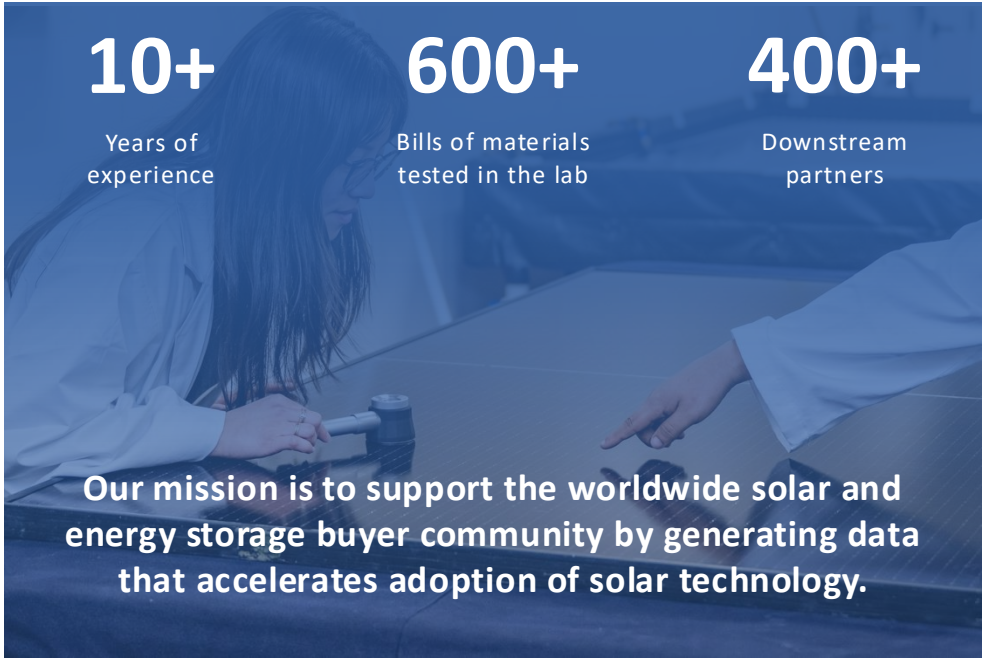
Overview of Indian Module Manufacturers Serving the U.S. Market

Sishir Garemella
Head of International Business Development
Kiwa PVEL

We Create Trust

Kiwa PVEL is the Independent Lab of the Downstream Solar Market



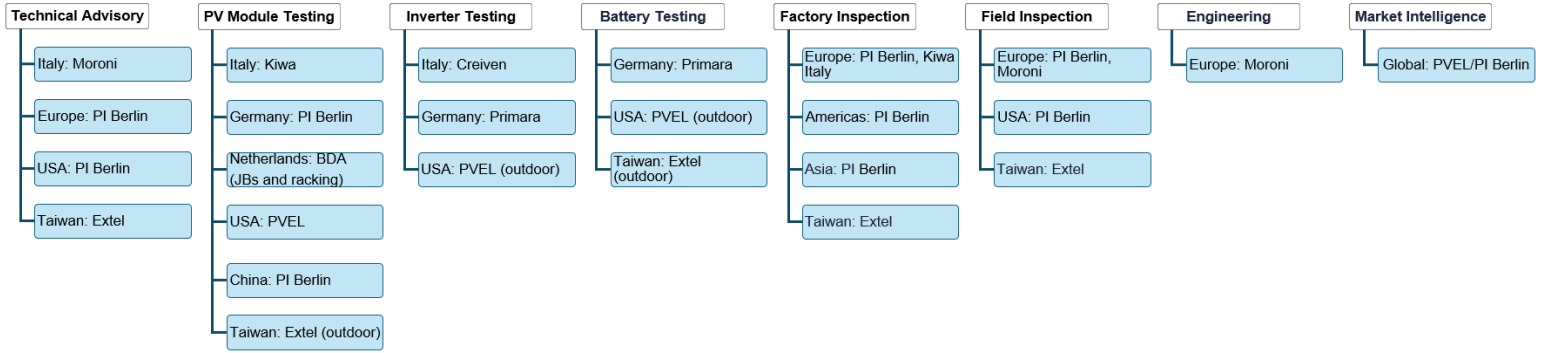
Services at a glance

- 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

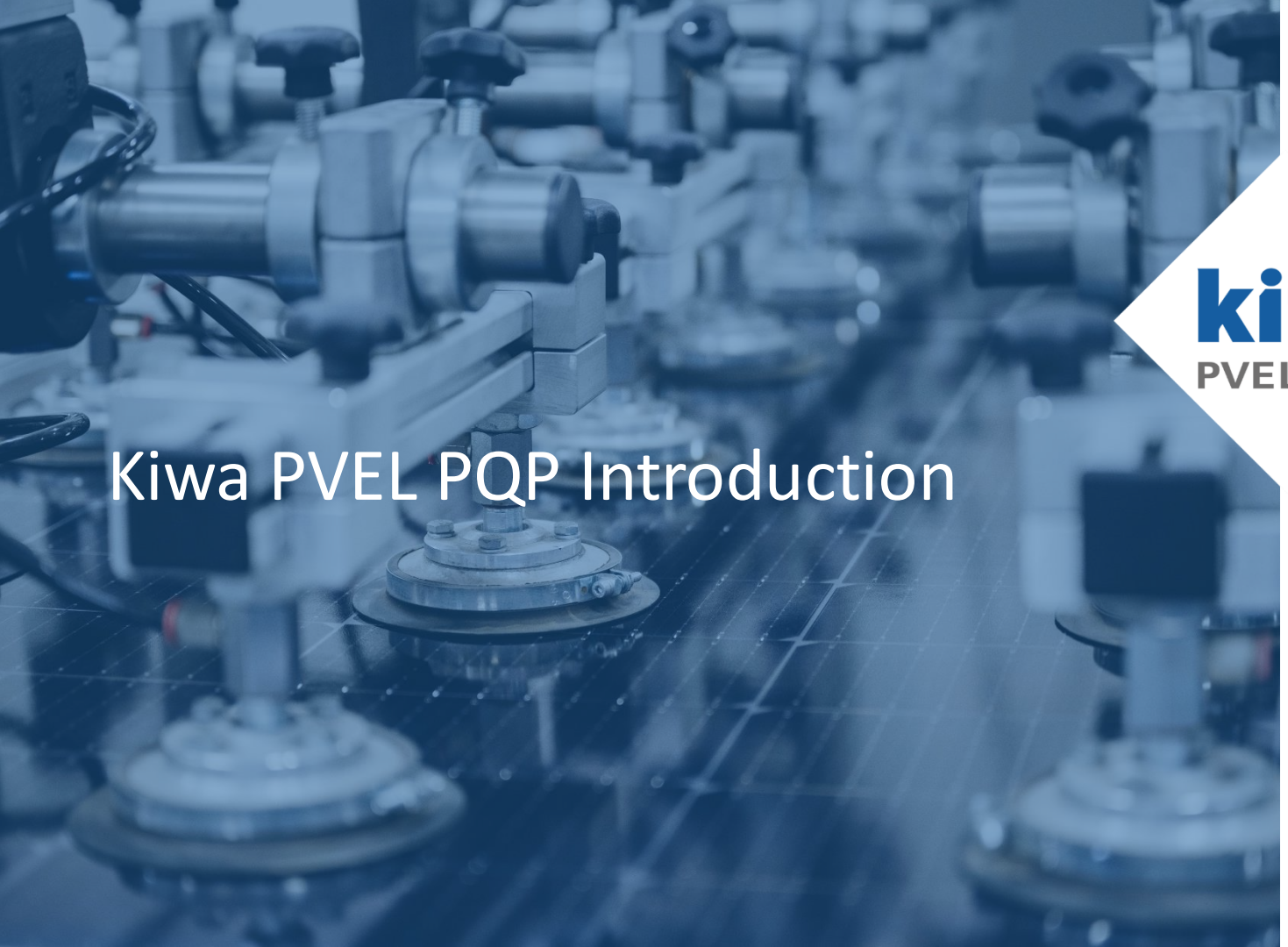
See more details at kiwa.com/pvel

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 Introduction

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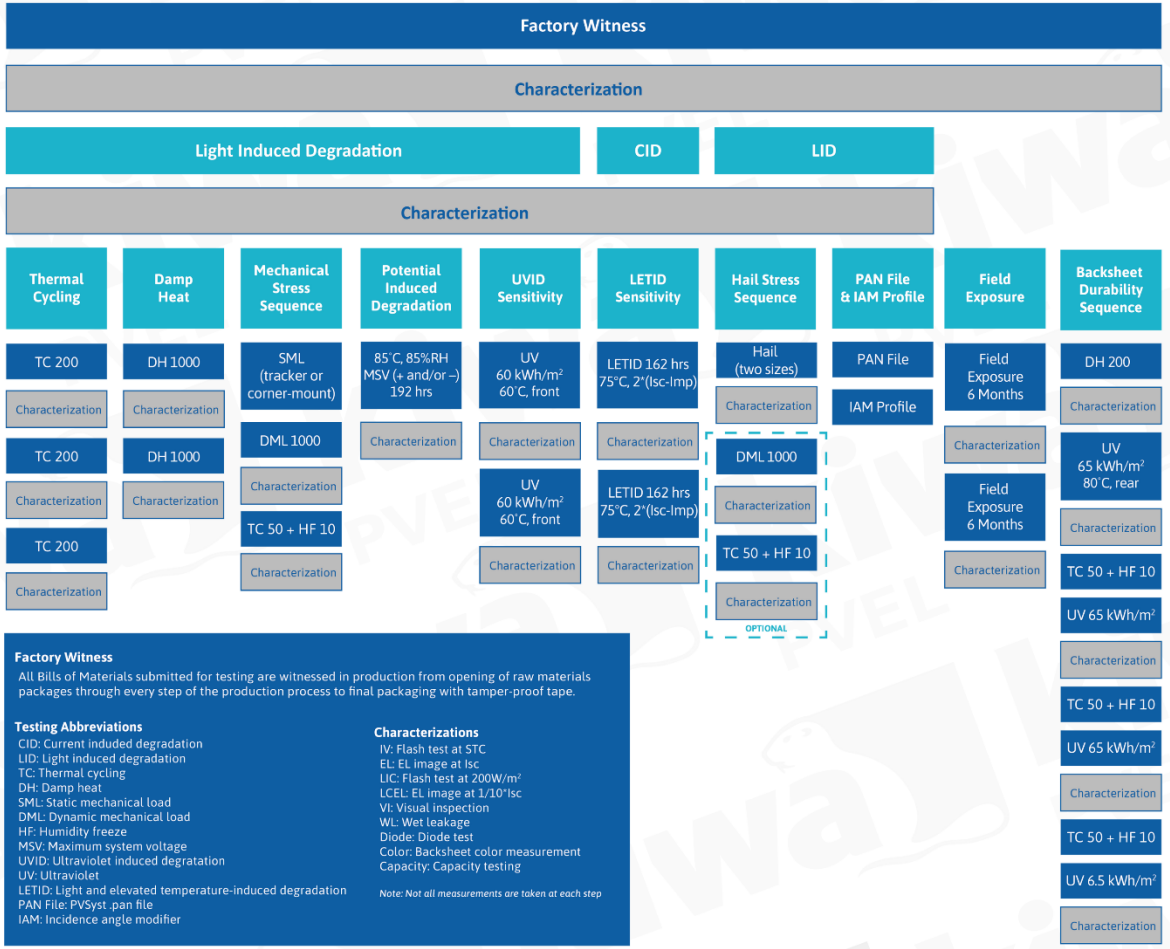
Kiwa PVEL PQP Test Sequence

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.

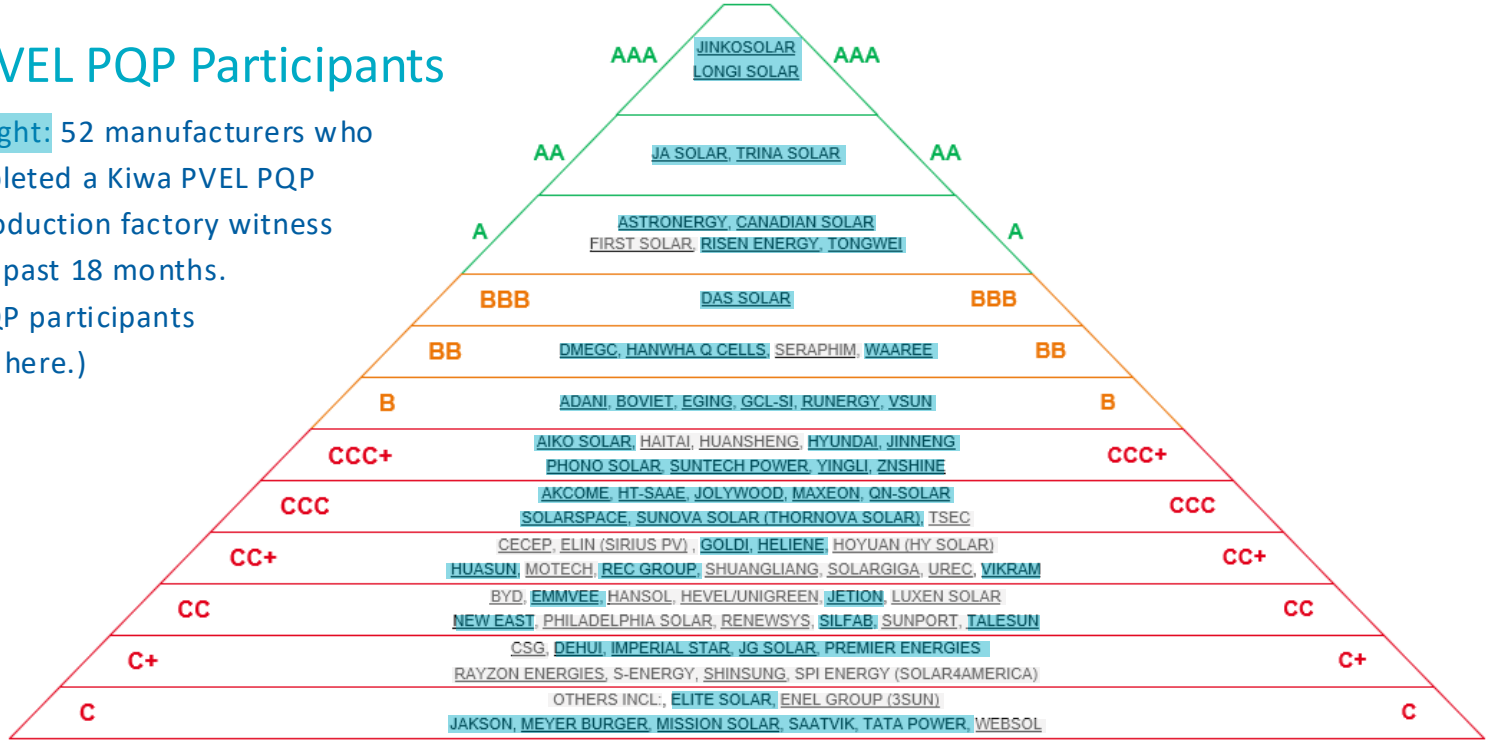
Learn more at kiwa.com/pvel/pqp



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 2024 Scorecard has been accessed nearly than **~ 40,000 times** from solar industry professionals across the globe.

TOP PERFORMER 2024 kiwa PVEL PV MODULE RELIABILITY SCORECARD

- The 2024 PV Module Reliability Scorecard was 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 ≥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//backsheet.
  - Deep dive into Kiwa PVEL's industry leading IAM test.

Find it at www.scorecard.pvel.com

Indian Module Manufacturers in the Kiwa PVEL PQP

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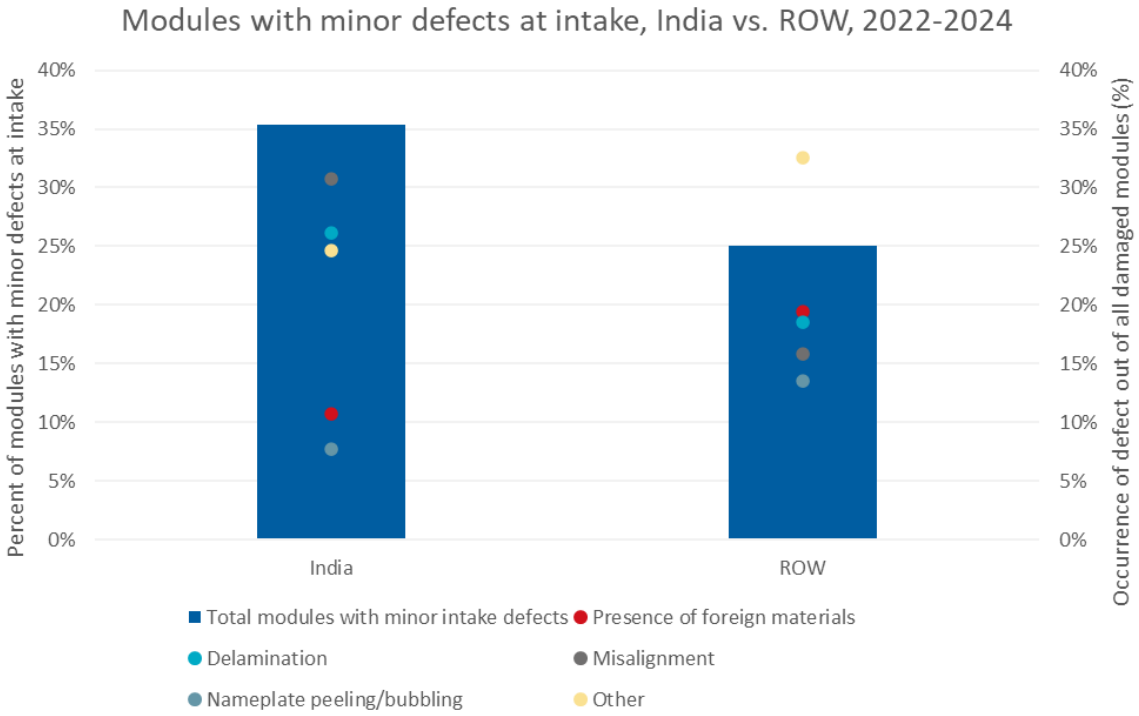
Overview Indian Solar Manufacturing

- CHINA PLUS ONE STRATEGY
- STRONG LOCAL DEMAND (~ 87 GW as on April 2024)
- PRODUCTION LINKED INCENTIVES
- BASIC CUSTOMS DUTY + APPROVED LIST OF MODULE MANUFACTURERS (ALMM)
- ~ 65 GW MODULE CAPACITY (as on Dec 2023)
- EXPORTS INCREASED 91% to $2bn in FY24 – USA share was 98.5%
- AT LEAST 8 INDIAN MANUFACTURERS HAVE ANNOUNCED US PRODUCTION PLANS

PQP Participants

ALL OF THE MAJOR INDIAN MANUFACTURERS TEST WITH KIWA PVEL

Intake



Reliability Testing

Thermal Cycling

TC200

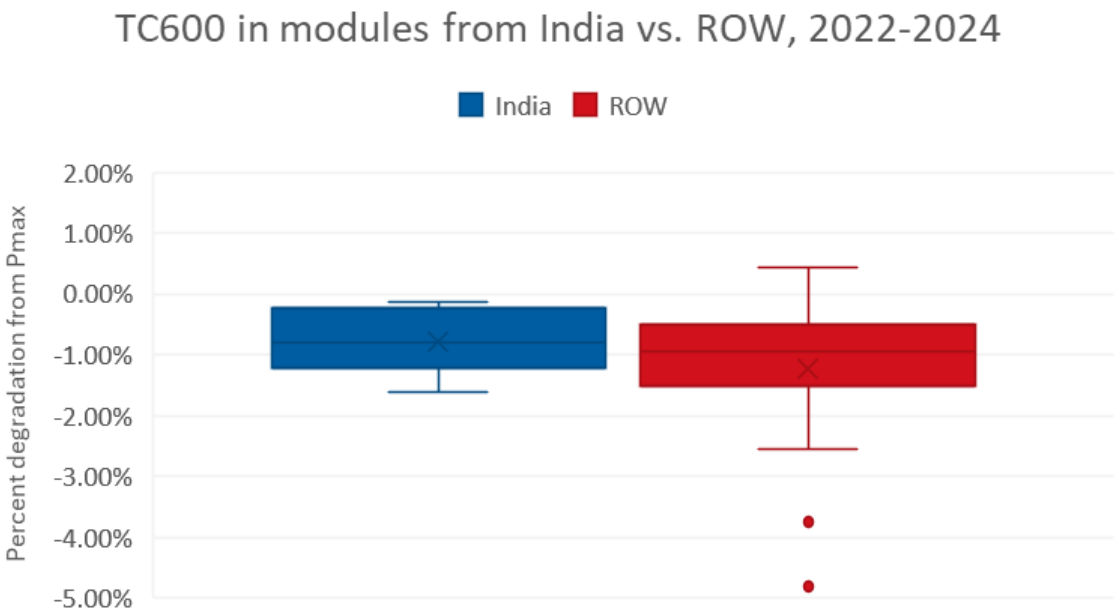
Characterization

TC200

Characterization

TC200

Characterization



- The module is subjected to 600 temperature cycles from -40°C to +85°C.
- This test helps to identify cell soldering issues.

Reliability Testing

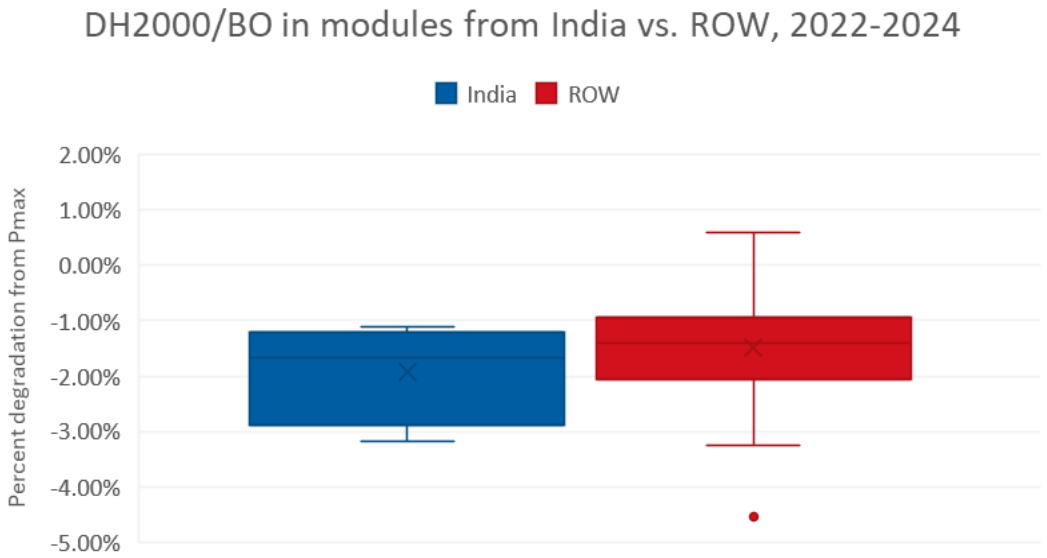
Damp Heat

DH1000

Characterization

DH1000

Characterization



- The module is subjected to +85°C and 85% relative humidity for 2000 hours.
- This test reveals corrosion and/or delamination in susceptible modules.

Reliability Testing

Mechanical Stress Sequence

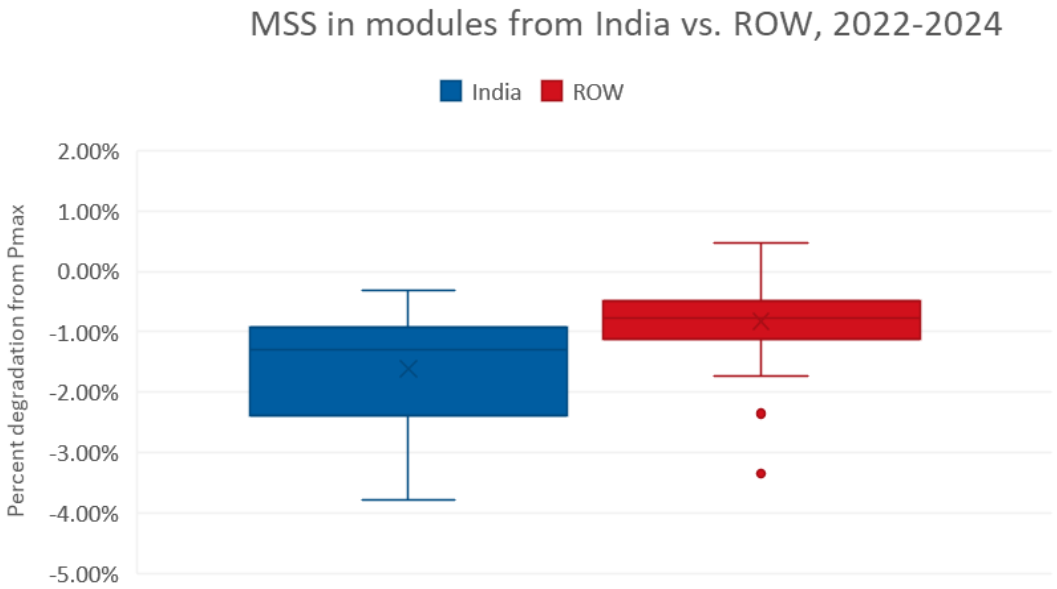
SML (tracker or corner mount)

DML1000

Characterization

TC50 + HF10

Characterization



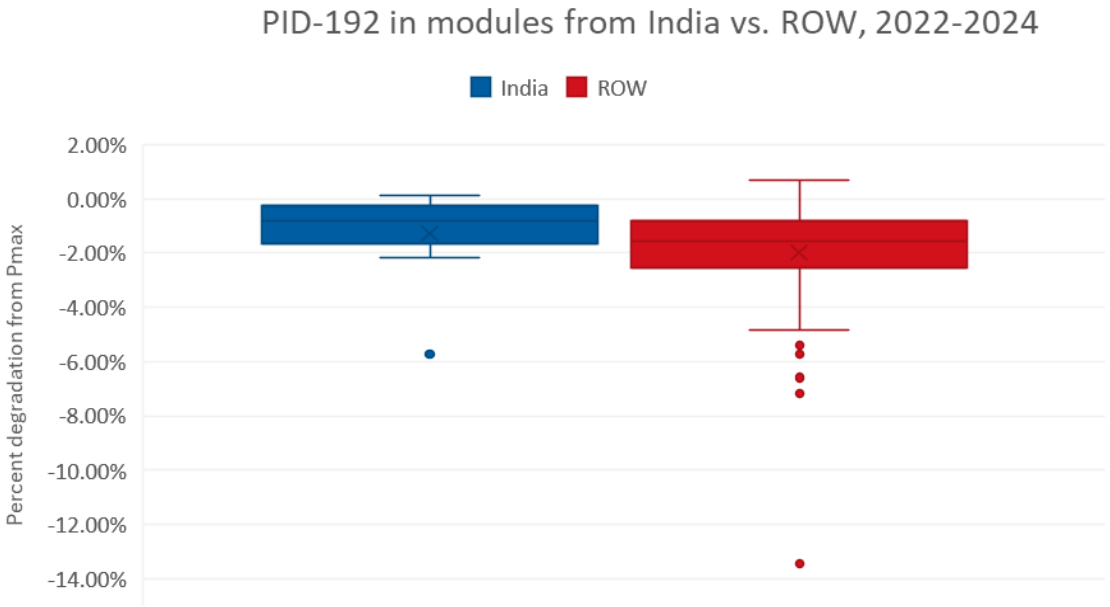
- SML includes 3 rounds of downward and upward force at 2400 Pa. The subsequent DML test comprises 1000 cycles of positive-negative loading at ±1000 Pa.
- This test reveals mechanical strength of the cell interface as well as the durability and rigidity of the PV module itself.

PID Results

Potential Induced Degradation

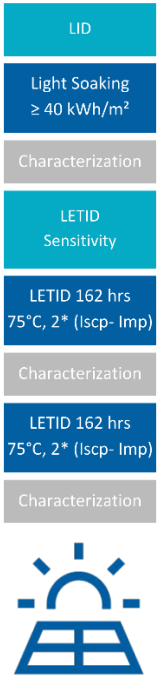
85°C, 85% RH
MSV (+ and -)
192 hours

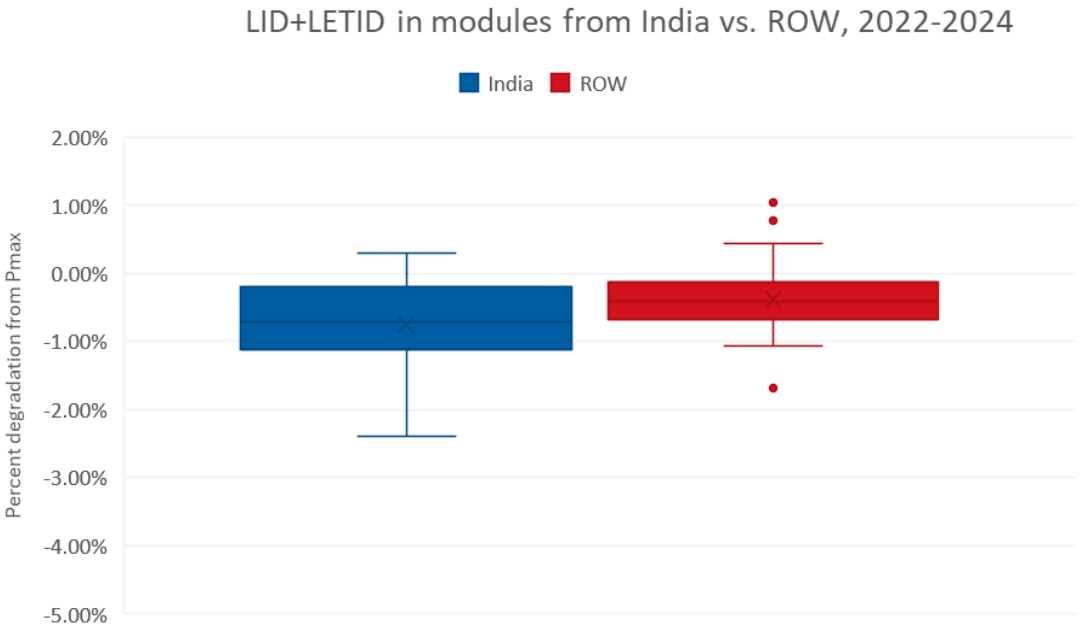
Characterization



- The module is subjected to +85°C, 85% relative humidity and maximum system voltage for 192 hours.

LID/LETID Results





- LID: 17 modules exposed outdoors to light-soak and flash test until stability.
- LETID: 2 post-LID (post-CID in V11 PQP) modules are subjected to 75°C with a low current injected for 486 hours (324 hours in V11 PQP).

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.

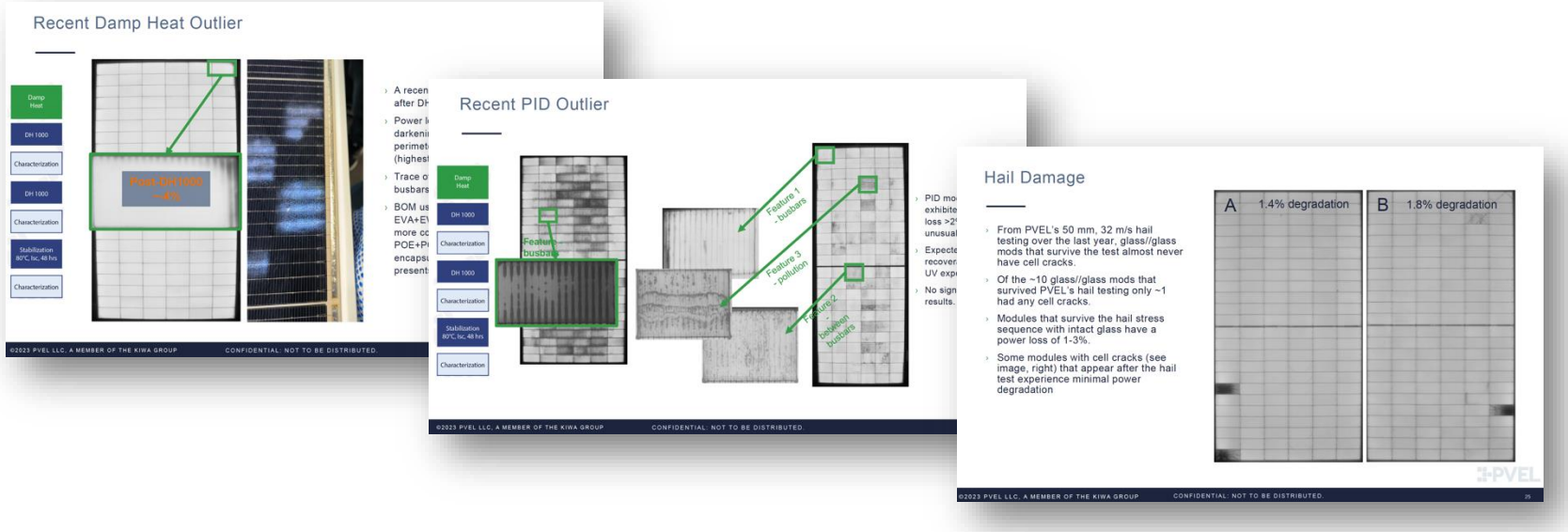
- Subscribers receive a quarterly Dashboard of Kiwa PVEL's **Product Qualification Program (PQP) test results** over a rolling period of 36-months. This allows for easy Approved Vendor List (AVL) management and identification of potential new suppliers.

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-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%

- 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.



- 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:

Conclusions

1. Indian solar manufacturing on the rise - Kiwa PVEL adding new customers each year

2. Reliability results from Indian manufacturers broadly in line with its global peers

3. Intake issues higher – More focus on QA / QC

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