



# Should we be positive about n-type? A 2024 PV Module Reliability Scorecard Preview

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# Kiwa PVEL is the Independent Lab of the Downstream Solar Market

**10+**

Years of  
experience

**600+**

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.**

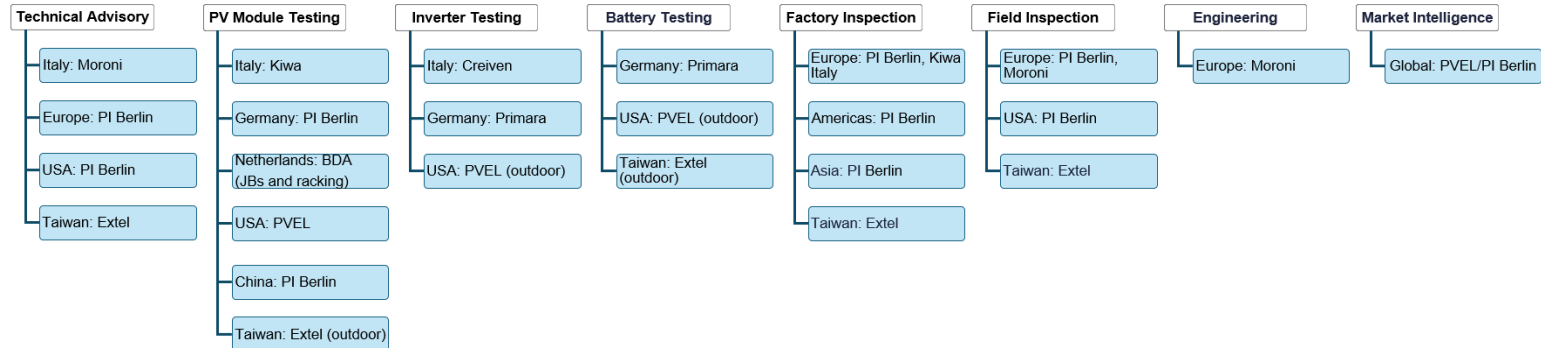
## Services at a glance

- Extended reliability and performance testing for PV modules
- Batch testing of PV modules
- Outdoor testing at PVUSA, an iconic grid-connected research site
- Data services for PV buyers and investors

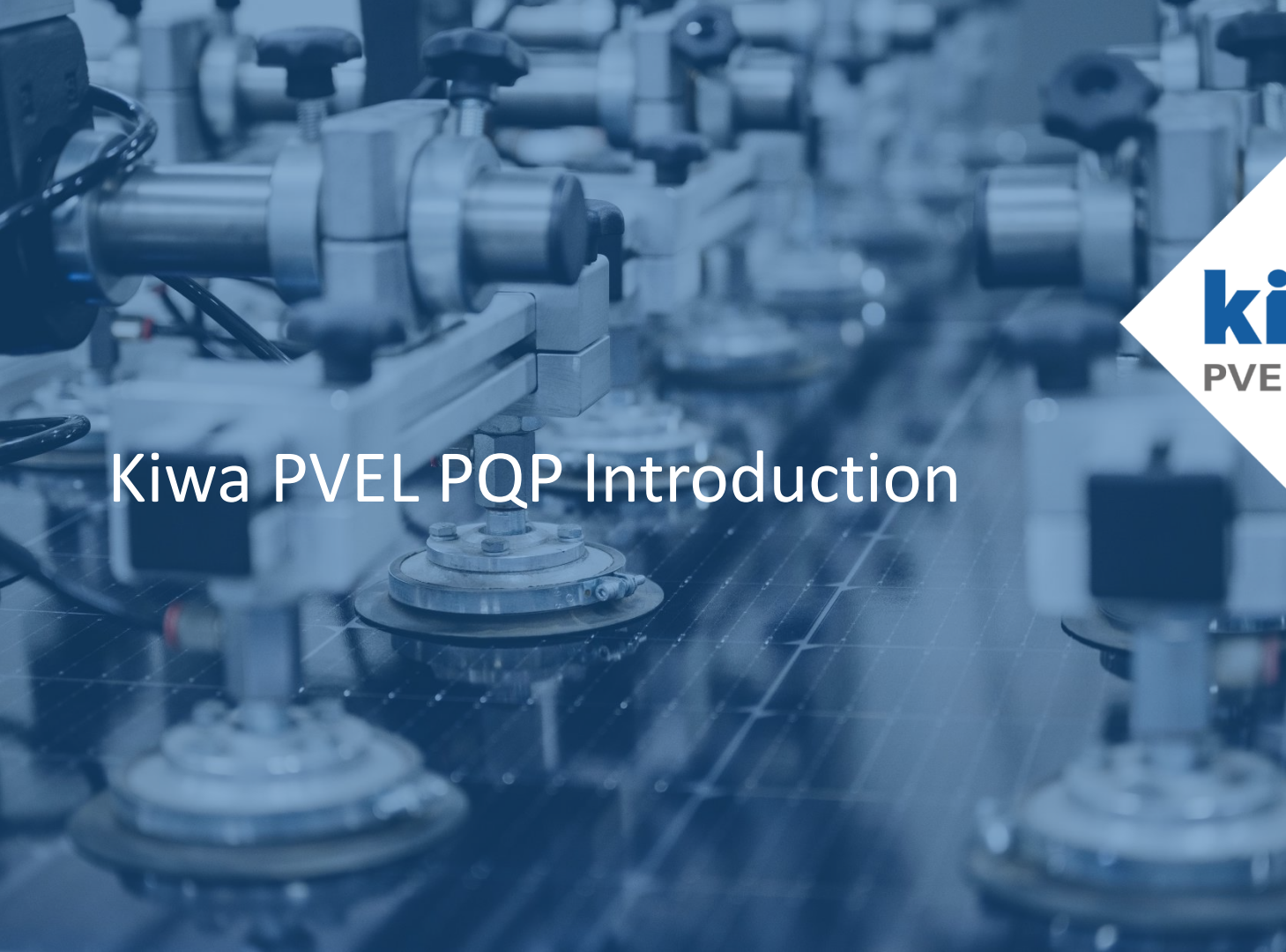
See more details at [kiwa.com/pvel](https://kiwa.com/pvel)

# 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 solar businesses at a glance:



- 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 PVEL PQQ Introduction

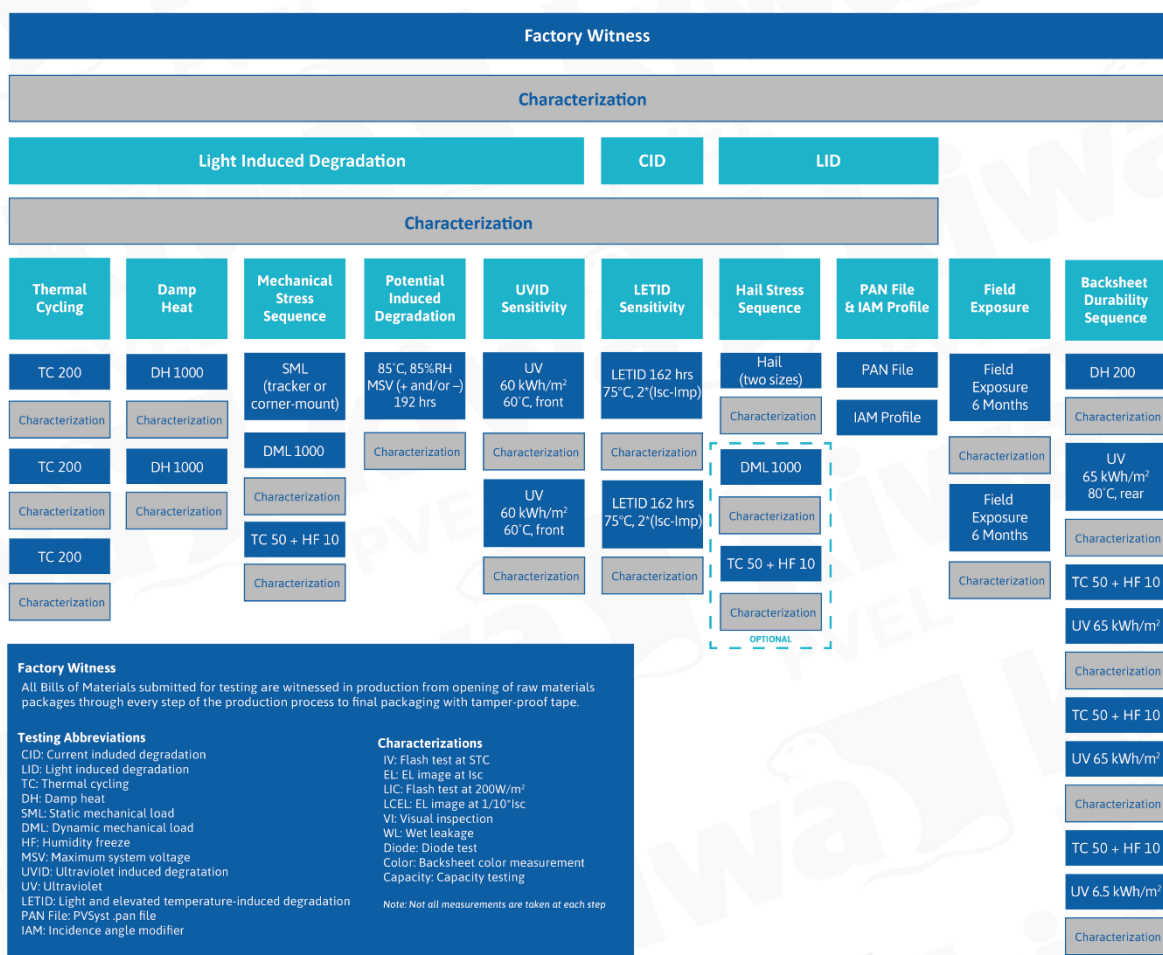


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# Kiwa PVEL PQP Test Sequence

These test streams evolve based on feedback from Kiwa PVEL's downstream partners, module manufacturers, and the industry's collective understanding of module failure modes and test mechanisms.

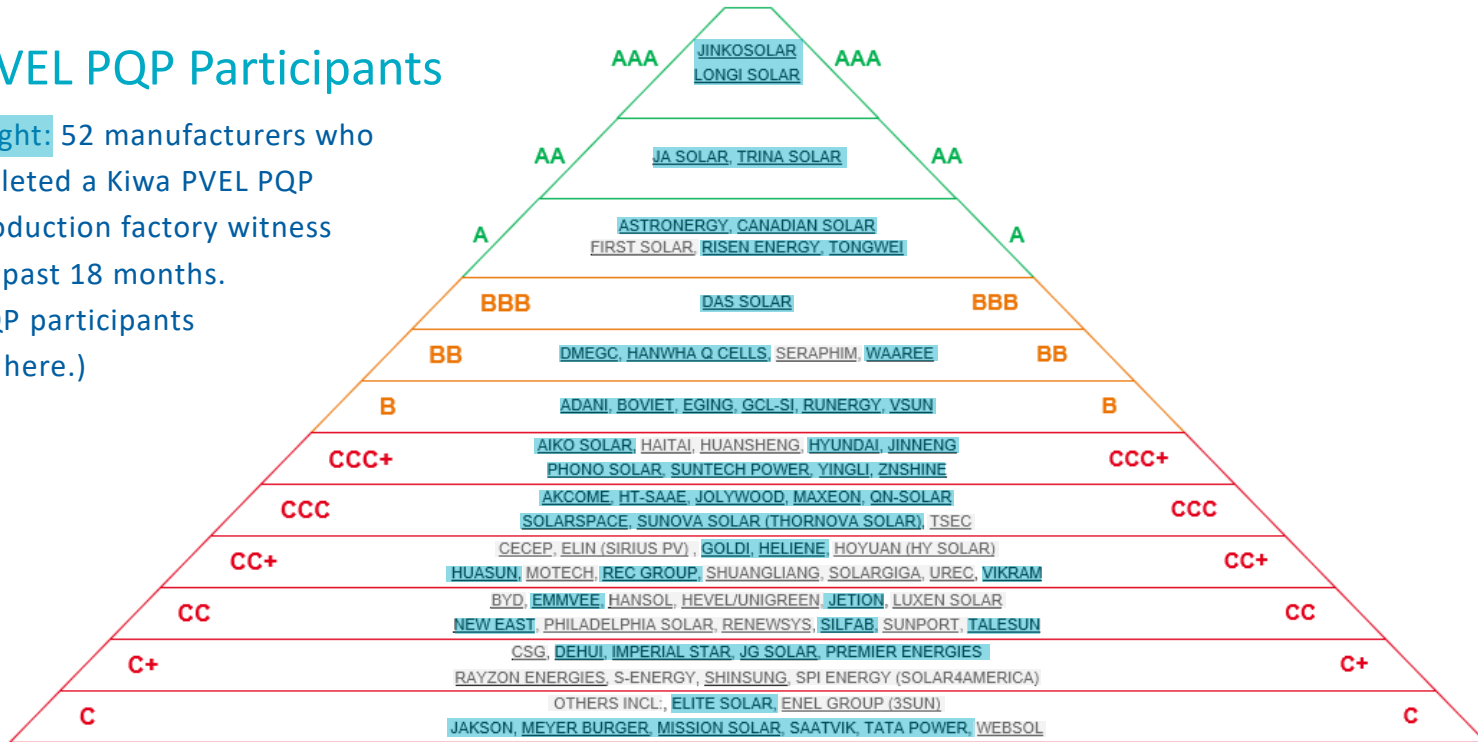
Learn more at [kiwa.com/pvel/pqp](https://kiwa.com/pvel/pqp)



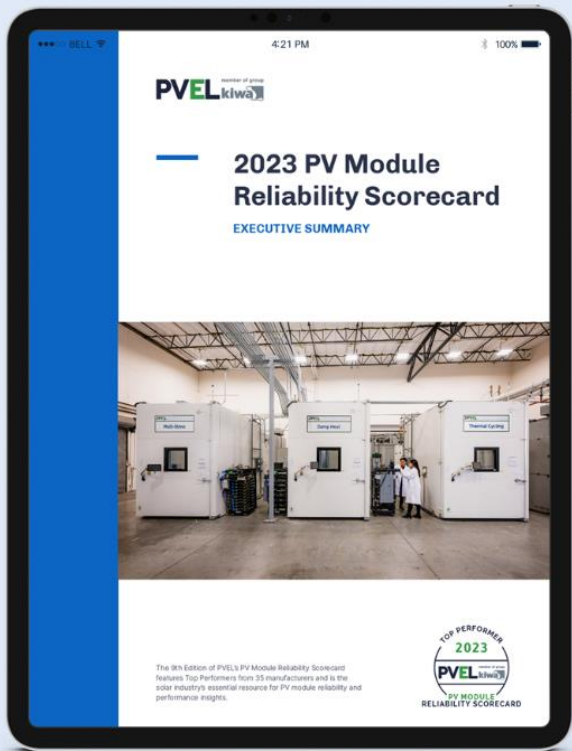
# Bankability Pyramid

## Kiwa PVEL PQP Participants

Blue highlight: 52 manufacturers who have completed a Kiwa PVEL PQP sample production factory witness within the past 18 months. (Not all PQP participants are shown here.)



Provisional End Q2'24 Ratings: subject to changes post company reporting & PV-Tech in-house data refreshes.



The annual PV Module Reliability Scorecards lists top performing manufacturers and insights from Kiwa PVEL's PQP. To date, the 2023 Scorecard has been accessed by more than **50,000 unique visitors** from over 160 countries.



- The 2024 PV Module Reliability Scorecard will be released on June 5, 2024.
- New for the 10th Edition:
  - New Top Performer category for hail: modules that didn't experience glass breakage (or major visual defects/wet leakage failures) with  $\geq 40$  mm hail.
  - Higher bar for LID+LETID Top Performers.
  - Better recognition of manufacturers who are Top Performers in multiple categories.
  - Key takeaways on cell technology impacts and glass//glass vs. glass//backsheets.
  - Deep dive into Kiwa PVEL's industry leading IAM test.

Find it June 5th at [www.scorecard.pvel.com](http://www.scorecard.pvel.com)



2024 Scorecard Preview  
Mostly Focused on n-type



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# Thermal Cycling Results

Thermal Cycling

TC200

Characterization

TC200

Characterization

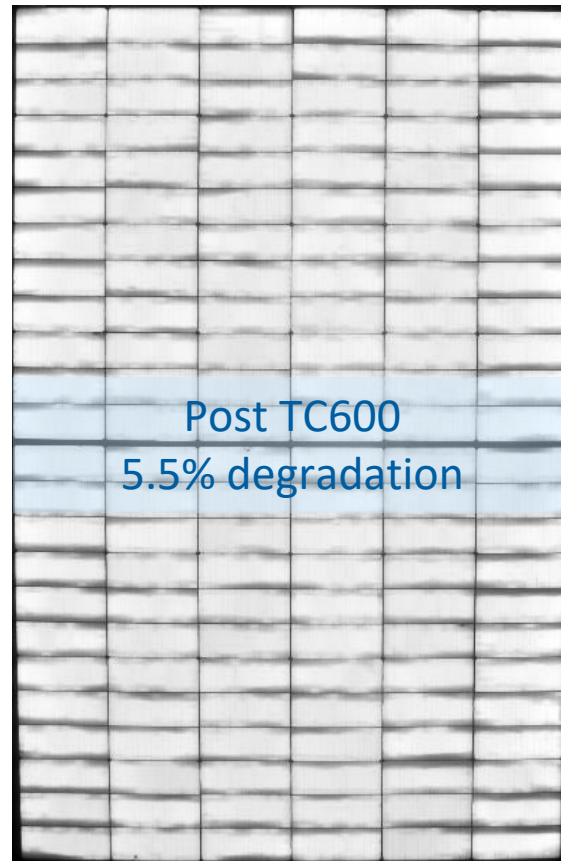
TC200

Characterization



## Key Takeaways

- 84% of BOMs tested degraded by  $< 2\%$ .
- The median degradation rate for PERC and TOPCon was 0.6 and 0.7%, respectively.
- But five TOPCon BOMs recorded a power degradation failure versus just one PERC BOM.
- Higher degradation for glass//backsheet modules.
- HJT BOMs produced in 2023 showed stronger TC results than those from previous years.
- 11 manufacturers experienced at least one TC failure, including some major junction box issues such as shorted bypass diodes, exposed wires and melted connectors.



# Damp Heat Results

Damp Heat

DH1000

Characterization

DH1000

Characterization



## Key Takeaways

- Only 69% of BOMs tested degraded by < 2%.
- The median degradation rate for PERC and TOPCon was 1.4 and 1.6%, respectively.
- HJT degradation ranged from < 1% to > 6%.
- 85% of glass//glass BOMs and only 46% of glass//backsheet BOMs had degradation less than 2%.
- 11% of BOMs experienced one or more DH failures due to delamination, junction box lids falling off, electrical insulation faults and power loss.



# Mechanical Stress Sequence Results

Mechanical  
Stress Sequence

SML  
(tracker or corner mount)

DML1000

Characterization

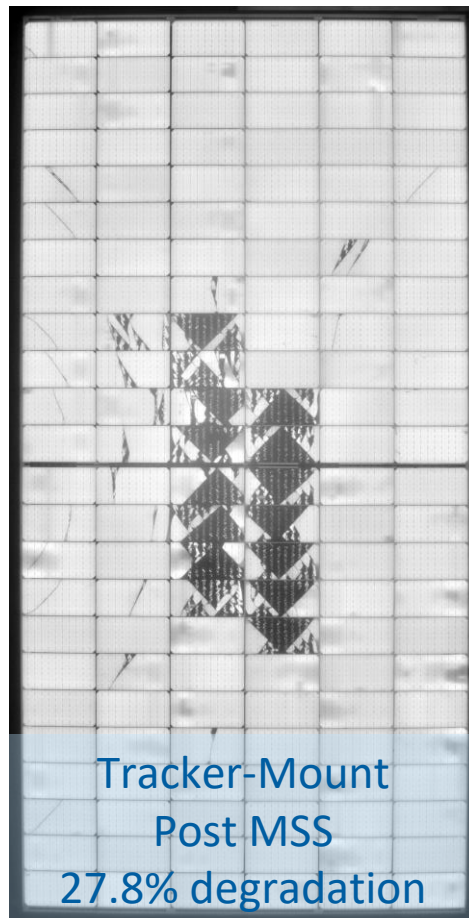
TC50 + HF10

Characterization

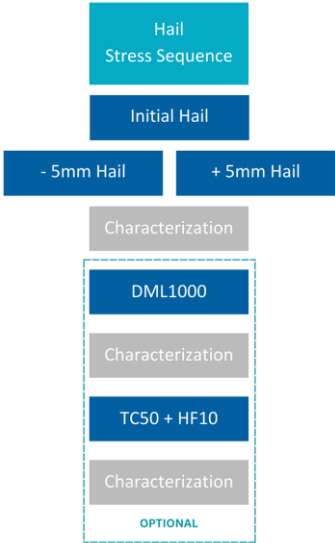


## Key Takeaways

- 95% of BOMs completing MSS had < 2% power loss.
- No cell cracks seen in glass//glass modules, but glass breakage is a risk with lots of field reports.
- Extreme deflection on some tracker mounted glass//backsheet modules is ugly.
- Negligible cell technology impacts.
- Nine manufacturers experienced at least one failure during MSS testing, including glass breakage, frame breakage or delamination.
- The SML+DML combination is key.

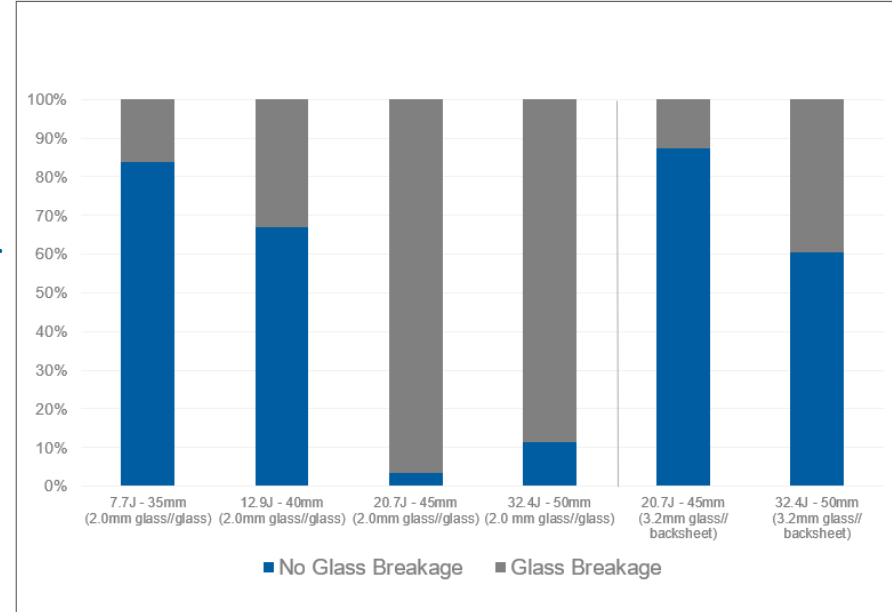


# Hail Stress Sequence Results



## Key Takeaways

- 50 mm hail glass breakage rates:
  - 89% of 2.0 mm glass//glass
  - 40% for 3.2 mm glass//backsheet
- No hail-related power degradation > 3%.
- Negligible cell technology impacts.
- New hail hardened module designs are apparently coming.
- Junction box lids falling off from hail impacts is a nuisance.



# Potential Induced Degradation Results

Potential  
Induced Degradation

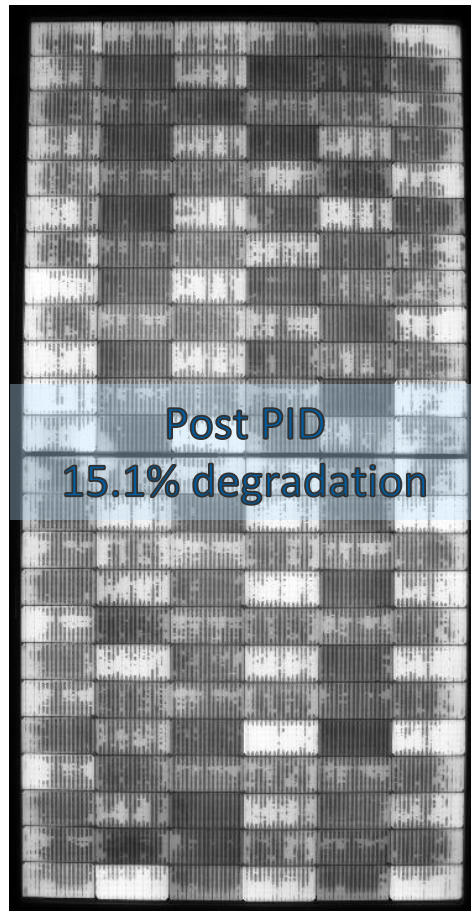
85°C, 85% RH  
MSV (+ and -)  
192 hours

Characterization



## Key Takeaways

- Only 58% of BOMs tested degraded by < 2%.
- The median degradation for glass//glass, glass//backsheet, PERC and TOPCon all ranged from 1.6 to 2.0%.
- Encapsulant choice matters: same cells, three encapsulant suppliers, three results: 1.1%, 2.6% and 3.3%
- 11 manufacturers experienced at least one “failure”, many due to PID-polarity which is often reversible with UV exposure. Field relevance still needs research.



# LID and LETID Results

LID

Light Soaking  
≥ 40 kWh/m<sup>2</sup>

Characterization

LETID  
Sensitivity

LETID 162 hrs  
75°C, 2\* (Iscp- Imp)

Characterization

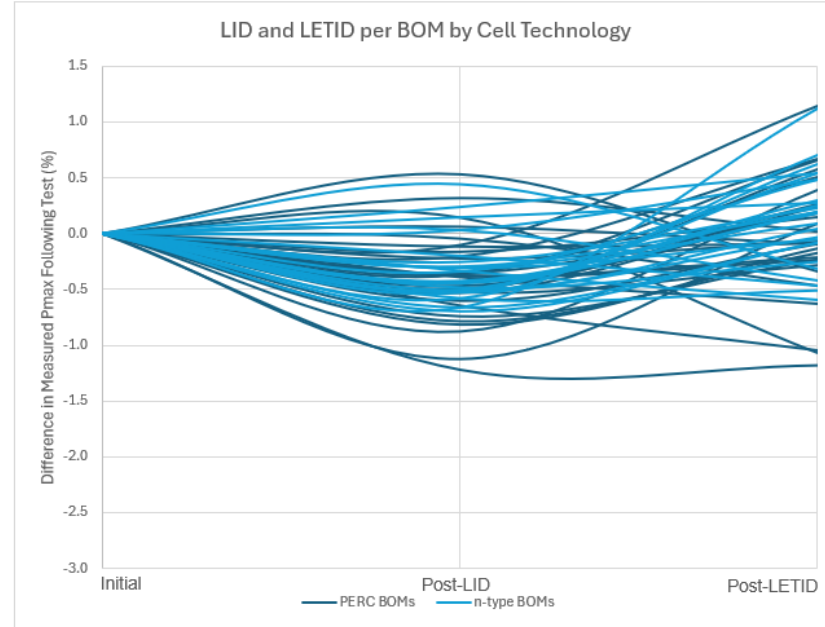
LETID 162 hrs  
75°C, 2\* (Iscp- Imp)

Characterization



## Key Takeaways

- 96% of BOMs tested had an average LID + LETID power loss < 1%.
- The median post-LID power loss was 0.38% for PERC and 0.43% for n-type.
- Post-LETID, PERC had a 0.1% median power loss and n-type had a 0.2% median power gain.
- Power gain is likely from cell treatment processes.
- 26% of manufacturers experienced at least one “pre-stress” failure, including missing junction box lids, peeling nameplate labels, wet leakage issues, delamination and diode failures.





# UVID Results

UVID  
Sensitivity

UV 60 kWh/m<sup>2</sup>  
60°C front

Characterization

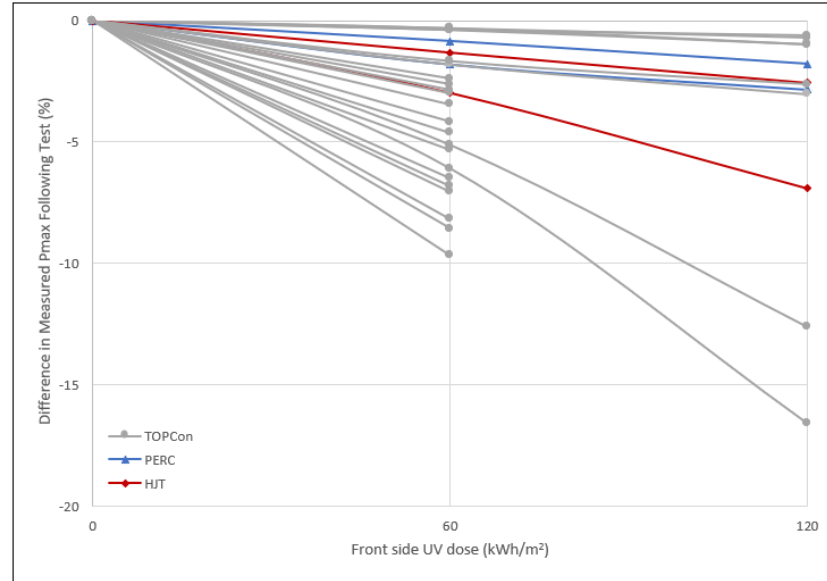
UV 60 kWh/m<sup>2</sup>  
60°C front

Characterization



## Initial Key Takeaways

- Power loss following 120 kWh/m<sup>2</sup> of UVID ranged from 0.6% to 16.6%.
- UVID-stable TOPCon BOMs are possible, but some manufacturers have work to do.
- Initial results show HJT susceptibilities, and higher degradation for PERC than expected.
- The degradation mechanisms behind UVID are not fully understood. Research is ongoing.



# PAN Results

PAN Files &  
IAM Profile

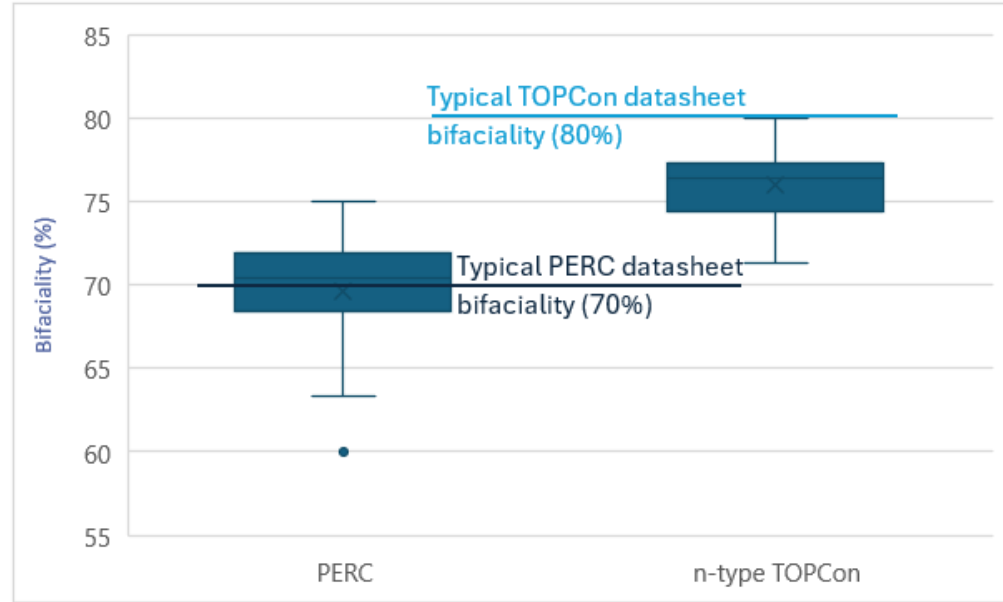
Pan File

IAM Profile



## Key Takeaways

- The Top Performer energy yield threshold increased by 0.95% compared to the 2023 Scorecard
- Average temperature coefficients:
  - -0.26 %/°C for HJT
  - -0.30%/°C for TOPCon
  - -0.32%/°C for PERC
- Average bifacialities:
  - 86.7% for HJT
  - 75.4% for TOPCon
  - 69.3% for PERC
- Low light performance is a mixed bag:
  - -4.3% for TOPCon
  - -3.6% for PERC



# IAM Results

PAN Files &  
IAM Profile

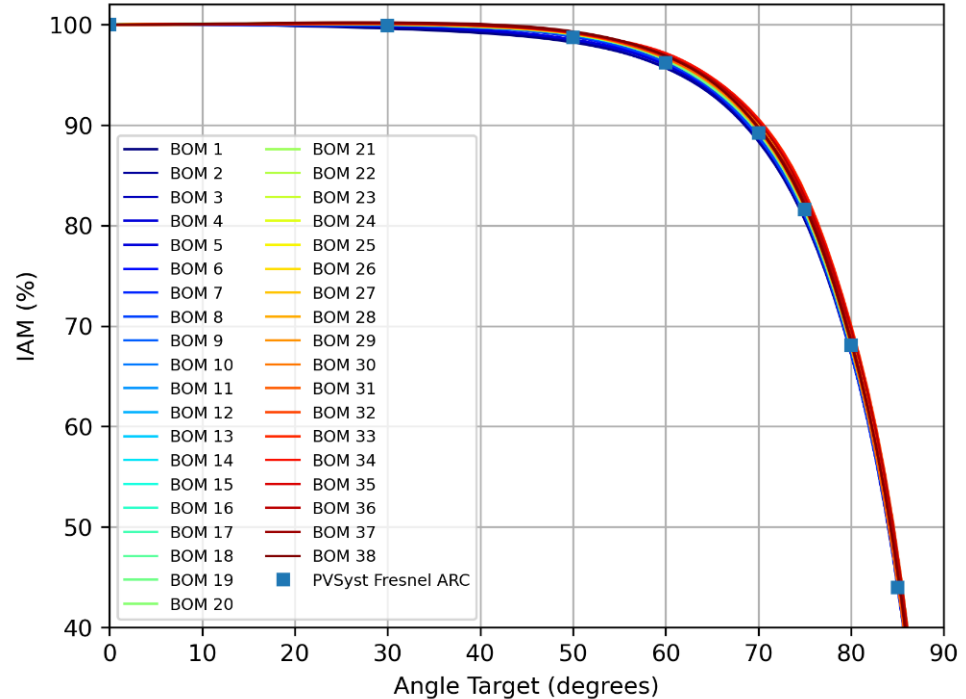
Pan File

IAM Profile



## Key Takeaways

- World class measurement accuracy shows minimal variation in IAM performance.
- The typical module outperforms the PVsyst Fresnel ARC default by a median of 0.17%.
- The highest performing BOM had a modelled energy yield 0.52% higher than the lowest performing BOM.
- Kiwa PVEL's measured data doesn't align with aggressive IAM assumptions.



# Premium Partner Program



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# Kiwa PVEL's Premium Partner Program – Dashboard

*Achieve data-driven vendor management and identify PV modules that meet your reliability needs.*

- Subscribers receive a quarterly Dashboard of Kiwa PVEL's **Product Qualification Program (PQP)** test results over a rolling period of 36-months. This allows for easy Approved Vendor List (AVL) management and identification of potential new suppliers.

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-48h)
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	Pending	-0.09%	Test not required	-0.20%	Test not required	-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%	-5.05%
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	-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%

- PQP results from over 45 module manufacturers are included in the Dashboard, with nearly 30 manufacturers sharing their non-anonymized results. Nearly 200 BOMs are included, with over 60% of BOMs non-anonymized.
- Get direct access to detailed PQP test reports for all manufacturers who have agreed to share.

# Kiwa PVEL's Premium Partner Program – Other Benefits

- Subscribers receive a comprehensive quarterly presentation including key insights from Kiwa PVEL's testing.

### Recent Damp Heat Outlier

- Damp Heat
- DH 1000
- Characterization
- DH 1000
- Characterization
- Stabilization: 85°C, 1h, 48 hrs
- Characterization

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### Recent PID Outlier

- A recent after DH
- Power is darker in perimeter (highest)
- Trace of busbars
- BOM us EVA+EV more CO POE+PI encaps present

- Damp Heat
- DH 1000
- Characterization
- DH 1000
- Characterization
- Stabilization: 85°C, 1h, 48 hrs
- Characterization

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### Hail Damage

- PID mo exhibit loss >2 unusual
- Expect recover UV exp
- No sig results.

- From PVEL's 50 mm, 32 m/s hail testing over the last year, glass/glass mods that survive the test almost never have cell cracks.
- Of the ~10 glass/glass mods that survived PVEL's hail testing only ~1 had any cell cracks.
- Modules that survive the hail stress sequence with intact glass have a power loss of 1-3%.
- Some modules with cell cracks (see image, right) that appear after the hail test experience minimal power degradation

A 1.4% degradation

B 1.8% degradation

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- Kiwa PVEL holds quarterly 1:1 calls with each Premium Partner Program subscriber to discuss in-depth insights and provide feedback on procurement decisions.



# Kiwa PVEL's Premium Partner Program – Participants

■ A sample of manufacturers agreeing to share results in the Dashboard:



■ A sample of current Premium Partner Program subscribers:





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Contact Kiwa PVEL:  
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[www.kiwa.com/pvel](http://www.kiwa.com/pvel)