



Exploring the Rise of PV Module Failures and Their Potential Causes

Insights from the 2026 PV Module Scorecard

Kiwa PVEL

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Kiwa PVEL is the Independent Lab of the Downstream Solar Market

12+

Years of
experience

700+

Bills of materials
tested in the lab

400+

Downstream
partners

Our mission is to support the worldwide solar and energy storage buyer community by generating data that accelerates adoption of solar technology.

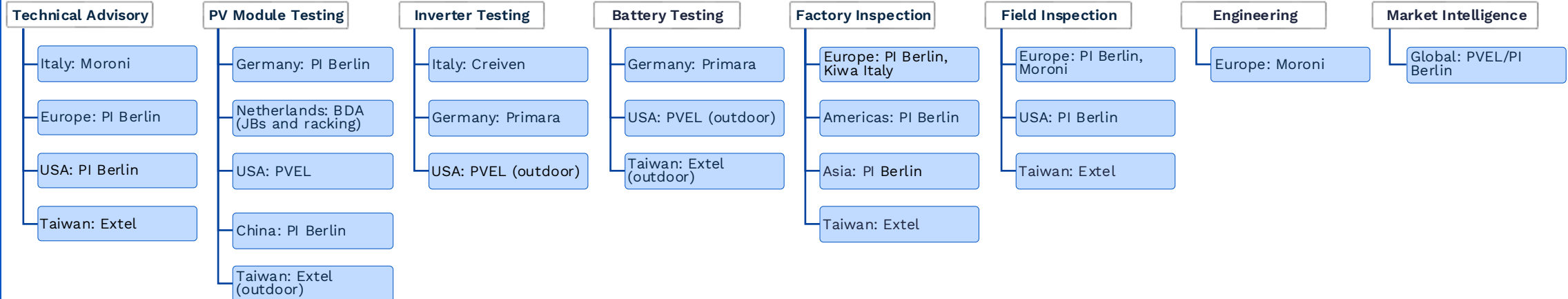
Services at a glance:

- Extended reliability and performance testing for PV modules
- Batch testing of PV modules
- Outdoor testing of PV modules, inverters and energy storage
- Data services for PV buyers and investors

See more details at kiwa.com/pvel

Kiwa Overview

- Kiwa is a global testing, inspection and certification (TIC) company, founded in 1948.
- Headquartered in Rijswijk, the Netherlands with more than 10,000 employees, working in over 37 countries. Kiwa is primarily active in renewable energy, construction, manufacturing, fire safety, medical devices, food & water.
- Kiwa's mission is to create trust by contributing to the transparency of the quality, safety and sustainability of products, services and organizations as well as of personal and environmental performance.
- Kiwa's solar businesses at a glance:



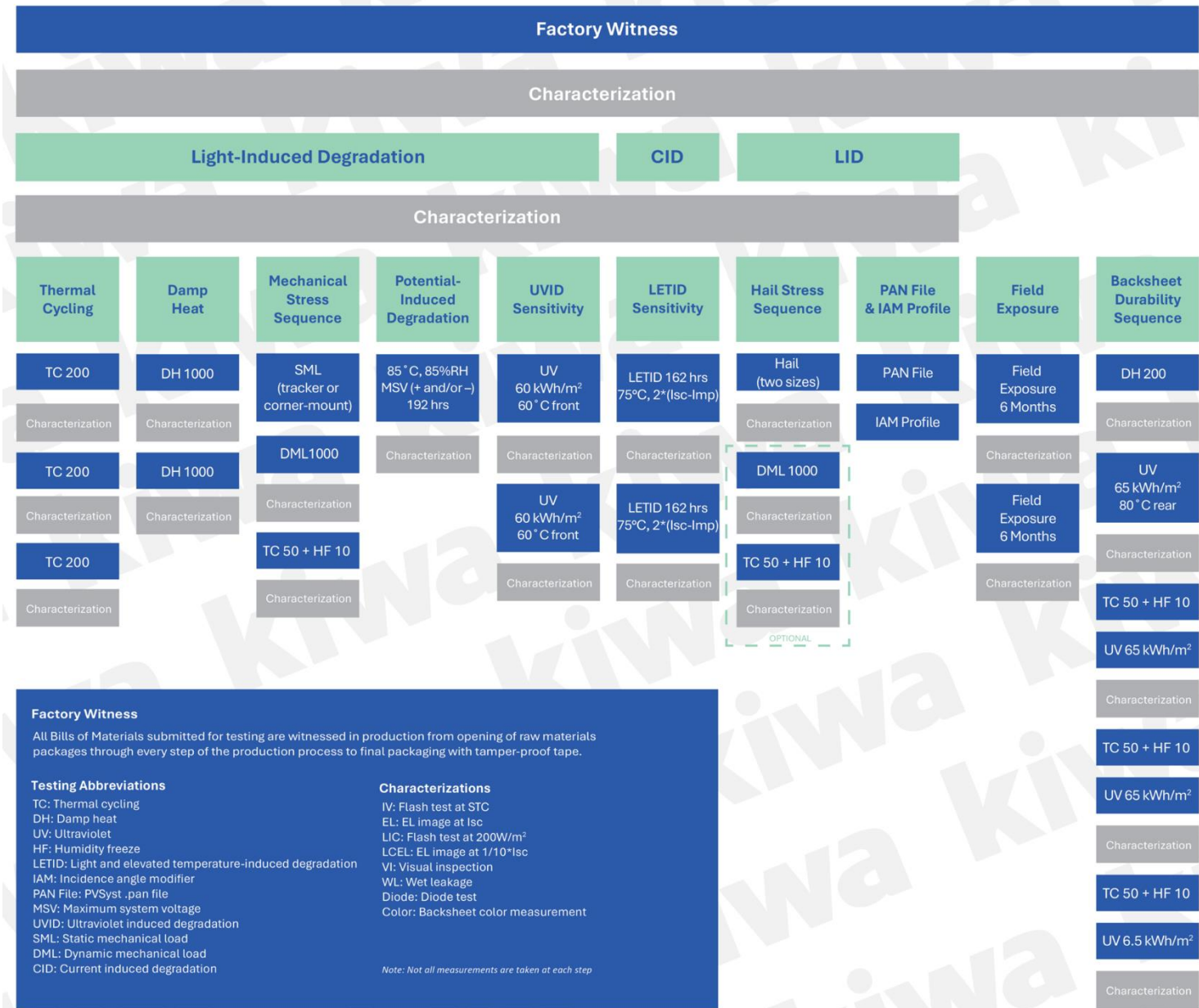
See more details at kiwa.com/solar

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/pqp12.



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.
- Top Performer criteria:
 - 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.



2026 PV Module Scorecard

Main Findings and Selected Test Results

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Key highlights from the 2026 PV Module Scorecard

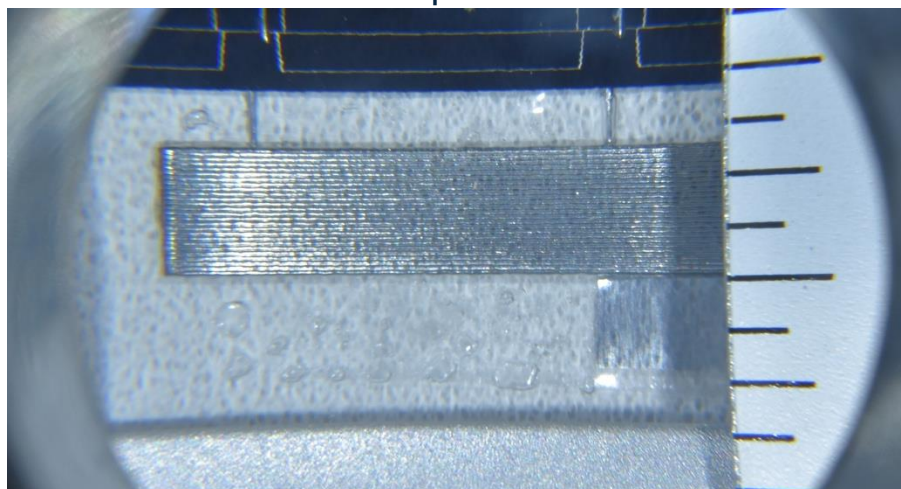
- **43 manufacturers are named Top Performers**, including 13 first time Top Performers.
- **UVID is a new Top Performer test category.**
- **No ‘all-stars’:** No single model/BOM excelled across all tests – a first for the Scorecard.
- **Power loss is decreasing for some tests, but failure risk is rising:** 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.**
- **Higher powered modules result in higher energy:** Energy yields continue to improve due to better temperature coefficients and bifacialities.

Failure examples

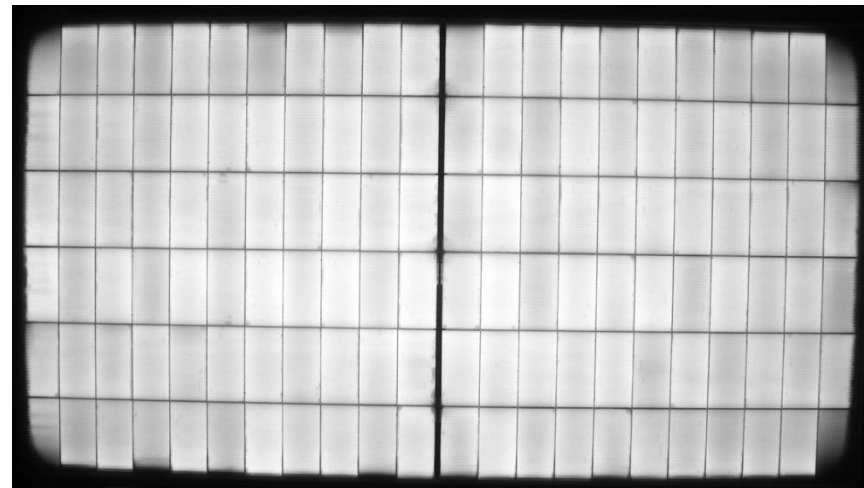
Safety – exposed metal at pre-stress



Visual – bubbles at pre-stress



Power loss – 13.5% power loss after DH2000



Diode – failed diode after TC200



DH - Key Highlights from 2026 Scorecard

- 69% of BOMs had <2% degradation after DH200.
- 32% of BOMs had a DH failure.
- Delamination (23% of DH BOMs) was #1 DH failure, driven more by materials and lamination process than encapsulant thickness.

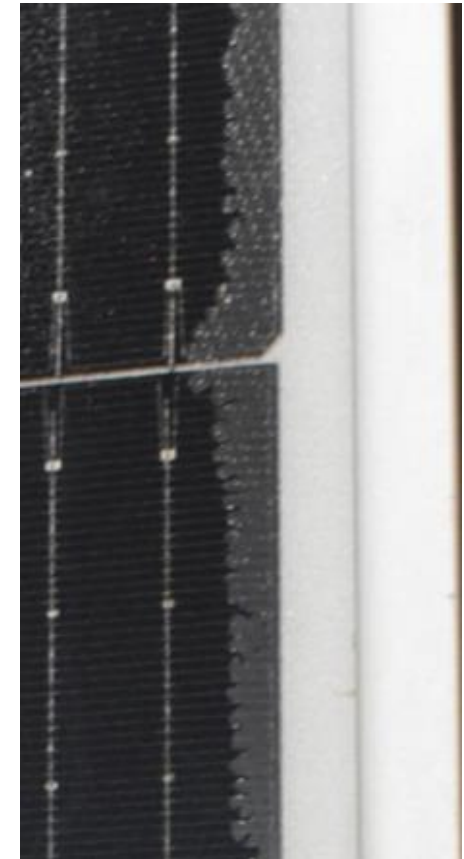
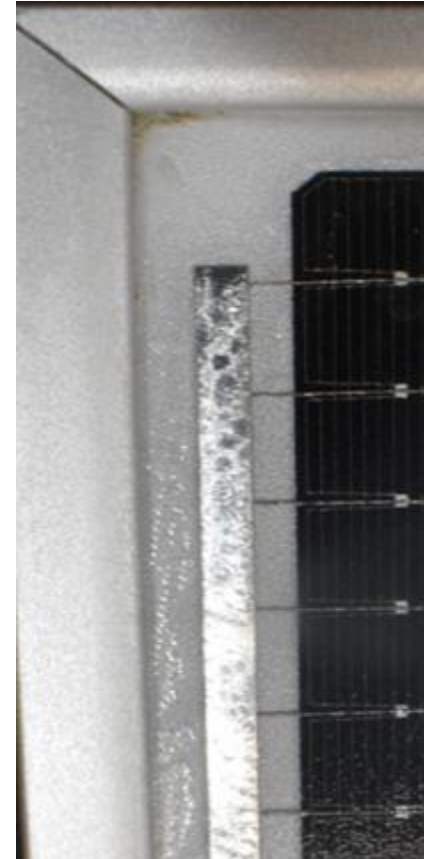
DH test result spotlight

Delamination was one of the top PQP failures over the past year, with multiple glass//glass BOMs from a wide range of module manufacturers exhibiting delamination and/or bubbles at the module perimeter.

This is considered a major defect when those bubbles/delamination reduce electrical creepage distances to less than the minimum specified in IEC 61730.

This example was one of those cases, where two BOMs from the same module manufacturer suffered significant delamination despite the use of two different encapsulant types.

This issue is further discussed in [Kiwa PI Berlin's 2026 PV Module Manufacturing Quality Report](#).



Two BOMs from the same module manufacturer exhibited major delamination defects following DH2000. In both cases, the bubbles/delamination reduced the electrical creepage distance to 0 mm, significantly below the IEC 61730 minimum of 10.4mm for 1500 V modules.

MSS - Key Highlights from 2026 Scorecard

- Power loss is negligible with all unbroken MSS BOMs having <2% power loss.
- 30% of BOMs failed, mostly due to module breakage (26% of BOMs had at least one broken module).
- Pinched glass was a key failure mode, and thinner frames (<35mm) increased breakage rates.

MSS test result spotlight

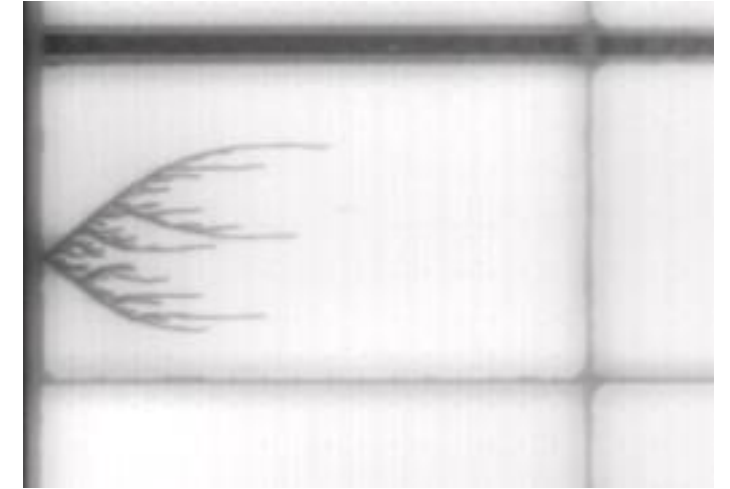
Studies have shown that edge pinch is one of the key root causes leading to glass breakage.

This was evident for one recent BOM where one module's front glass was broken during the static mechanical load (SML) portion of MSS.

Analysis of the broken module showed evidence of a pinch point between the frame and glass located close to the center of the long frame.

The second module of the same BOM did not experience glass breakage, but its EL image showed a cracked cell at a similar location.

These results confirmed the existence of very localized stress exerted on the glass and cells.



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 (this is an exceedingly rare occurrence of a cell crack being created in a glass//glass module).

HSS - Key Highlights from 2026 Scorecard

- Power loss is negligible with all unbroken HSS BOMs having <2% power loss.
- 2.0 mm//2.0 mm modules had a 61% breakage rate with 45 mm hail.
- Thicker glass modules had a 7% breakage rate with 45 mm hail.
- 23% of BOMs had an HSS failure. HSS failures are recorded if modules break when tested at both hail sizes, or when a manufacturer requests a hail retest.

HSS test result spotlight

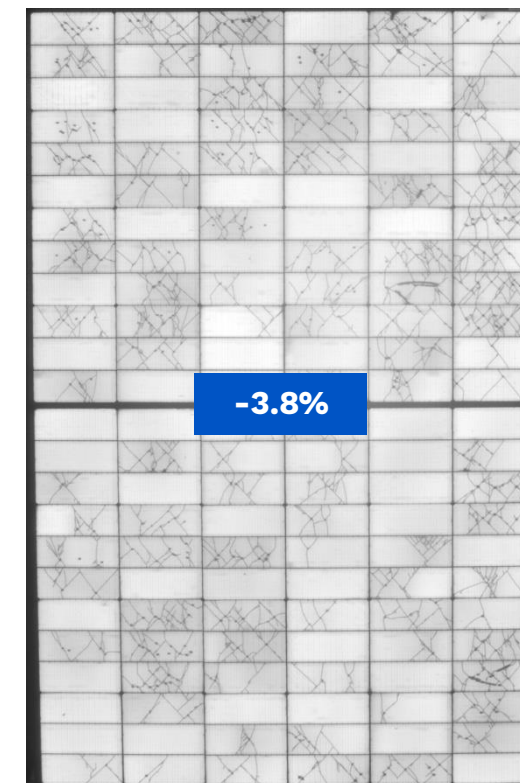
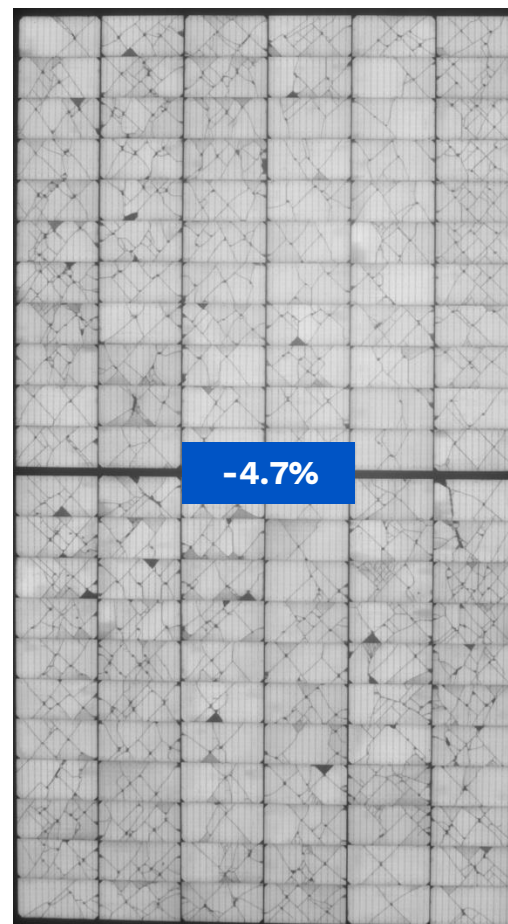
Modern modules are highly resistant to power loss caused by hail-induced cell cracks for two reasons.

First, most modules are of glass//glass construction, which makes cell cracks extremely unlikely to occur, except in very specific loading scenarios.

Second, for modules where cell cracks have occurred, there are enough busbars covering the cell that a crack is unlikely to completely disconnect an area.

This means that even modules with extreme numbers of cell cracks only lose up to 5% power, as shown here with two BOMs from Kiwa PVEL's recent cell cracking study.

Hail testing is therefore much more meaningful when focused on glass breakage, rather than cell cracking.



Two example BOMs with extreme levels of Kiwa PVEL-induced cell cracks from a cell cracking power loss study. Both BOMs had relatively minimal power loss after 1.5 years in the field.



2026 PV Module Scorecard

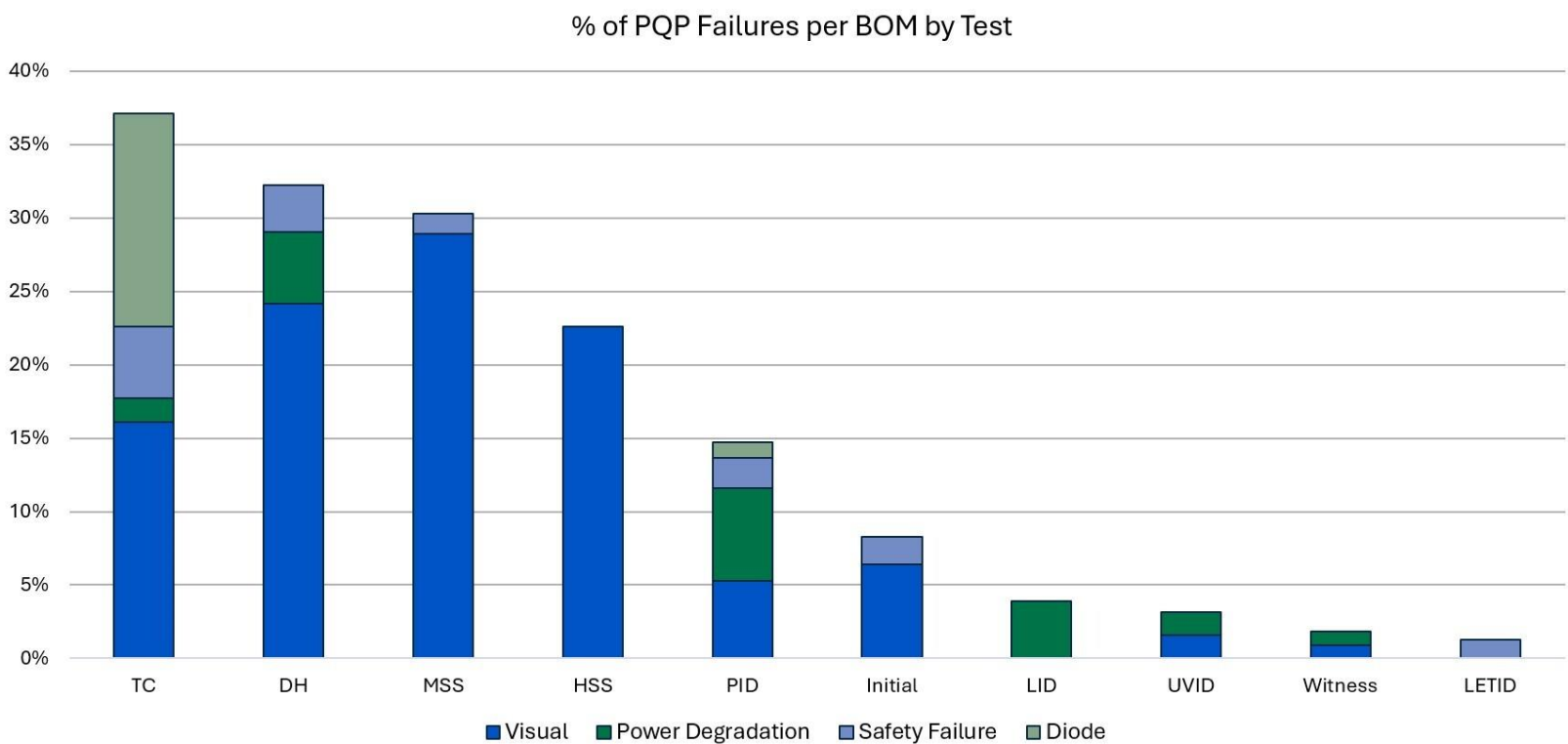
Failure Trends

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PQP failure statistics

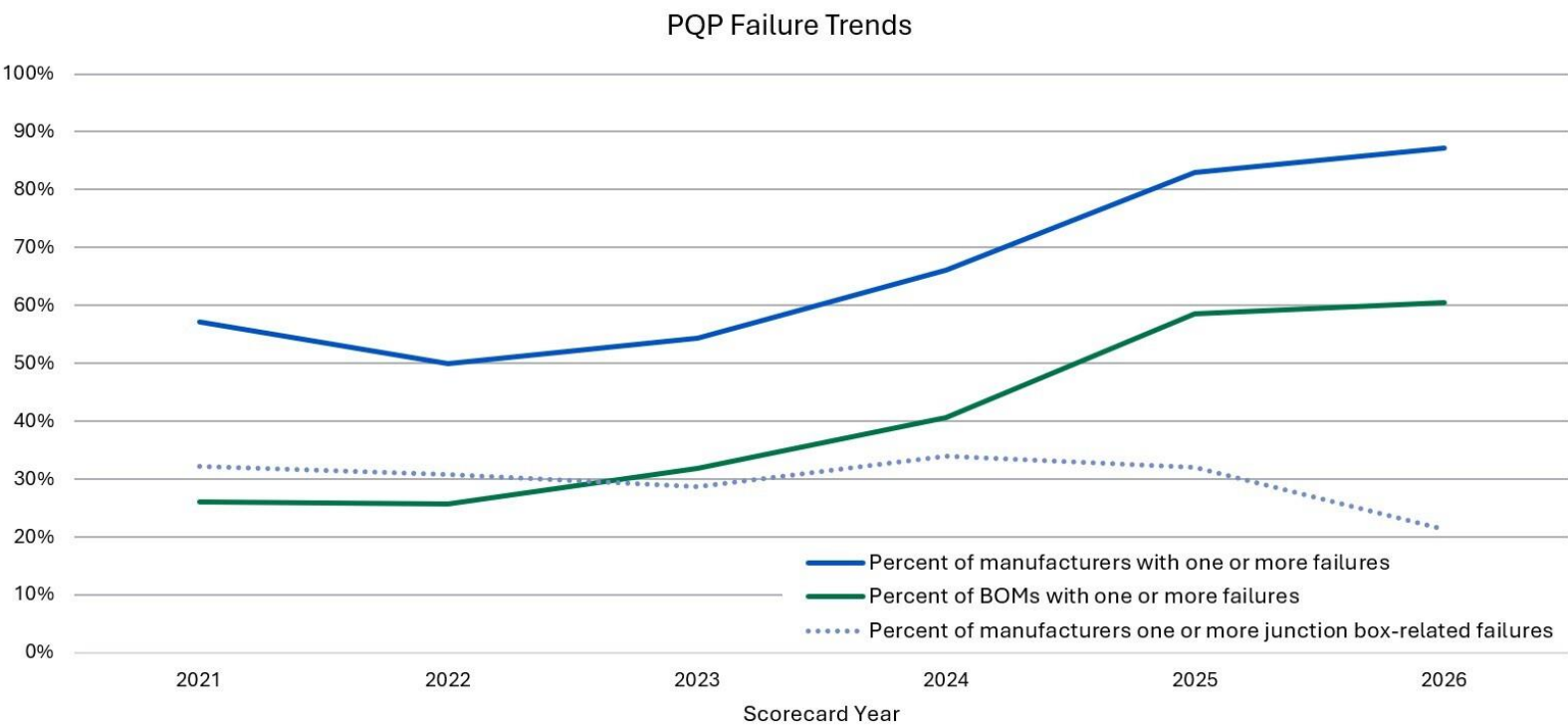


The bar chart displays the percentage of BOMs experiencing at least one failure in each applicable test sequence of the PQP by failure type.

New for 2026, the per-test failure rate has been calculated based on the number of BOMs that underwent that specific test, rather than based on the total number of 2026 Scorecard BOMs. This has caused the per-test failure rates to increase from previously calculated statistics, but it is a more accurate representation of how many BOMs experienced a failure for each test.

The most common type of failure is a visual inspection major defect, which accounts for 73% of all failures. Of the visual inspection failures, 50% are due to module breakage and 46% are due to delamination.

PQP failure statistics



The history of reported failures across the past six Scorecards has been included in the line graph below.

While the rate of increase has diminished, the percentage of manufacturers and BOMs experiencing at least one failure has hit a historic high.

The peak in failure rates is despite the reduction in junction box related failures over the past year; however, junction box related failures remain some of the most impactful as seen in the diode failure example above.



Kiwa PVEL's Premium Partner Program

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Module purchasing companies can subscribe to the Premium Partner Program to receive a quarterly Dashboard of Kiwa PVEL's Product Qualification Program (PQP) test results. This allows for easy Approved Vendor List (AVL) management and identification of potential new suppliers.

PQP results from over 45 module manufacturers are included in the Dashboard, with at least 35 manufacturers sharing their non-anonymized results. Over 300 BOMs are included, with almost 200 BOMs non-anonymized.

Manufacturer	Module Model & Datasheet	PVEL Project #	BOM #	Factory Location	Wafer Edge Length (mm)	PQP Pass / Fail	Wet Leakage Result	Visual Inspection Result	TC 600	DH 2000/Post-BO	MSS	P.I.D. 192 (Negative Bias)	P.I.D. 192 (Positive Bias)	LID (>60 kWh/m2)	LETID (post 486h)
Manufacturer B	BBB-BB-BBB	2222	2	China	182	Pass	Pass	Pass	-2.15%	Test not required	Test not required	Test not required	Test not required	Test not required	-3.48%
Manufacturer B	BBB-BB-BBB	2222	3	China	182	Test not required	Pass	Pass	Test not required	Test not required	Test not required	Test not required	Test not required	Test not required	-3.57%
Manufacturer C	CCC-CC-CCC	3333	1	China	166	Pending	Pass	Pass	Pending	-0.09%	Test not required	-0.20%	Test not required	NOD	-3.53%
Manufacturer C	CCC-CC-CCC	3333	1	China	182	Pending	Pass	Pass	Pending	Pending	Test not required	Pending	Test not required	Pending	-3.35%
Manufacturer D	DDD-DD-DDD	4444	1	China	158.75	Pending	Pass	Pass	Pending	Pending	-2.97%	Pending	-1.04%	-0.27%	-0.50%
Manufacturer D	DDD-DD-DDD	4444	2	China	166	Pass	Pass	Pass	-1.11%	-0.28%	Test not required	-0.58%	Test not required	NOD	-0.57%
Manufacturer D	DDD-DD-DDD	4444	3	China	158.75	Pass	Pass	Pass	NOD	NOD	-0.50%	-0.08%	Test not required	-1.02%	-1.34%
Manufacturer D	DDD-DD-DDD	4444	1	China	182	Pending	Pass	Pass	Pending	-1.19%	Test not required	-1.95%	-1.29%	-0.24%	-1.23%
Manufacturer E	EEE-EE-EEE	5555	1	China	158.75	Pass	Pass	Pass	-2.16%	-0.28%	Test not required	-0.12%	Test not required	-0.85%	-1.01%
Manufacturer F	FFF-FF-FFF	6666	1	Turkey	158.75	Pass	Pass	Pass	-3.76%	-0.75%	-1.47%	-4.03%	Test not required	-0.11%	-1.65%
Manufacturer F	FFF-FF-FFF	6666	1	Turkey	182	Pending	Pass	Pass	Pending	Test not required	Test not required	Test not required	-0.99%	Test not required	-1.02%
Manufacturer F	FFF-FF-FFF	6666	2	Turkey	182	Pending	Pass	Pass	Test not required	-1.43%	Test not required	-2.27%	-0.85%	NOD	-1.13%
Manufacturer G	GGG-GG-GGG	7777	1	China	158.75	Pass	Pass	Pass	Test not required	Test not required	Test not required	-1.84%	Pending	-0.32%	-0.94%
Manufacturer G	GGG-GG-GGG	7777	2	China	158.75	Pass	Pass	Pass	Test not required	Test not required	Test not required	-1.17%	Test not required	Test not required	-1.60%
Manufacturer G	GGG-GG-GGG	7777	1	China	158.75	Fail	Pass	Fail PID-192	-1.72%	-2.07%	Test not required	-3.86%	Test not required	NOD	-2.09%

A selection of the current Premium Partner Program subscribers:





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

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