Should we be positive about n-type?

Insights from the 2024 PV Module Reliability Scorecard

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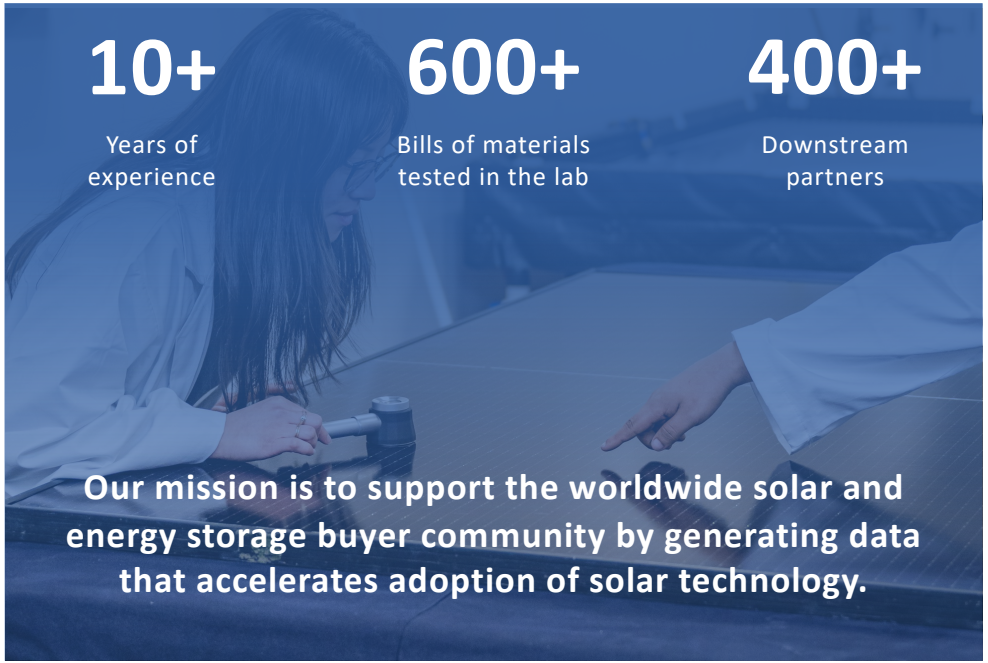
We Create Trust

Kiwa PVEL is the Independent Lab of the Downstream Solar Market



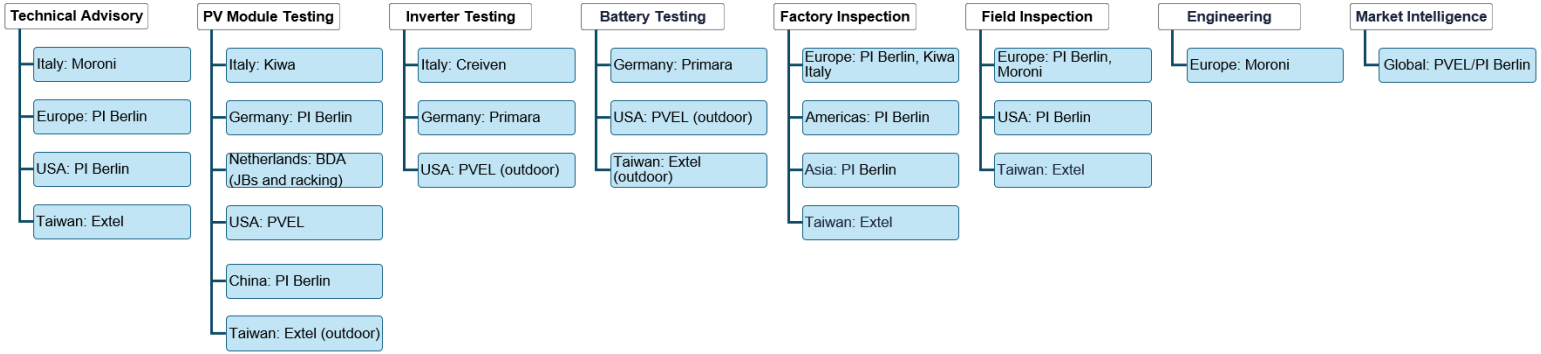
Services at a glance

- 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

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:

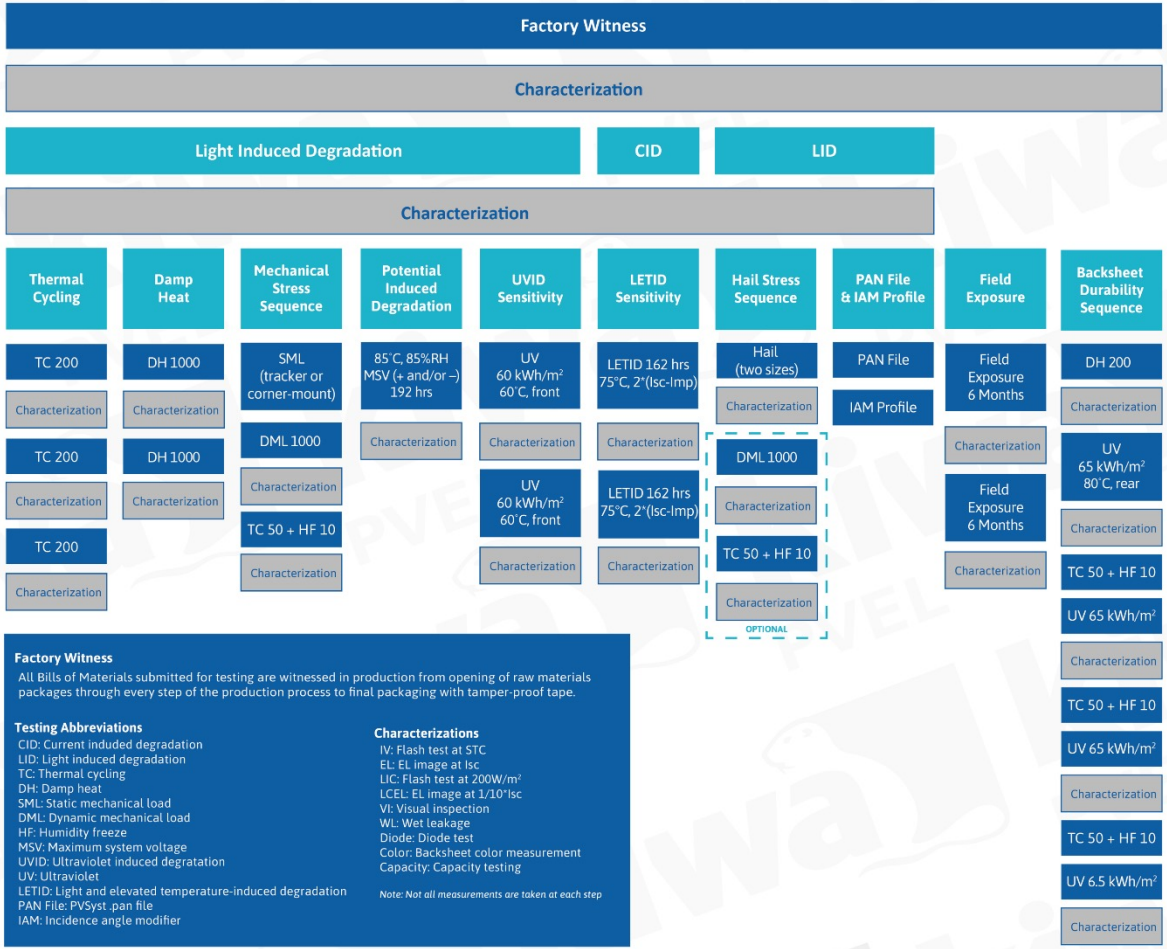


- Kiwa's mission is to create trust by contributing to the transparency of the quality, safety and sustainability of products, services and organizations as well as of personal and environmental performance.

Kiwa PVEL 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



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

Visit www.scorecard.pvel.com

TOP PERFORMER 2024
kiwa PVEL
PV MODULE RELIABILITY SCORECARD

- More Top Performers
- Global Presence - **13** Countries
- New Players - **20** First Timers

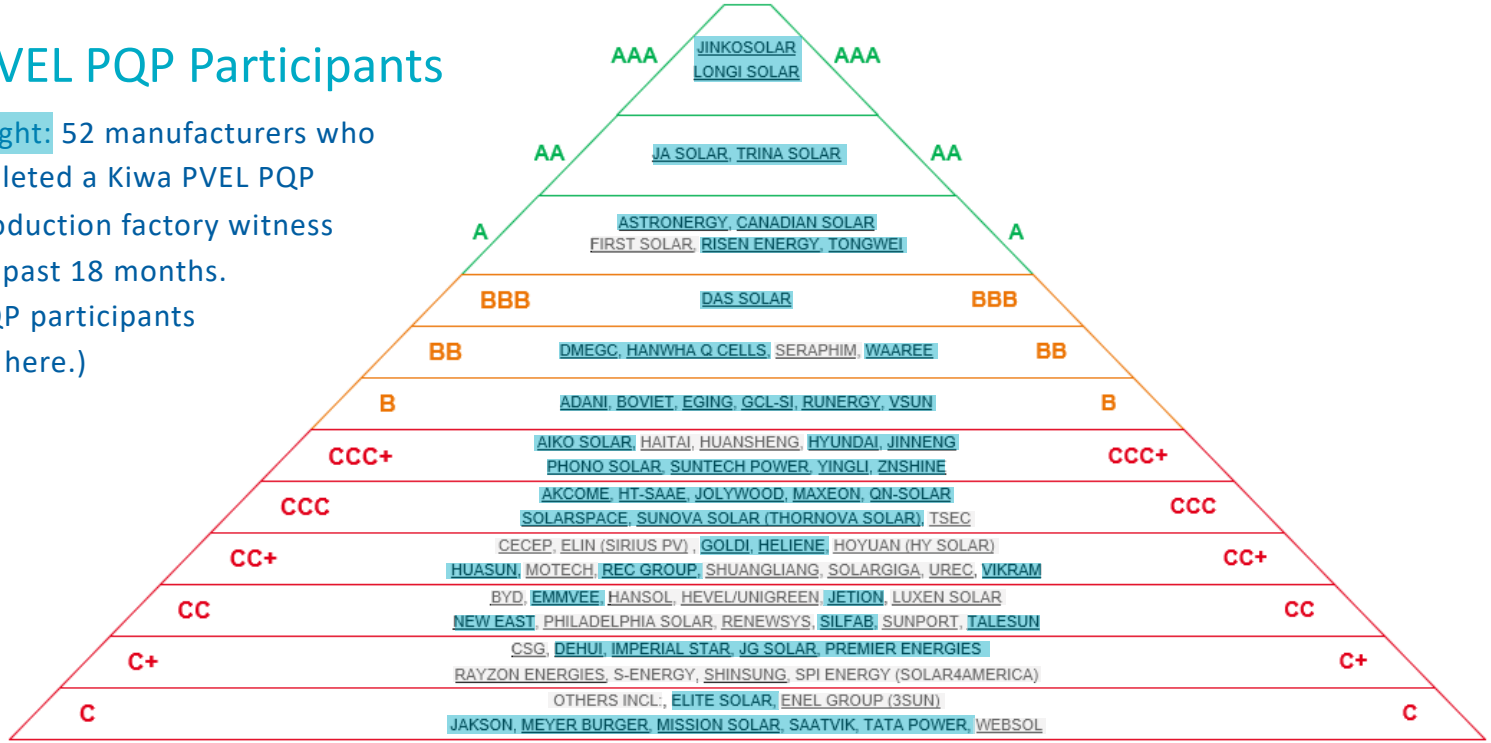
...

- More failures than ever before
- **66%** BOM had at least one failure
- Only **4** BOMs (~1% of the total) were Top Performers in all seven categories

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.

Some 2024 Scorecard Highlights

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Three Key Takeaways

1. Comparison of Test Results across Technologies
2. Deep Dive on UVID Results
3. Deep Dive on PAN and IAM Results

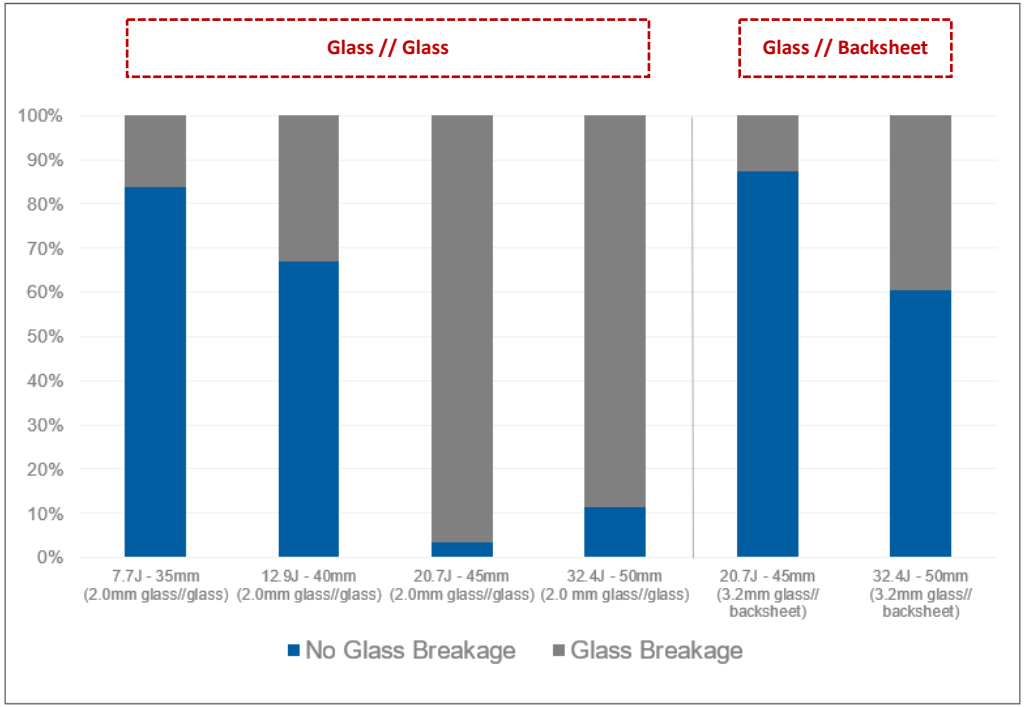
1 Comparison of Test Results across Cell Technologies

	TEST	Median for PERC	Median for TOPCon	Key Takeaways
	Thermal Cycling	0.6%	0.7%	While median degradation is statistically aligned, there were more negative outliers for TOPCon
	Damp Heat	1.4%	1.6%	While median degradation is statistically aligned, there were more negative outliers for TOPCon
	Mechanical Stress Sequence	0.9%	0.8%	No meaningful difference across results cell technologies
	Hail Stress Sequence	0.9%	0.8%	No meaningful difference across results cell technologies See next slide for more
	PID	1.6% - 2.0%		Range shown also represents that of G//G and G//BS. Cell and backsheet types not a key driver but encapsulant matters
	LID + LETID	0.3%	0.2%	Industry has largely seemed to solve this issue

Note on HJT: Improvement in TC results. DH results have a wide range. LID + LETID degradation is negligible.

Hail Stress Sequence Results

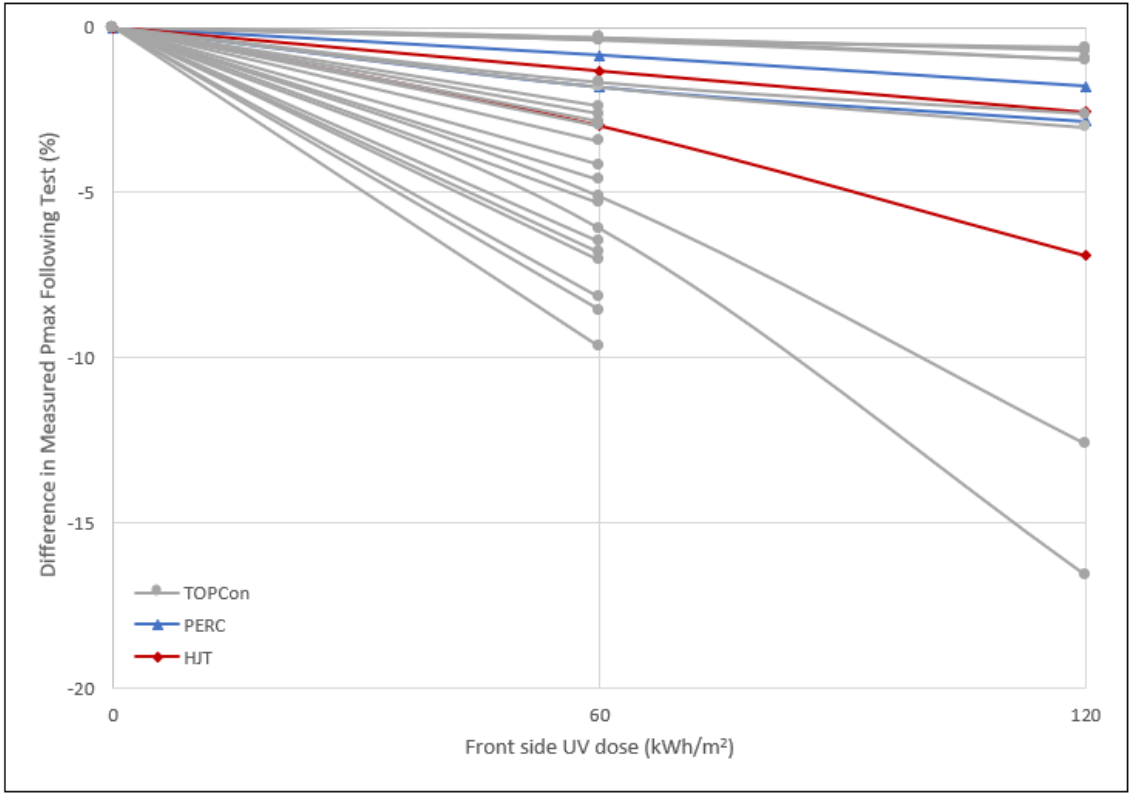
- 50 mm hail glass breakage rates:
  - 89% of 2.0 mm glass//glass
  - 40% for 3.2 mm glass//backsheet
- No hail-related power degradation > 3%.
- Negligible cell technology impacts.
- New hail hardened module designs are apparently coming.
- Junction box lids falling off from hail impacts is a nuisance.



2 UVID Results

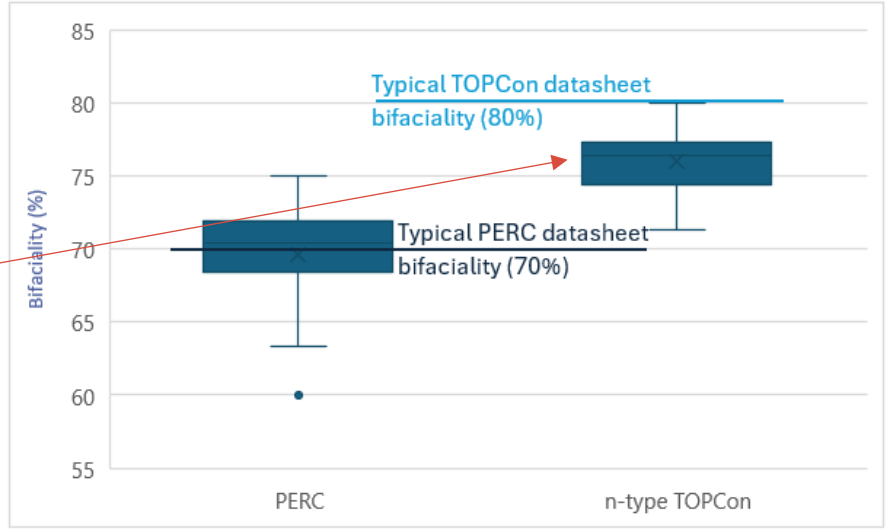
Initial Key Takeaways

- Power loss following 120 kWh/m^2 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.



3 PAN Results

	PERC	TOPCon	HJT
Avg. Pmp Temp Coefficient (%/°C)	-0.32	-0.30	-0.26
Avg. Bifaciality (%)	69.3	75.4	86.7
Avg. Low Light Performance* (%)	-3.6	-4.3	Redacted

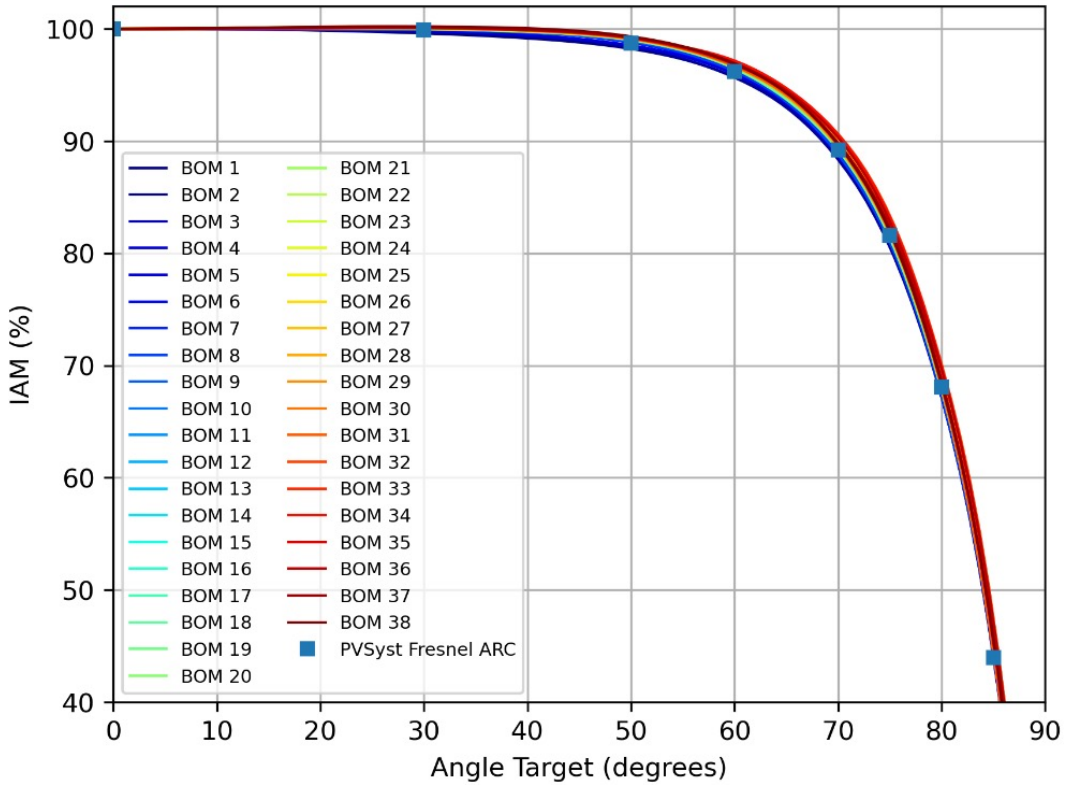


*As measured via the relative efficiency deviation at 200 W/m^2 compared to 1000 W/m^2. For HJT, the distribution of results was too wide and not statistically representative of that cell technology

The Top Performer energy yield threshold increased by 0.95% compared to the 2023 Scorecard

3 IAM Results

- 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.



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