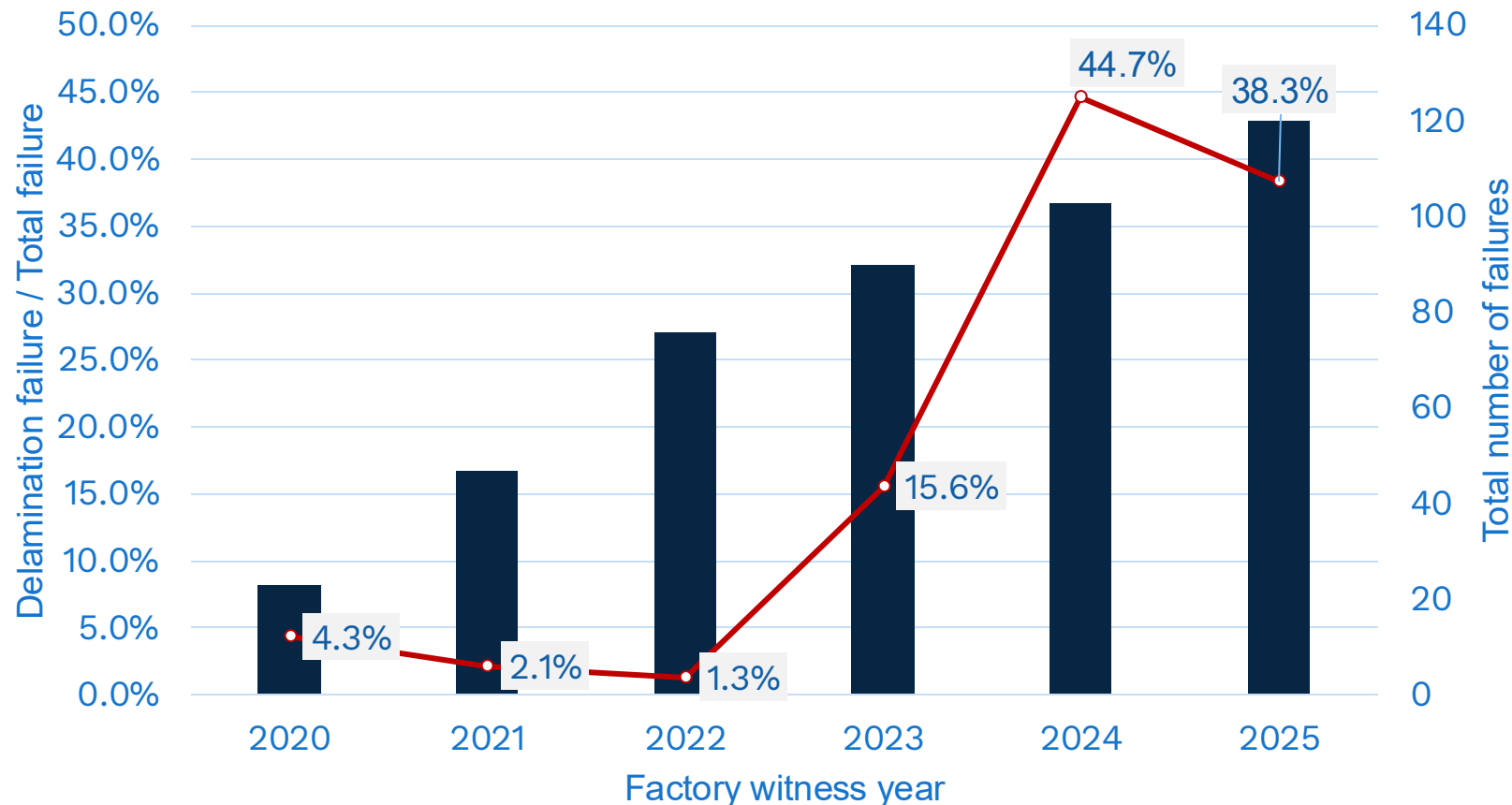


Silverman, Timothy J., et al. "Tough Break: Many Factors Make Glass Breakage More Likely." , Nov. 2024. <https://doi.org/10.2172/2479454>

Delamination – A Rising and Under-appreciated major concern

45% of manufacturers had at least one major delamination defect.

1/3 of these defects came after DH testing (DH1000 or DH2000), but also observed during initial characterizations and after TC, MSS, PID and UVID.



Delamination – Examples and Consequences



Delamination, corner



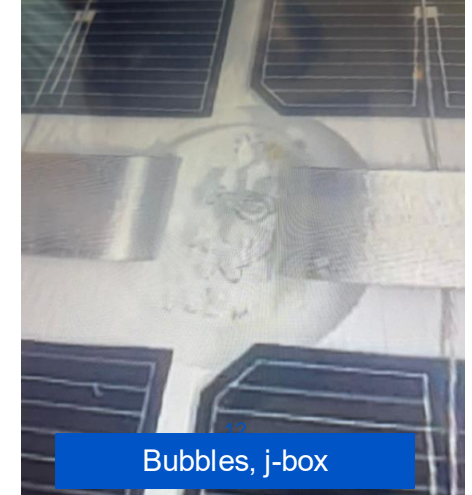
Bubbles, edge



Delamination, label

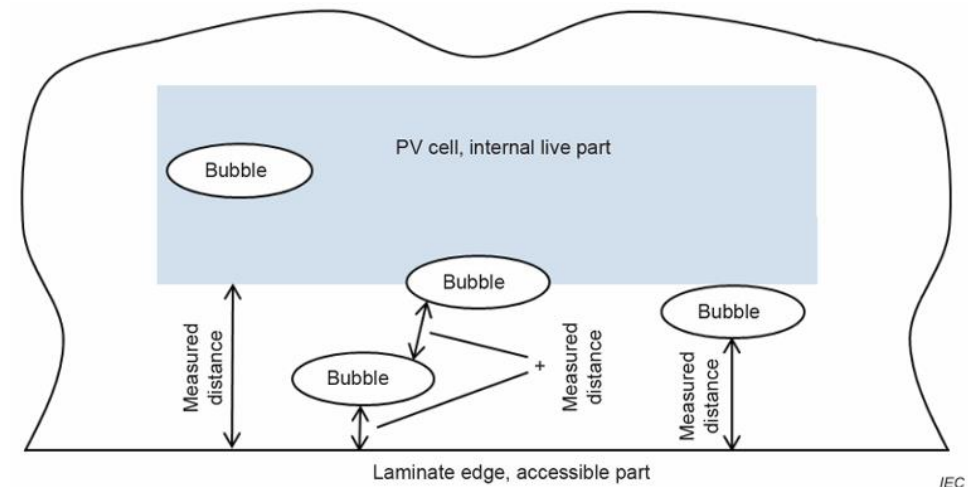


Delamination, edge



Bubbles, j-box

Per IEC61730, bubbles are assumed to be conductive. Considered a Major Defect when creepage distance is below IEC 61730-1 requirements.



a) Example for delamination assessment when measuring creepage distances and clearances, or distance through insulation

Delamination – Field Failure



45% of manufacturers had at least one major delamination defect.

Compromised creepage distances can lead to catastrophic field failures, as shown here.

Delamination Risk Factors – Preliminary Conclusions

Factor	Importance level	Note
Module design	★	No obvious differences between G//B and G//G modules.
Module size	★	No obvious differences for big floppy modules.
Encapsulant type	★★★	EPE as front and rear encapsulant seems to trigger the greatest number of major defects.
Encapsulant thickness	★★	A thinner encapsulant does not show a higher risk of delamination in DH (<i>unexpectedly</i>).
Edge pinch	★★★	Failure rate increases as encapsulant size decreases in width.
Lamination method	★★★	Locking frame appears least susceptible to delamination.
Lamination process	★★	Lamination temperature and time are not the main failure drivers (<i>also unexpectedly</i>).
Gel content	★	Does not seem to be a direct predictor.
Peel force	★	Does not seem to be a direct predictor.
Solder flux	★★★	Improper flux recipe can lead to delamination extending from string busbars.

Layup issues: PV Module Field Failure Due to String to String Distance

Kiwa PI Berlin's failure analysis team has investigated multiple field incidents over the past year where inadequate inter-cell distances were identified as a root cause.

Failure Finding:

- Fire due to short circuit formed by contact between two strings of opposite polarity.
- Visual inspection revealed many modules failed IEC/UL 61730 requirements.
 - Required creepage distance: 0.3 mm
 - Measured creepage distance: 0–0.2 mm

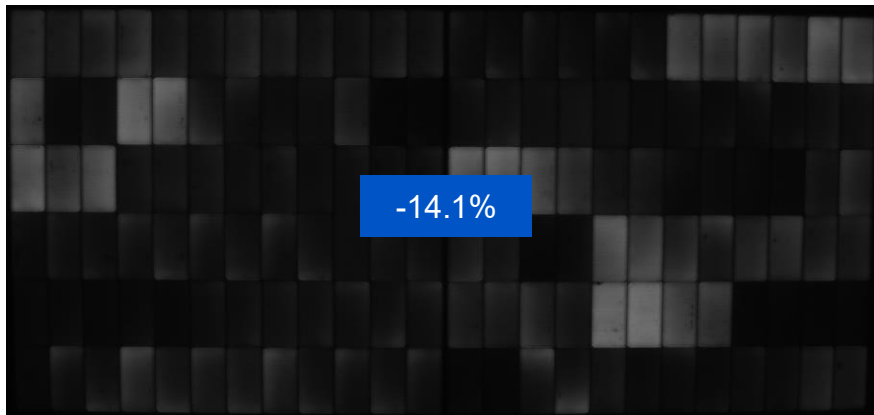


UVID – Getting Better But Not Solved

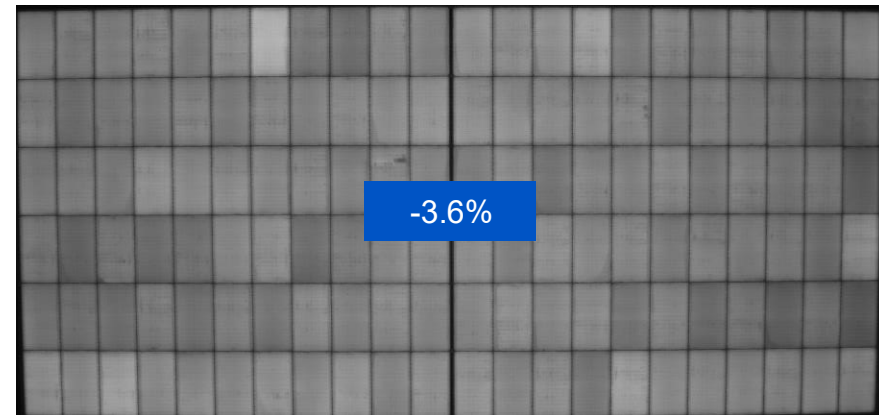
28/68 (38%) BOMs tested in UVID named 2026 Top Performers with <2% power loss.

Median UVID power loss for 2025 TOPCon BOMs was 3.0%, up from 4.3% for 2024 BOMs.

UVID is still not solved for many. Example of same module and cell manufacturer, different UVID results:



BOM-1 (M10 cells)



BOM-2 (G12R cells)

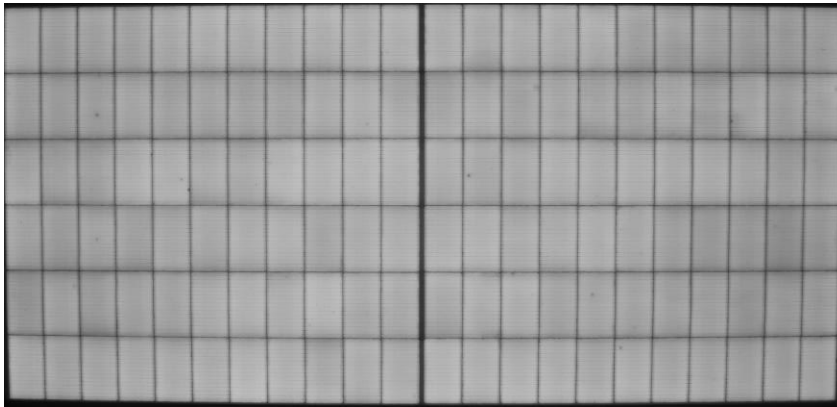
Kiwa PVEL presented much more on UVID during the 3AO.4.5 session on Monday: UV-Induced Degradation in TOPCon Modules: Linking Accelerated and Outdoor Testing

PID – Getting Better But Not Solved

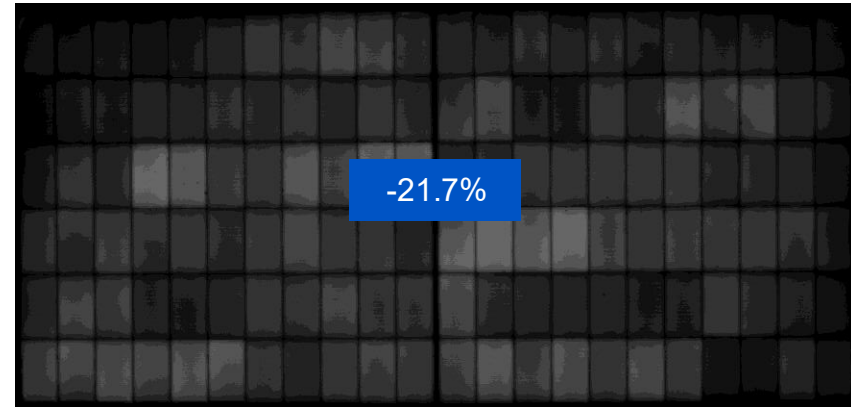
83% of 2025 BOMs had <2% PID(-) power loss.

But PID outliers still appear – 2000V modules/system will not help with this failure mode.

This was the worst case over the past year:



Initial: nothing to see here



Post-PID192(-): whaaa' happened??

The manufacturer submitted new PQP samples for a PID retest and achieved <2% following PID192(-). This demonstrates that strong quality control of cells is both possible and necessary to ensure suitable PID resistance.



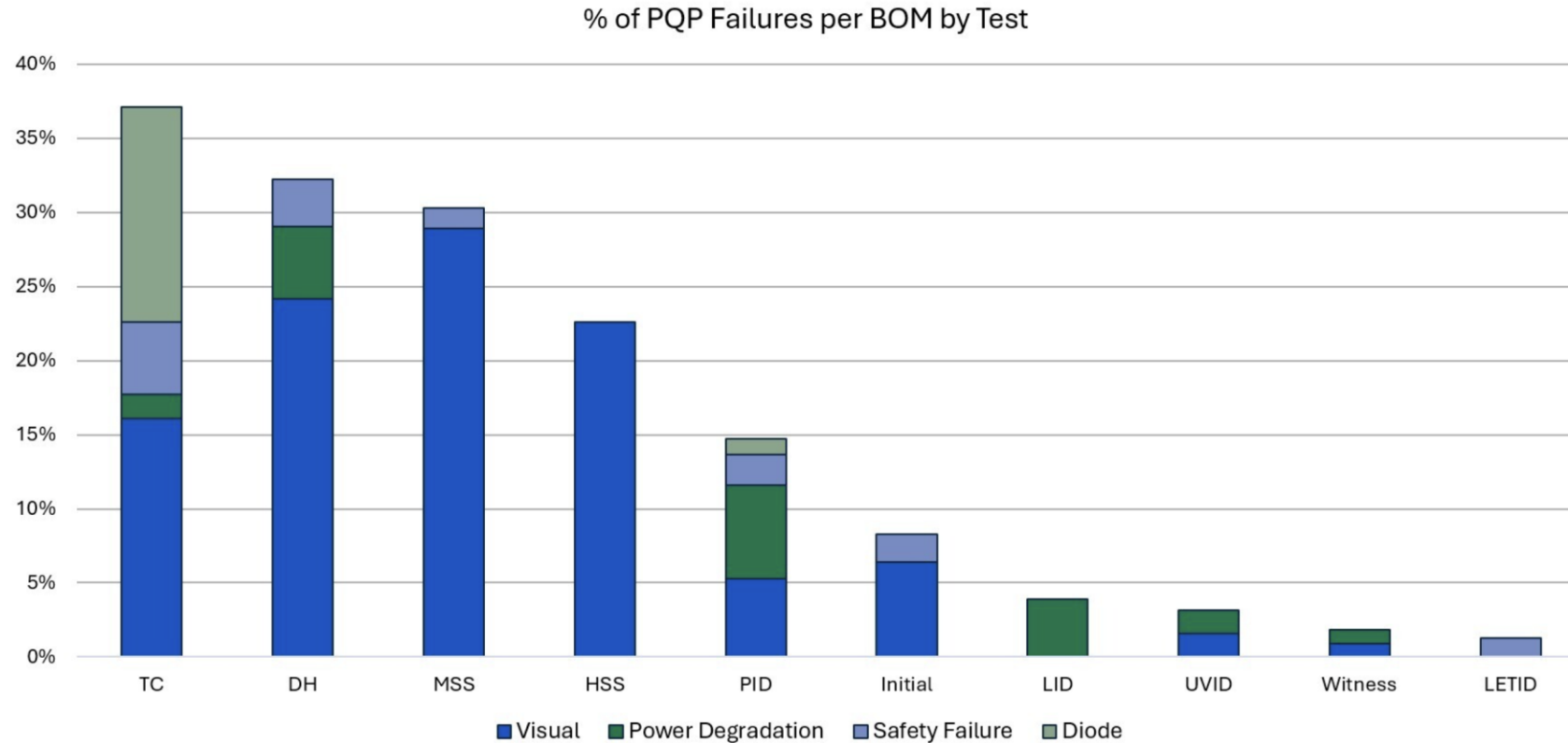
See more of the 2026 Scorecard including all Top Performers at
www.scorecard.pvel.com

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Failure breakdown by test



The percentage of PQP failures per BOM by test sequence. Initial failures are those that were detected during characterizations prior to stress-testing. Witness failures occurred when the manufacturer decided not to ship the modules following the PQP sample production factory witness due to a quality issue.