

26 May 2021

# TOP-PERFORMING PV MODULES: 2021 PVEL Scorecard



PRESENTED BY



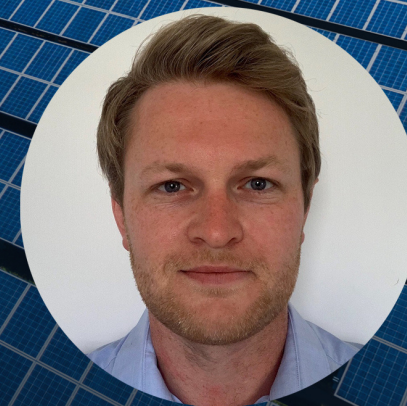
**Armando Solis**  
Director of Engineering  
Lightsource bp



**Tara Doyle**  
Chief Commercial Officer  
PVEL



**Tristan Erion-Lorico**  
Head of PV Module Business  
PVEL



**Liam Stoker**  
Editor in Chief  
Solar Media

MODERATED BY



# PVEL's PQP: The Lightsource bp Perspective

PV Tech Webinar

Armando Solis – Director of Engineering

# Key Value of the PQP to an Owner/Developer

What does it mean to us?

## Bankability

- Owners and Financiers expect quality and robust product for major project components; namely solar modules.
- Reliance on a product with limit project experience for 20+ year projects with off-take.

## Risk Mitigation

## Reliability and Quality

## Warranty and Agreement Confidence

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## Reliability and Quality

- PAN File Validation for accurate energy modelling and financial projections.
- Independent Engineer acceptance during finance due-diligence process.
- P90/P99 values improved with less uncertainty related to module variability.
- Degradation – What they say vs what tests show vs. what we can bank on.

## Warranty and Agreement Confidence

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## Risk Mitigation

- Structural Integrity is critical to projects installed in high wind prone areas.
- Hail Hail HAIL!
- Insurance is critical component to project lifetime; products/components must withstand conditions and carry warranty.

## Warranty and Agreement Confidence

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## Warranty and Agreement Confidence

- Bill of Materials (BOM) can be verified from what is tested to what is purchased/received.
- 25+ year warranties can be relied upon as an owner and for 3<sup>rd</sup> party investors/financiers.
- Key Elements to long term ownership – longevity, degradation, and warranty.



Thank You!



## 2021 PVEL PV MODULE RELIABILITY SCORECARD



**Tara Doyle**  
Chief Commercial Officer  
PVEL



**Tristan Erion-Lorico**  
Head of PV Module Business  
PVEL

PVEL is the independent lab of the downstream solar & energy storage market

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

**10+**

Years of  
experience

**500+**

Bills of materials  
tested in the lab

**400+**

Downstream  
partners

**30+<sub>GW</sub>**

GW annual project  
pipelines supported



# Introducing the 7<sup>th</sup> edition of the PVEL PV Module Reliability Scorecard

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## A Message from Our CEO

The solar industry has seen unprecedented growth in the past decade. The global manufacturing base has grown twentyfold, going from 20 gigawatts in 2010 to over 400 gigawatts today.

In a world of fake news, the challenge is finding the right data – the data that matters. Watch the video. I'll show you why.

Jenya Meydbray, CEO  
PV Evolution Labs



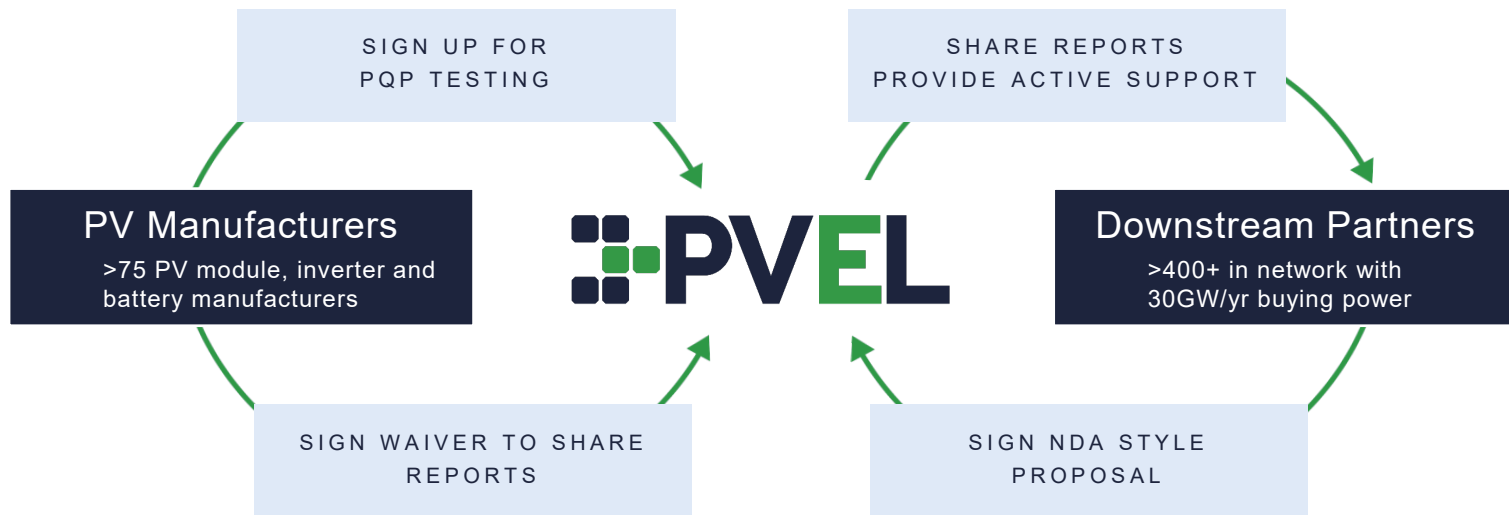
## PV Module Production Qualification Program (PQP)

Our Scorecard summarizes test results from PVEL's PQP for PV modules

Factory Witness, Characterizations and Light-Induced Degradation Measurement							
Thermal Cycling	Damp Heat	Backsheet Durability Sequence	Mechanical Stress Sequence	Potential-Induced Degradation	LeTID Sensitivity	PAN File & IAM Profile	Field Exposure
TC 200	DH 1000	DH 1000	Static Mechanical Load	85°C, 85%RH MSV (+ and/or -) 96 hrs	LeTID 162 hrs (75°C, Isc-Imp)	PAN File	Field Exposure 6 Months
Characterization	Characterization	Characterization	Characterization	Characterization	Characterization	IAM Profile	Characterization
TC 200	DH 1000	UV 65 kWh/m²	Dynamic Mechanical Load	85°C, 85%RH MSV (+ and/or -) 96 hrs	LeTID 162 hrs (75°C, Isc-Imp)		Field Exposure 6 Months
Characterization	Characterization	Characterization	Characterization	Characterization	Characterization		Characterization
TC 200	Stabilization 85°C, Isc, 48 hrs	TC 50 + HF 10	Characterization	Characterization	LeTID 162 hrs (75°C, Isc-Imp)		Characterization
Characterization	Characterization	Characterization	TC 50	Characterization	Characterization		
		UV 65 kWh/m²	Characterization				
		Characterization	HF 10				
		TC 50 + HF 10	Characterization				
		Characterization					
		UV 65 kWh/m²					
		Characterization					
		TC 50 + HF 10					
		UV 6.5 kWh/m²					
		Characterization					

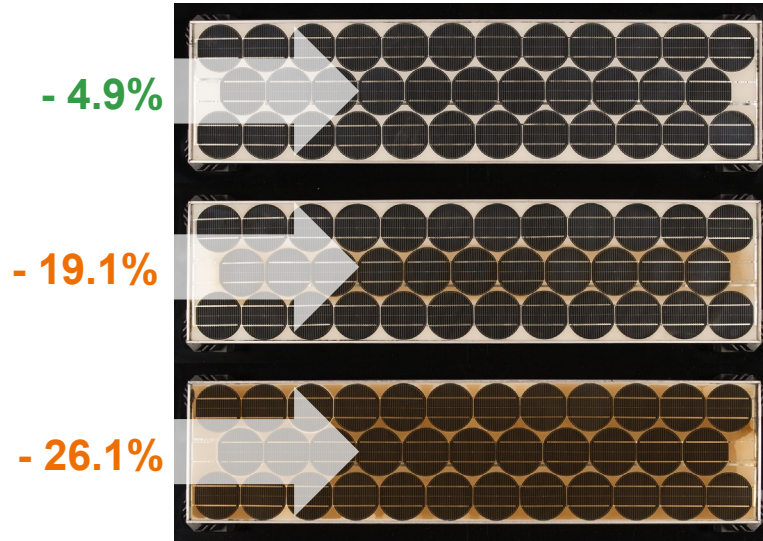
## Our Scorecard is based on test results available in our PQP reports

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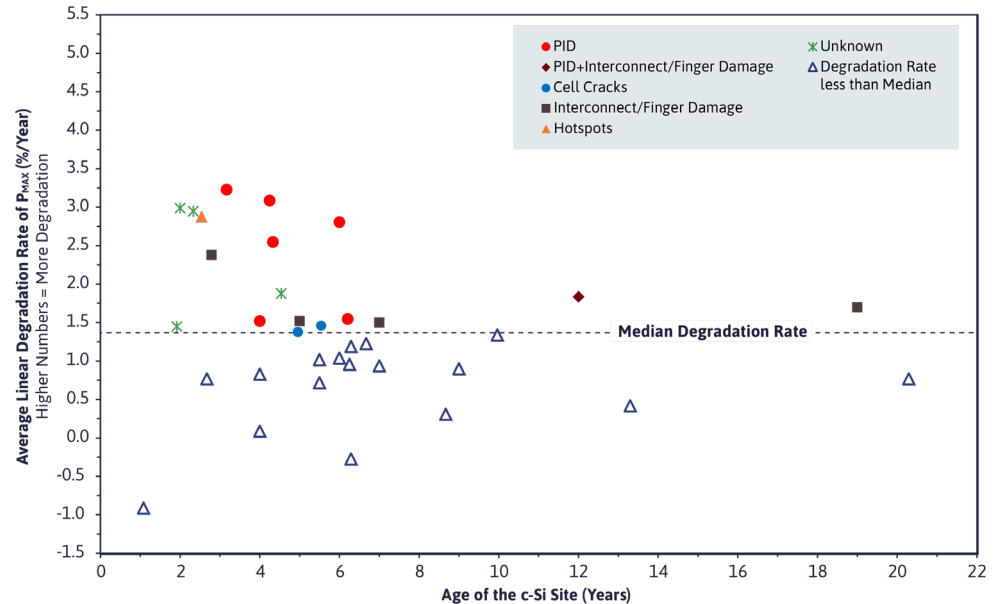
Field data informs our PQP – and drives buyer concerns – so data from the field is cited throughout our 2021 Scorecard

## Dramatically different degradation rates after 35 years of field operation



Source: "35 years of photovoltaics: Analysis of the TISO-10-kW solar plant, lessons learnt in safety and performance—Part 2." Progress in Photovoltaics.

## Newer PV modules have higher degradation rates



Source: Analysis of Field Degradation Rates Observed in the All India Survey of PV Module Reliability 2018", IEEE Journal of Photovoltaics

# Key takeaways from the 2021 Scorecard

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## Highs

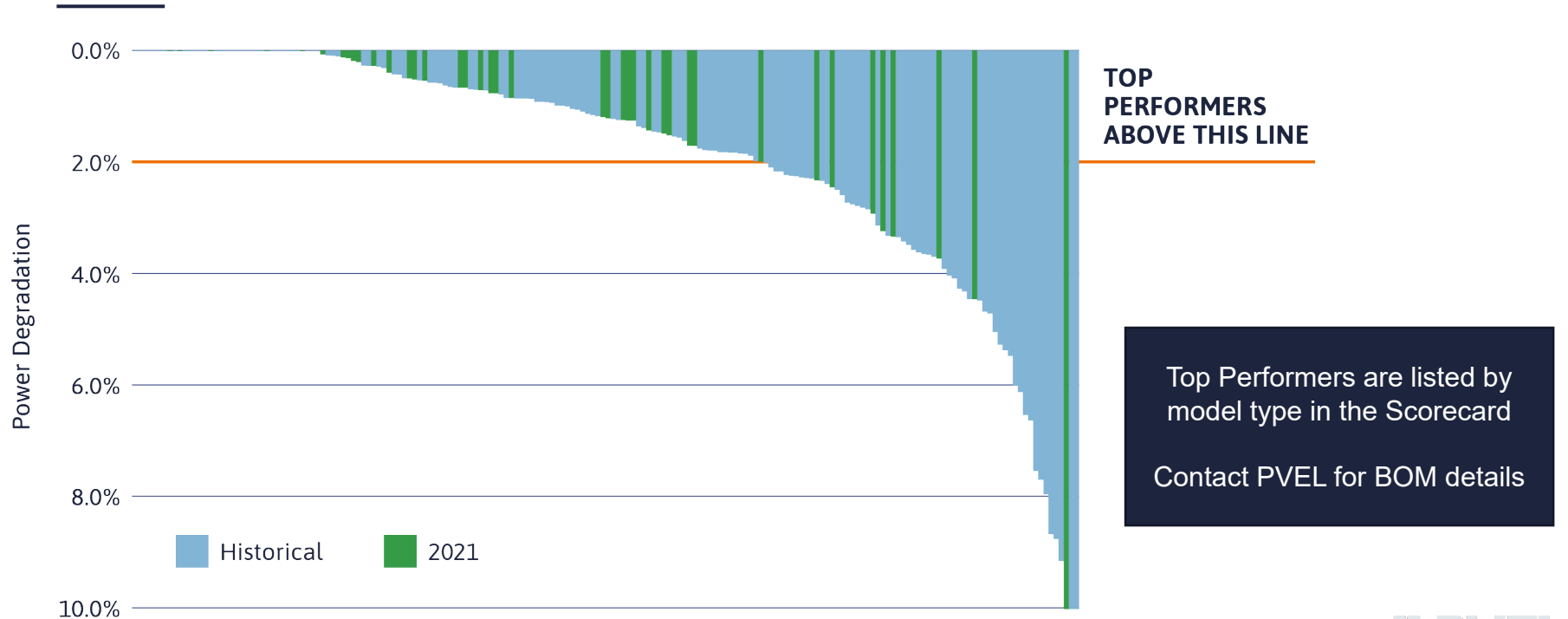
- › Highest number of manufacturers listed in Scorecard history
- › Continued improvement in thermal cycling and PAN performance
- › Strong results from some higher wattage and higher efficiency modules

## Lows

- › One third of manufacturers experienced a junction box failure
- › 26% of BOMs suffered at least one failure
- › Surprisingly poor results from select BOMs

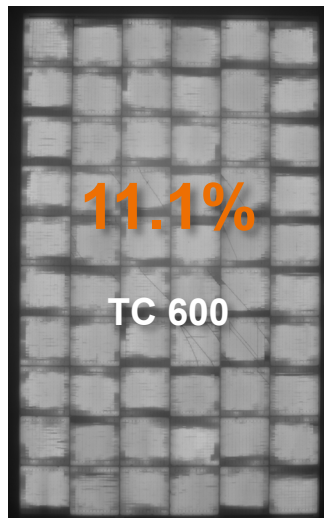
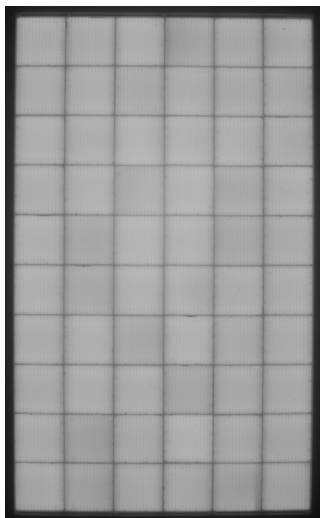


## Drilling down on thermal cycling

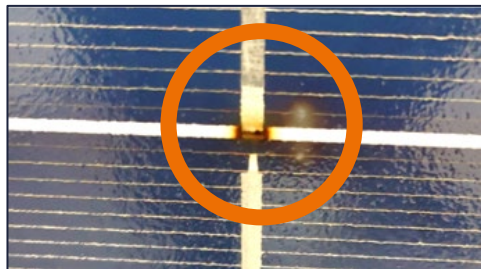


## Thermal cycling in the field and in the lab

- › Multibusbar (MBB) performance in the PQP is worse on average than standard busbar performance – but with proper soldering, MBB products can be Top Performers and deliver valuable performance and reliability benefits



*TC 600 failure in the lab in PQP*



*Field failure in Italy*

*Information and photos provided  
by MRP Energy*



## Mechanical stress sequence: Strong MBB results in this new Top Performer category

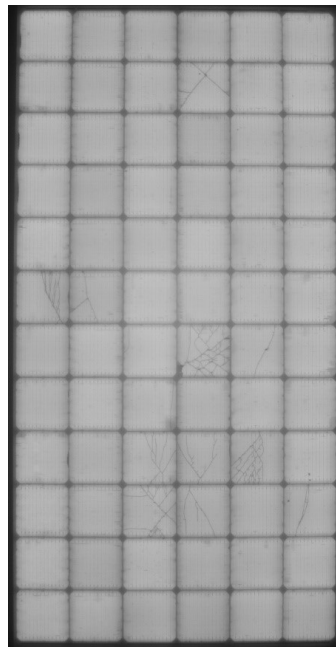
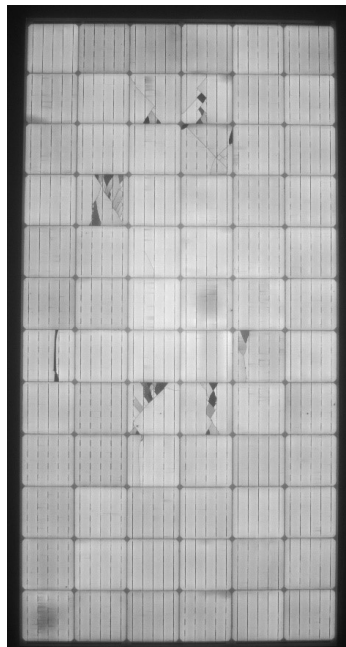
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Static Mechanical  
Load

Dynamic  
Mechanical Load

Thermal Cycling

Humidity Freeze

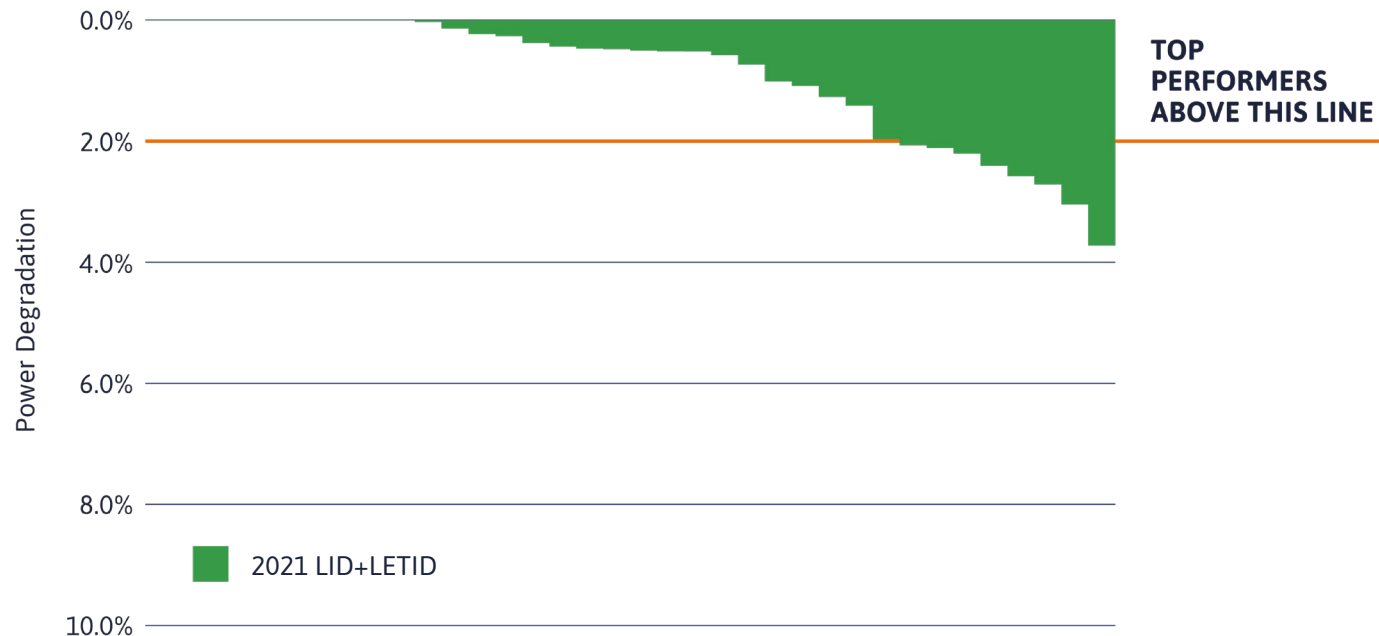


The 5-busbar module (left) shows significantly more inactive areas than the 12-busbar module (right).



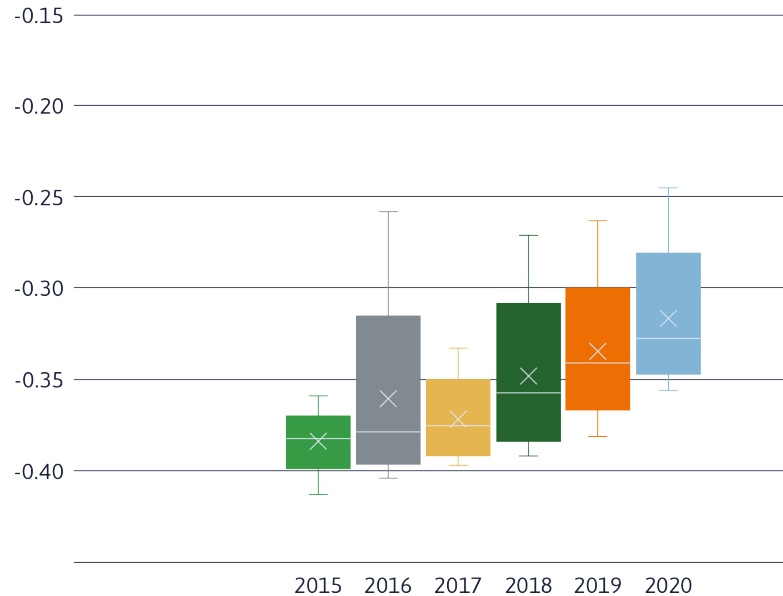
# The impact of LID and LETID on project valuations

IE	LID Default	LETID Default
1	≤1.5%	—
2	1% to ≥2%	1% to 8%
3	1.5%	
4	≤1.5% to 2.5%	
5	0 – 2%	—
6	1.5% or 2%	—

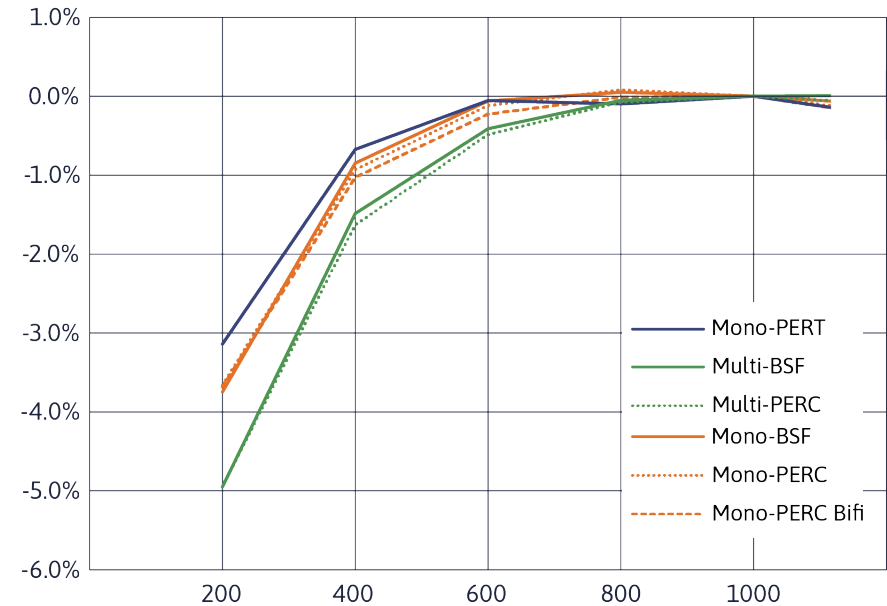


# Trends over time in PAN Performance

## Temperature coefficients over time



## Temperature vs. irradiance by cell type



PVEL

# 2021 Top Performers & Historical Scorecard



7x

**JinKO** Solar

**Trina**solar

6x

**JA** SOLAR

**Q**CELLS

**REC**  
SOLAR'S MOST TRUSTED

5x

**ASTRO**ENERGY  
A CHINT COMPANY

**GCL**

**LONGi**

4x

**adani**

**Phono** Solar

**SEG**

**Silfab**  
SOLAR

**SUNPOWER**  
FROM MAXEON SOLAR TECHNOLOGIES

**vikram**solar  
CREATING CLIMATE FOR CHANGE

3x

**BOVIET**  
SOLAR USA

**First Solar**

**HYUNDAI**  
ENERGY SOLUTIONS

2x

**LG**

**HT-SAAE**

**TALESUN**

1x

**ET** Solar

**DMEGC**

黄河水电西宁太阳能电力有限公司  
HHDC XINING SOLAR POWER CO., LTD.

**中来股份**  
JOLYWOOD

**risen**  
solar technology

**VSUN**  
Innovative & Smart

# There's even more inside the Scorecard

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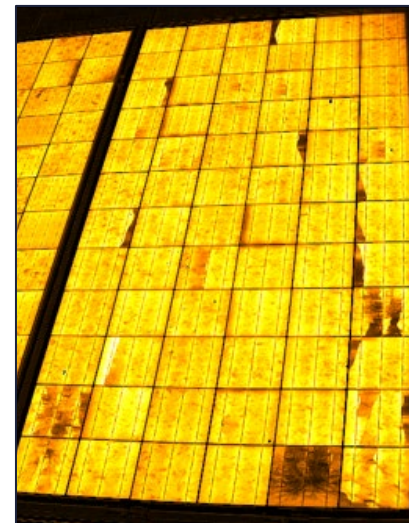
## Top Performers by model type

1. Thermal cycling
2. Damp heat
3. Mechanical stress sequence
4. PID
5. PAN Performance
6. LID+LETID

## Industry case studies



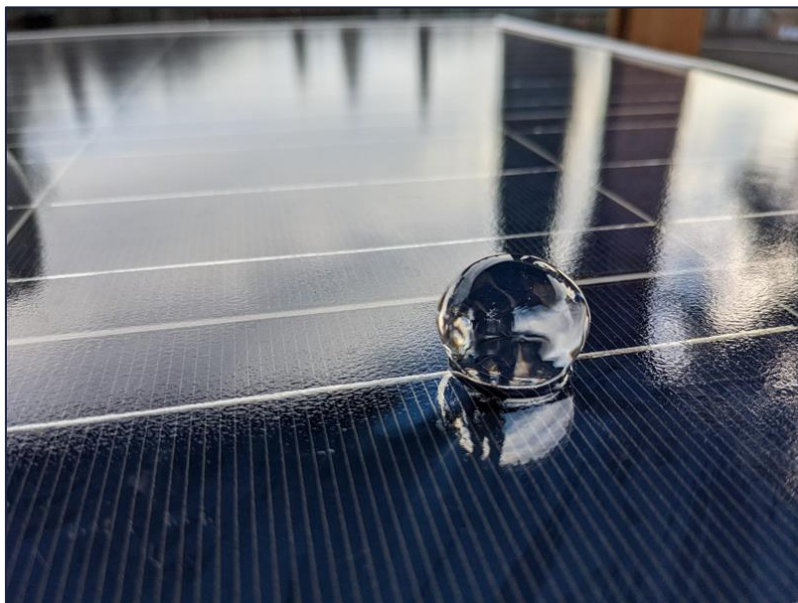
## More data from the field



# What's next for PV modules – and for the industry

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## Updating the PQP



## Testing large format modules

<b>Astronergy</b>	182mm, 144-cell, bifacial; 210mm, 132-cell, bifacial
<b>Boviet</b>	182mm, 144-cell, bifacial
<b>DMEGC</b>	182mm, 144-cell, bifacial
<b>ET Solar</b>	182mm, 144-cell, bifacial
<b>HT-SAAE</b>	182mm, 144-cell, bifacial
<b>Jinko</b>	182mm, 144-cell, bifacial
<b>Risen Energy</b>	210mm, 110-cell, bifacial
<b>Seraphim</b>	182mm, 144-cell, bifacial
<b>SunPower</b>	182mm, shingled, bifacial
<b>Trina Solar</b>	210mm, 120-cell, monofacial; 210mm, 110-cell, bifacial; 210mm, 110-cell, monofacial; 210mm, 132-cell, bifacial; 210mm, 132-cell, monofacial;
<b>VSUN</b>	182mm, 144-cell, bifacial
<b>Suntech</b>	182mm, 144-cell, monofacial



What's next for PVEL:  
Global growth as a member of the Kiwa Group



Available now at [modulescorecard.pvel.com](https://modulescorecard.pvel.com)



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MAKE DATA MATTER.

## LIGHTNING ROUND + Q&A

1

## LIGHTNING ROUND

Tristan Erion-Lorico  
Head of PV Module Business  
PVEL

### TOP 3

What are the most important material components to specify in a PV module?



2

## LIGHTNING ROUND

Tristan Erion-Lorico  
Head of PV Module Business  
PVEL

### PICK ONE

Which is better – glass//glass or glass//backsheet?



3

## LIGHTNING ROUND

Tristan Erion-Lorico  
Head of PV Module Business  
PVEL

### PICK ONE

Pick one: Boron-doped or gallium-doped modules?



4

## LIGHTNING ROUND

Tristan Erion-Lorico  
Head of PV Module Business  
PVEL

### TRUE/FALSE

Are n-type modules the modules of the future?



5

## LIGHTNING ROUND

Tristan Erion-Lorico  
Head of PV Module Business  
PVEL

### PICK ONE

Large-format modules are coming. Which wafer size will dominate the market in three years - 182mm or 210mm?



6

## LIGHTNING ROUND

Tara Doyle  
Chief Commercial Officer  
PVEL

### RATING

What is your percent confidence level that today's modules can withstand extreme weather?



7

## LIGHTNING ROUND

Tara Doyle  
Chief Commercial Officer  
PVEL

### TRUE/FALSE

Investor requirements for due diligence are becoming more rigorous.



8

## LIGHTNING ROUND

Tara Doyle  
Chief Commercial Officer  
PVEL

### TRUE/FALSE

Modules that are built today will last 40 years.



# 9

## LIGHTNING ROUND

Tara Doyle  
Chief Commercial Officer  
PVEL

### TRUE/FALSE

Buyers should be concerned about short-term raw materials supply chain disruptions driving price increases.



10

## LIGHTNING ROUND

Tara Doyle  
Chief Commercial Officer  
PVEL

### PICK ONE

If you could either specify BOMs or negotiate favorable warranty terms in a supply agreement – but not both – which would you choose?





MAKE DATA MATTER.

Q&A