



MAKE DATA MATTER.

# INSIGHTS FROM PVEL'S INDOOR AND OUTDOOR BIFACIAL TESTING

PV Evolution Labs (PVEL)

Tristan Erion-Lorico, Head of PV Module Business

[tristan.erion-lorico@pvel.com](mailto:tristan.erion-lorico@pvel.com)

April 2020

# PVEL is the Independent Lab for the Downstream Solar Market

---



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

## Global

400+ downstream partners worldwide with 30+GW of annual buying power

## Comprehensive

Testing for every aspect of a PV project from procurement to O&M

## Experienced

Pioneered bankability testing for PV products nearly a decade ago

## Market-driven

Continuously refining test programs to meet partner needs

# PVEL's Module Product Qualification Program (PQP) Test Sequences

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/m <sup>2</sup>	Dynamic Mechanical Load	85°C, 85%RH MSV (+ and/or -) 96 hrs	LeTID 162 hrs (75°C, Isc-Imp)	Characterization	Field Exposure 6 Months
Characterization	Characterization	Characterization	Characterization	Characterization	Characterization	Characterization	Characterization
TC 200	Stabilization 85°C, Isc, 48 hrs	TC 50 + HF 10	TC 50	LeTID 162 hrs (75°C, Isc-Imp)	Characterization	Characterization	Characterization
Characterization	Characterization	Characterization	Characterization	Characterization	Characterization	Characterization	Characterization
		UV 65 kWh/m <sup>2</sup>	HF 10				
		Characterization	Characterization				
		TC 50 + HF 10	UV 65 kWh/m <sup>2</sup>				
		Characterization	Characterization				
		UV 65 kWh/m <sup>2</sup>	TC 50 + HF 10				
		Characterization	Characterization				
		TC 50 + HF 10	UV 6.5 kWh/m <sup>2</sup>				
		Characterization	Characterization				

## PQP Bifacial Considerations

- › Measure and report STC bifaciality pre and post stress (including LID/LeTID)
- › Full bifaciality characterization following IEC TS 60904-1-2 as part of PAN testing to determine *bifaciality*,  $P_{max, BiFi100}$  and  $P_{max, BiFi200}$
- › Higher current will be used during TC as per draft 61215
- › For Field Exposure: two modules on fixed tilt white albedo, two modules over grass (same POA)

Maximum Power point ( <b>P<sub>max</sub></b> )		
300 W		
Short-circuit current ( <b>I<sub>sc</sub></b> )		
8.6 A		
Open-circuit voltage ( <b>V<sub>oc</sub></b> )		
43.2 V		
Bifaciality ( $\phi$ )	<b>P<sub>max,BiFi100</sub></b>	<b>P<sub>max,BiFi200</sub></b>
92%	328 W	356W



Source: Meyer Burger, 2018

## Bifacial PQPs Currently Under Test at PVEL

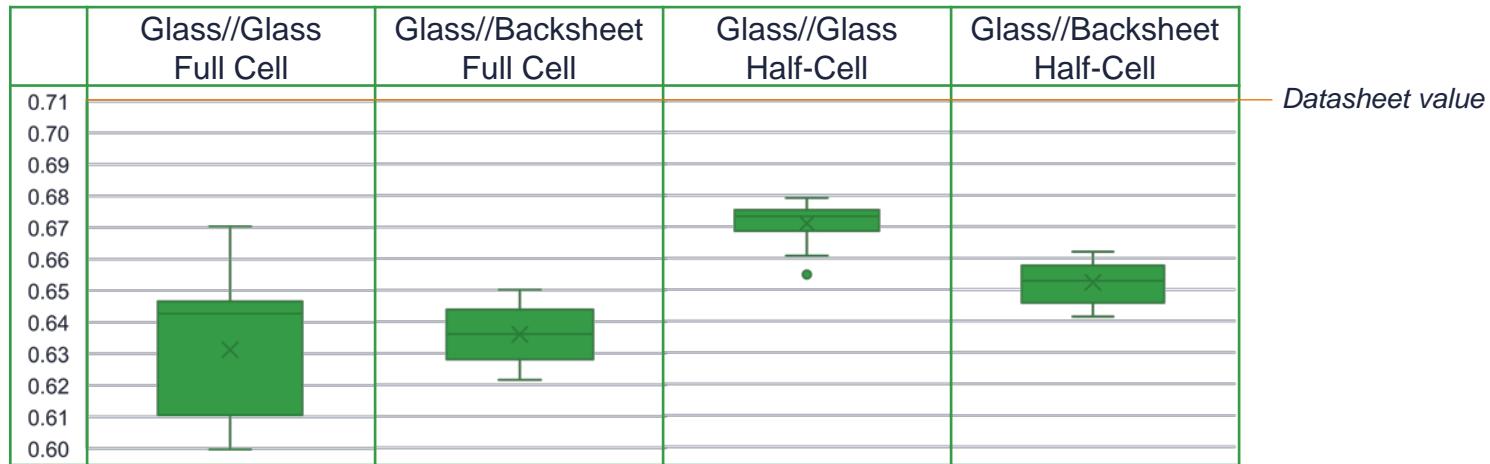
PVEL leads the industry in bifacial extended reliability and performance data

- › Current PQP – 16 bifacial BOMs, from 8 manufacturers:
  - full cell, half-cut cells
  - 156.75, 158.75, 166mm cells
  - 5BB, 6BB, 9BB, interdigitated back contact (IBC)
  - p-type, n-type
  - glass//glass, glass//backsheet
  
- › Last year's PQP – 13 bifacial BOMs, from 5 manufacturers:
  - full cell, half-cut cells
  - 156.75, 158.75, 166mm cells
  - 5BB, 6BB
  - p-type
  - glass//glass, glass//backsheet

# Initial Results: Bifaciality Ranges

---

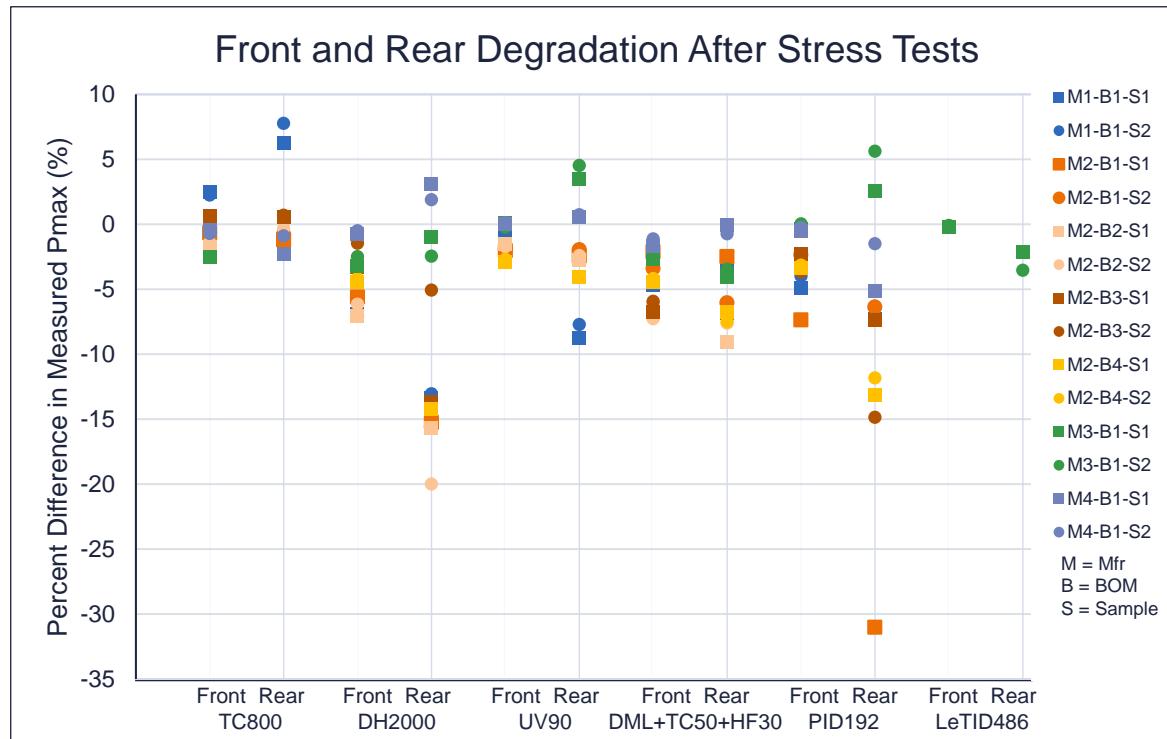
- › Bifaciality can differ based on module design
- › All BOMs shown below were produced by **the same manufacturer**
- › All BOMs shown below have **the same stated bifaciality of ~0.71** on their datasheet



# Initial Results: Reliability Testing at a Glance

---

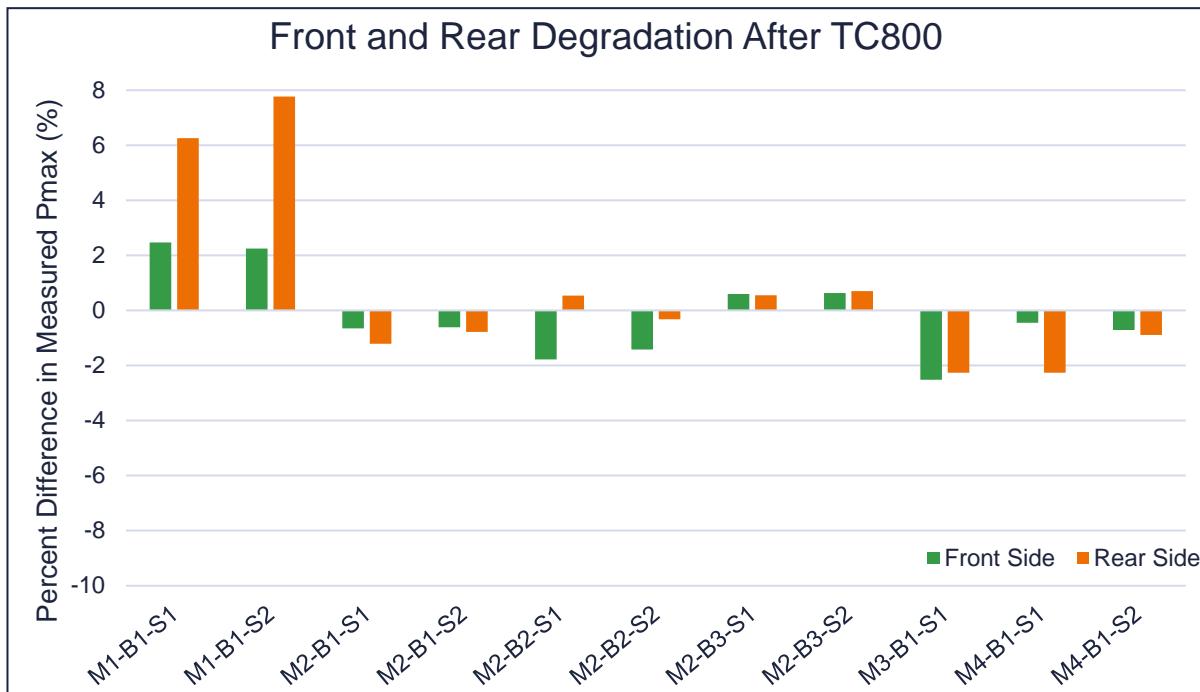
- Initial bifacial PQP results show a range of performance for both front and rear sides



# Initial Results: Thermal Cycling

---

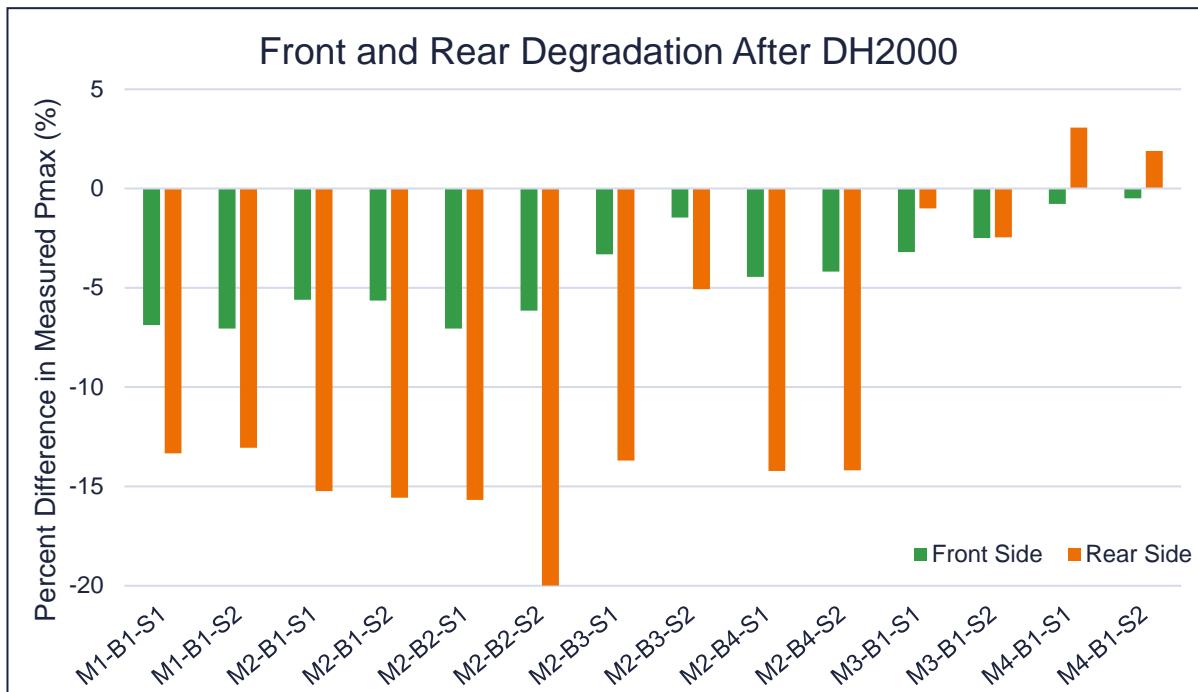
- Typically post-TC800 front and rear power degradation is relatively aligned
  - Reasons for Mfr. 1's increase in Pmax are under investigation



# Initial Results: Damp Heat

---

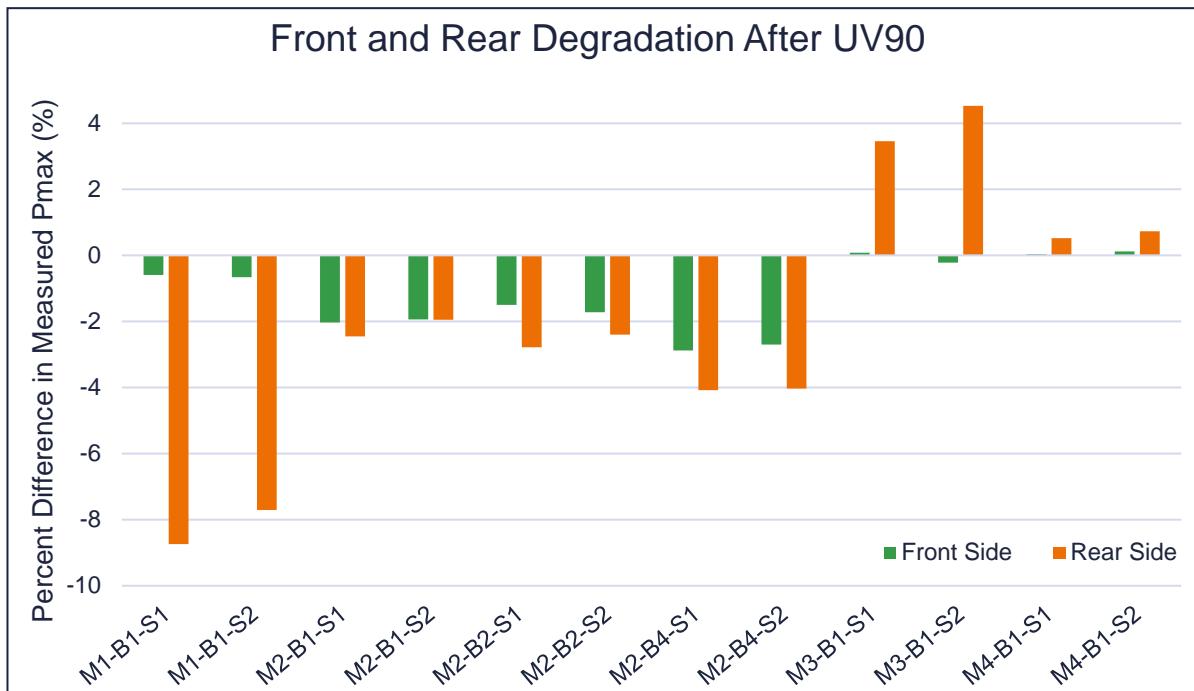
- Many PERC modules show signs of Boron-Oxygen destabilization following DH2000
  - The latest PQP (and draft IEC 61215) includes a post-DH stabilization process to mitigate BO impacts



# Initial Results: Front-Side UV

---

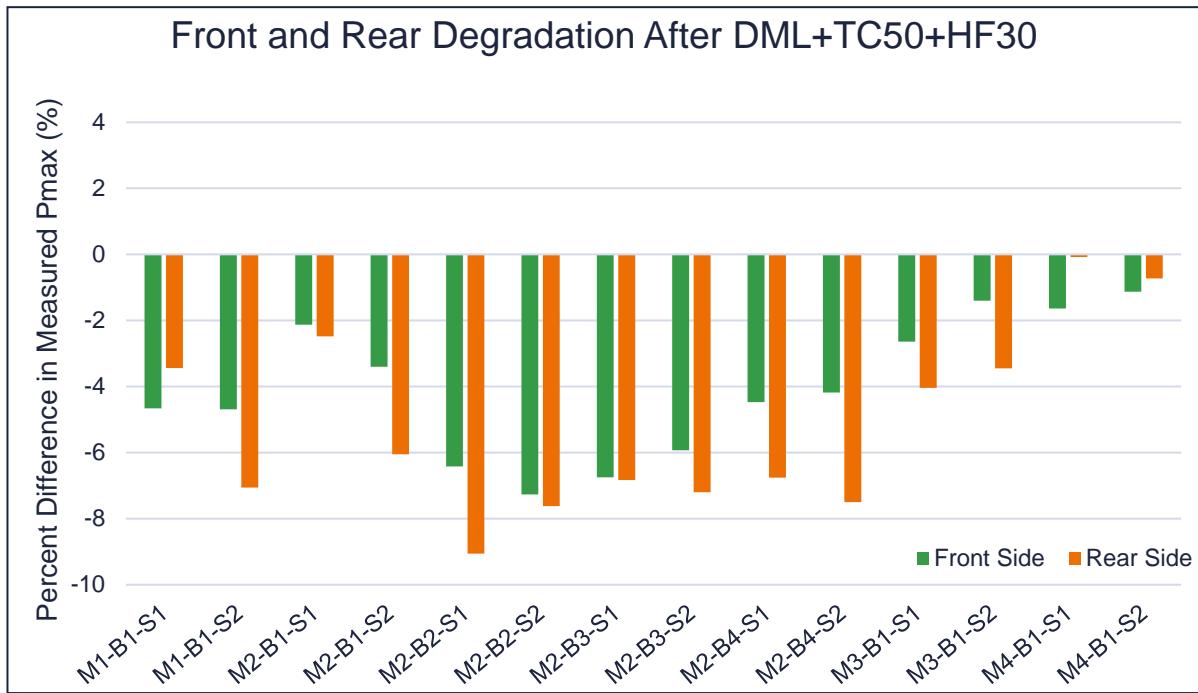
- UV aging appears to cause a range of impacts on rear side power degradation
  - Reasons for Mfr. 1's substantial rear-side decrease in Pmax are under investigation



# Initial Results: DML+TC50+HF30

---

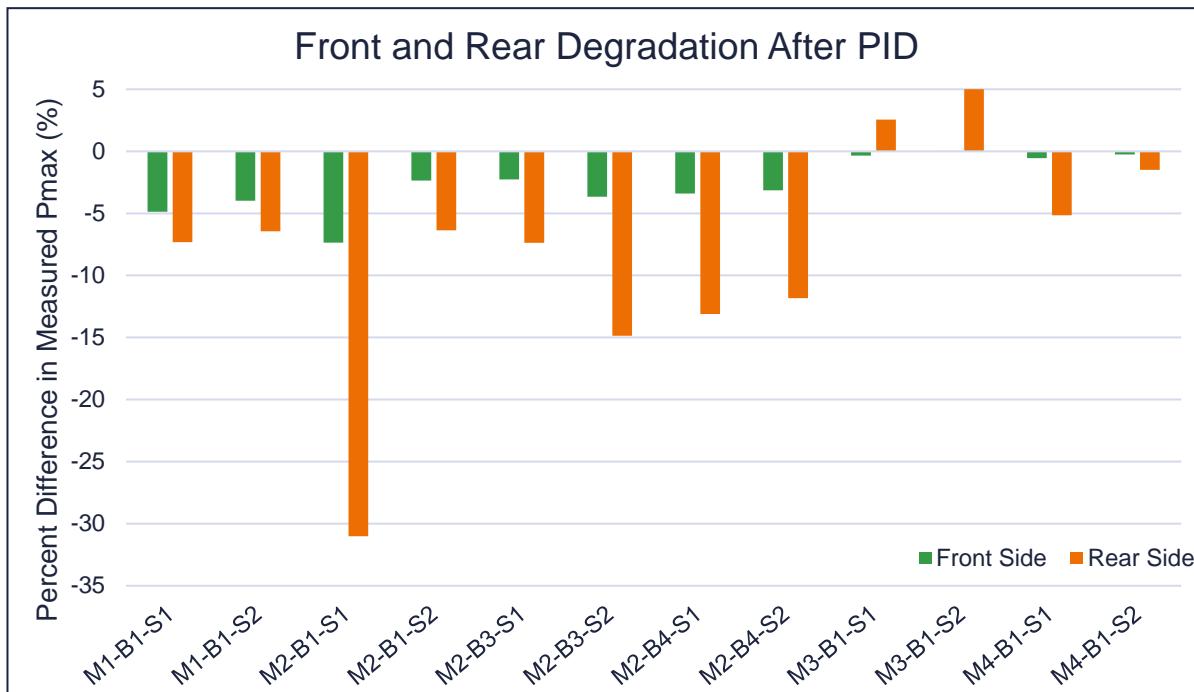
- › DML+TC50+HF30 also causes a range of results, some of which may be attributed to Boron-Oxygen destabilization during HF's high temp + no current conditions



# Initial Results: Potential-Induced Degradation

---

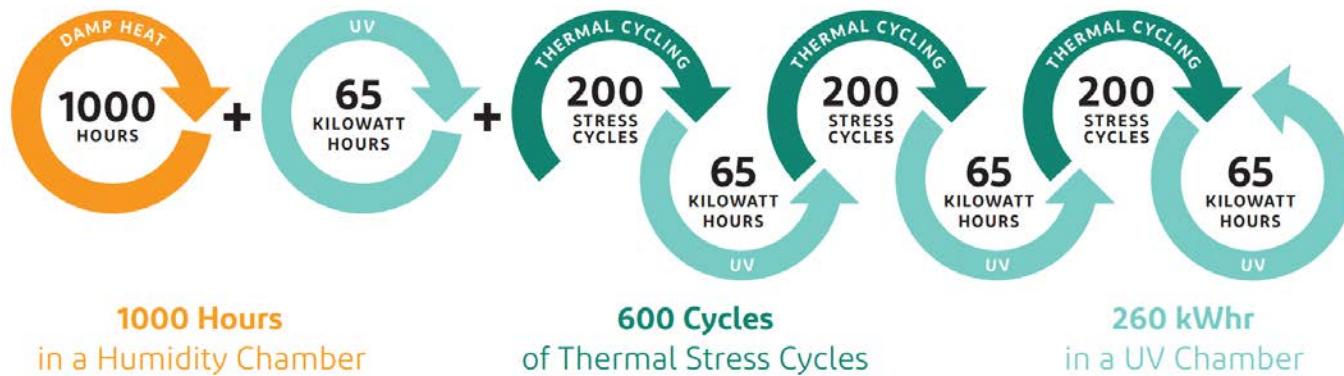
- › Rear-side polarization during PID testing can result in high degradation that is reversible in some cases – **but not all p-type bifacial modules are susceptible**



# Backsheet Testing

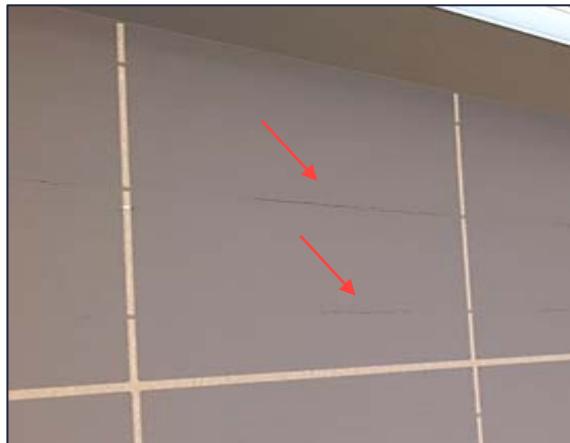
---

- › PVEL has completed a variety of backsheet tests with DuPont using their MAST test protocol
- › MAST submits modules to various stresses including extended UV exposure and thermal cycling to provide field-relevant backsheet durability results

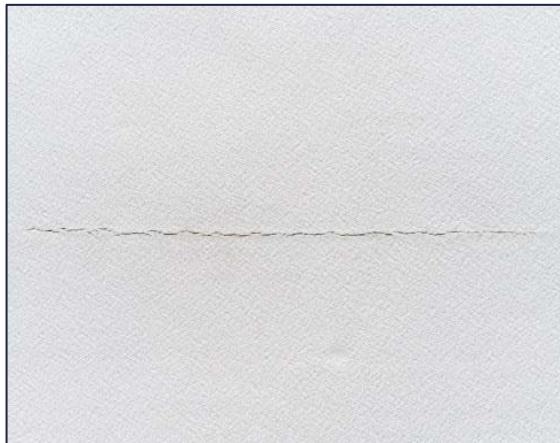


# PVEL's Backsheet Test Results

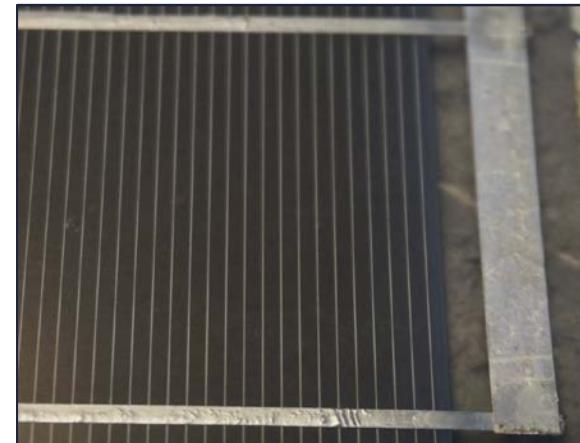
---



Isovoltaic 'AAA' Backsheet Field Failure  
(after 4 years)



Accelerated Lab Failure of  
PVDF (polyvinylidene fluoride)  
Source: PVEL



Clear Tedlar Shows No Cracking  
Following MAST  
Source: PVEL

# PVEL's 1500V Bifacial Testing in Davis, CA

---



- › 4 module manufacturers
- › NEXTracker
- › 0.37 GCR
- › 1.2 meter height
- › 2 x albedos
  - Grass/Dirt
  - White Sheet
- › Monofacial vs. bifacial
- › 1500V strings

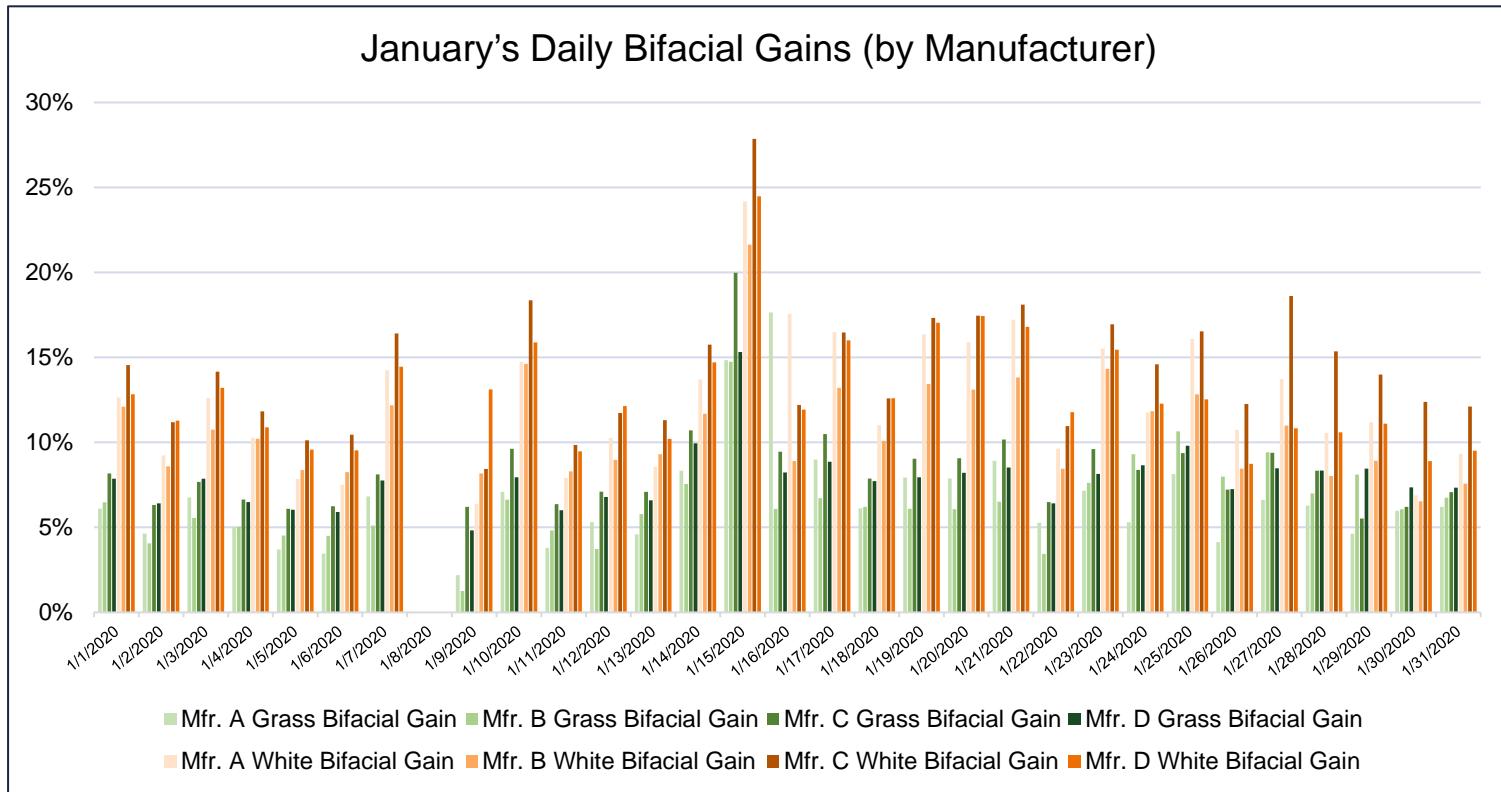
# PVEL's Outdoor Bifacial Study Participants

---

- › Additional manufacturers are participating on the same trackers with smaller sample sets
- › Study participants:
  - Astronergy (including 1500V strings)
  - ET Solar
  - First Solar
  - GCL
  - Jinko
  - LONGi (including 1500V strings)
  - Morgan Solar
  - Q CELLS (including 1500V strings)
  - Trina (including 1500V strings)

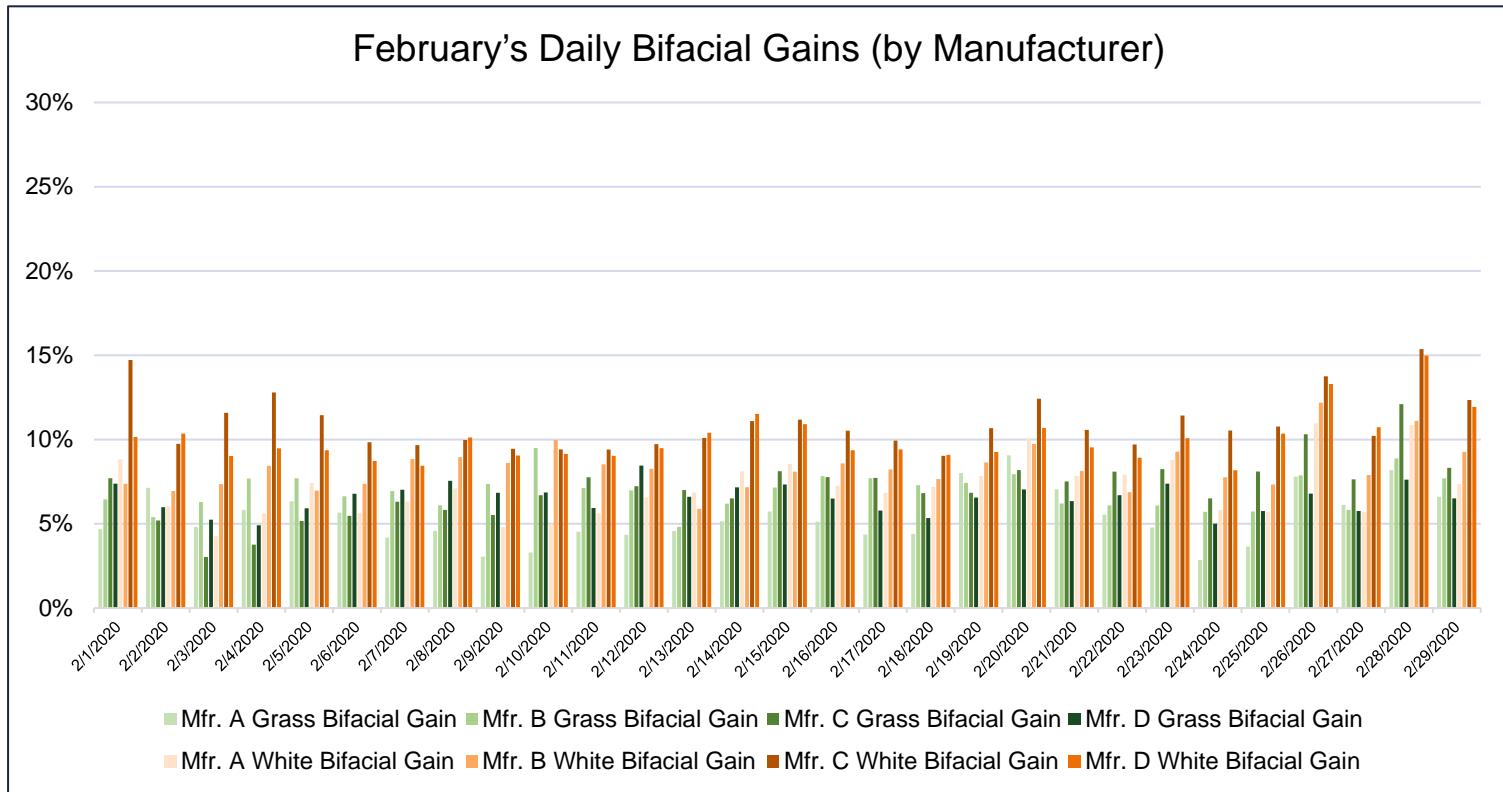


# Outdoor Performance Results: Bifacial Gains by Participant (January)



Data normalized to pre-light soak flash

# Outdoor Performance Results: Bifacial Gains by Participant (February)



Data normalized to pre-light soak flash

# Outdoor Performance Results: Summary (January and February)

---

- Weather data shows February had more than 2x the amount of insolation as January

	GHI (kWh/m <sup>2</sup> )	Albedo GHI (kWh/m <sup>2</sup> )	GHI Albedo Ratio (%)	POA (kWh/m <sup>2</sup> )	Albedo POA (kWh/m <sup>2</sup> )	POA Albedo Ratio (%)
Grass - January	56.9	11.4	20.0%	69.4	4.9	7.1%
White - January	56.2	25.7	45.8%	69.6	10.9	15.7%
Grass - February	109.5	27.2	24.8%	156.4	10.4	6.6%
White - February	116.5	54.8	47.0%	157.2	20.9	13.3%

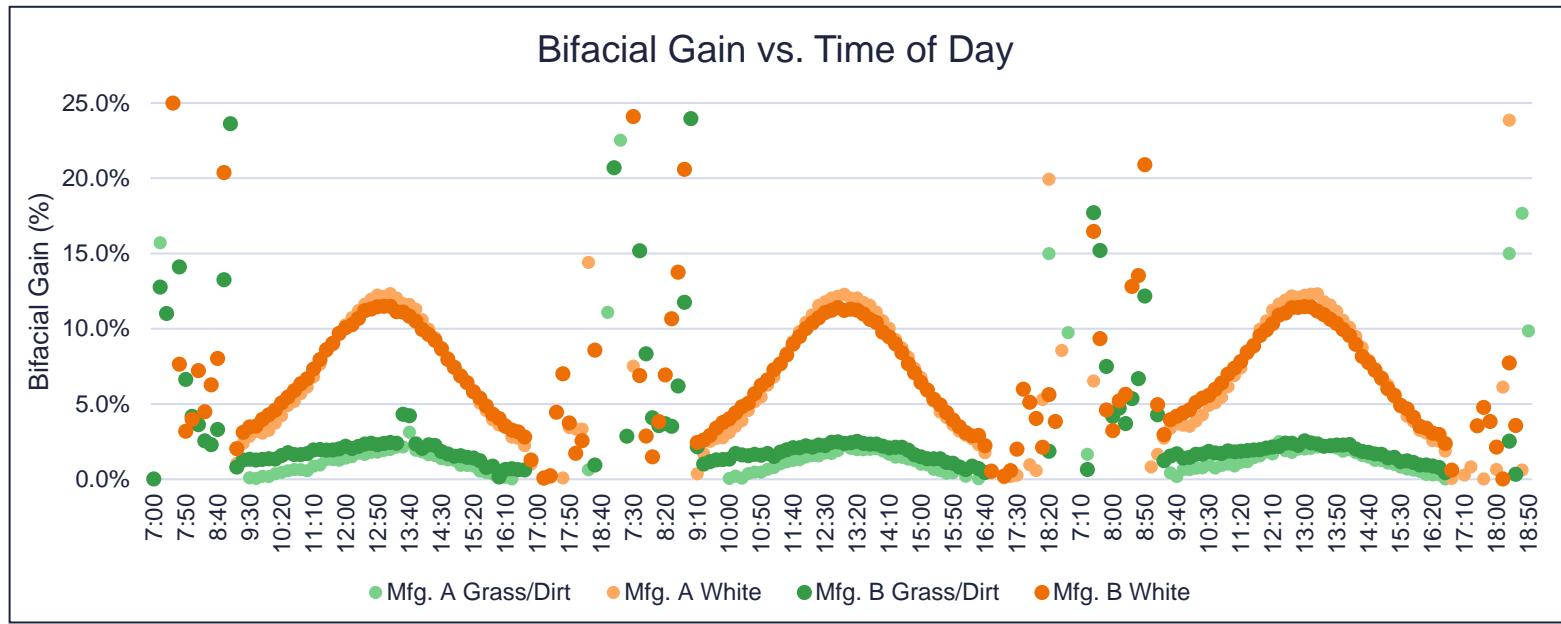
- Total bifacial gains for each month, per manufacturer:

	Bifacial Gain Grass - January	Bifacial Gain White - January	Bifacial Gain Grass - February	Bifacial Gain White - February
Mfr. A	5.64%	11.04%	5.36%	7.02%
Mfr. B	6.41%	9.98%	6.89%	8.30%
Mfr. C	7.69%	13.37%	7.08%	10.84%
Mfr. D	7.53%	11.61%	6.48%	10.01%

Data normalized to pre-light soak flash

# Outdoor Performance Results: Bifacial Gains by Time of Day

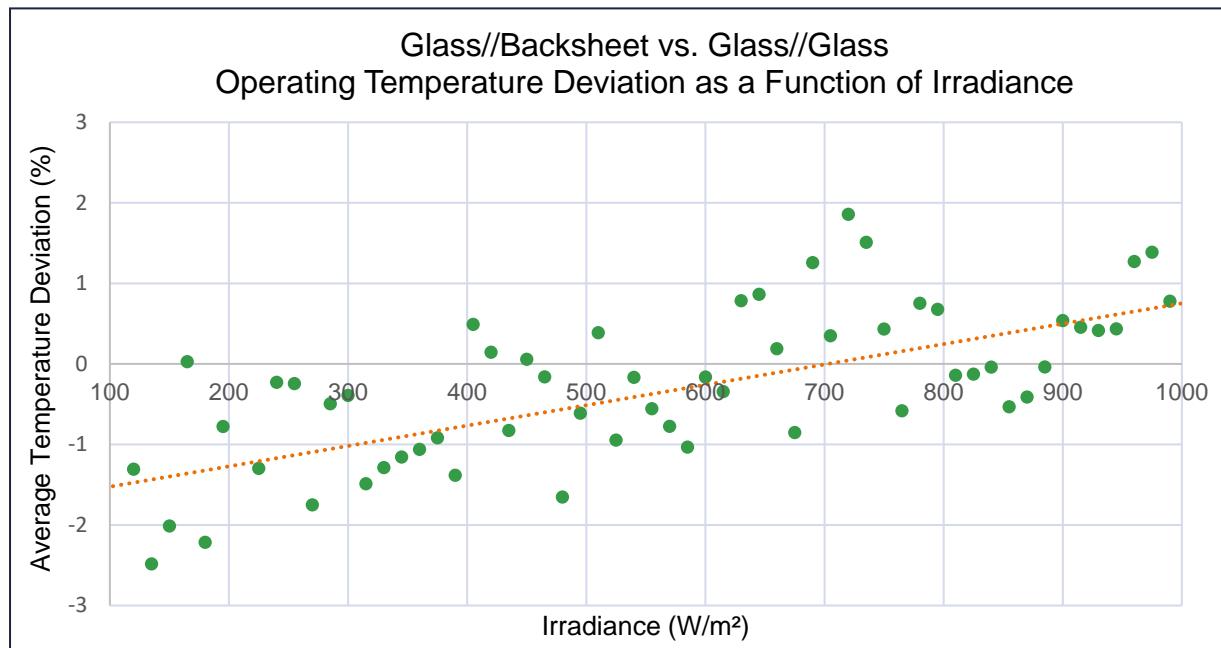
- Generally gains are highest mid-day, which could be lost to inverter clipping
- Lots of noise at start and end of day



# Outdoor Performance Results: Glass//Glass vs. Glass//Backsheet

---

- With identical cells to glass//glass, glass//backsheet operates at a lower temperature during periods of higher irradiance



Temperature and irradiance data taken in 5-minute intervals over 3 weeks.

A wide-angle photograph of a solar farm at sunset. The sky is filled with vibrant orange, yellow, and red clouds. In the foreground, numerous dark blue solar panels are arranged in a grid pattern. Three utility poles with wires are visible in the background. The overall scene conveys a sense of renewable energy and environmental sustainability.

THANK YOU!

**Tristan Erion-Lorico**

Head of PV Module Business

[tristan.erion-lorico@pvel.com](mailto:tristan.erion-lorico@pvel.com)





THIS MATERIAL IS BASED UPON WORK SUPPORTED BY THE U.S. DEPARTMENT OF ENERGY'S OFFICE OF ENERGY EFFICIENCY AND RENEWABLE ENERGY (EERE) UNDER THE SOLAR ENERGY TECHNOLOGIES OFFICE (SETO), AWARD NUMBER DE-EE0008546.

DISCLAIMER:

THIS PRESENTATION WAS PREPARED AS AN ACCOUNT OF WORK SPONSORED BY AN AGENCY OF THE UNITED STATES GOVERNMENT. NEITHER THE UNITED STATES GOVERNMENT NOR ANY AGENCY THEREOF, NOR ANY OF THEIR EMPLOYEES, MAKES ANY WARRANTY, EXPRESS OR IMPLIED, OR ASSUMES ANY LEGAL LIABILITY OR RESPONSIBILITY FOR THE ACCURACY, COMPLETENESS, OR USEFULNESS OF ANY INFORMATION, APPARATUS, PRODUCT, OR PROCESS DISCLOSED, OR REPRESENTS THAT ITS USE WOULD NOT INFRINGE PRIVATELY OWNED RIGHTS. REFERENCE HEREIN TO ANY SPECIFIC COMMERCIAL PRODUCT, PROCESS, OR SERVICE BY TRADE NAME, TRADEMARK, MANUFACTURER, OR OTHERWISE DOES NOT NECESSARILY CONSTITUTE OR IMPLY ITS ENDORSEMENT, RECOMMENDATION, OR FAVORING BY THE UNITED STATES GOVERNMENT OR ANY AGENCY THEREOF. THE VIEWS AND OPINIONS OF AUTHORS EXPRESSED HEREIN DO NOT NECESSARILY STATE OR REFLECT THOSE OF THE UNITED STATES GOVERNMENT OR ANY AGENCY THEREOF.