PVEL

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2022 PV MODULE RELIABILITY SCORECARD: PDF SUMMARY

TOP PERFORMER 2022 PVEL PV MODULE RELIABILITY SCORECARD

PV EVOLUTION LABS

member of group kiwa

Table of Contents

Visit https://www.modulescorecard.pvel.com to explore our full report.

This PDF summarizes the 2022 PV Module Reliability Scorecard. It lists Top Performers and highlights selected findings from testing. Note that data from PVEL's hail and backsheet testing are exclusively available in the online edition of the Scorecard.

About PV Evolution Labs

PV Evolution Labs (PVEL) is the leading reliability and performance testing lab for downstream solar project developers, financiers, and asset owners and operators around the world and a member of the Kiwa Group. With over ten years of experience and accumulated data, PVEL conducts testing that demonstrates solar technology bankability. Its trusted, independent reports replace assumptions about solar equipment performance with data-driven, quantifiable metrics that enable efficient solar project development and financing.

The PVEL network connects all major PV and storage manufacturers with 400+ global Downstream Partners representing 30+ gigawatts of annual buying power. PVEL's mission is to support the worldwide PV downstream buyer community by generating data that accelerates adoption of solar technology. Learn more online at pvel.com.

Methodology

PVEL's Scorecards summarize results from our independent testing and name specific PV module model types as Top Performers. Our consistent approach to testing and benchmarking PV module reliability drives data-driven solar procurement and investments for developers, financiers and asset owners.

Testing Unique BOMs

Although PVEL's Scorecard lists Top Performers by model type, they represent unique bills of materials (BOMs) that have undergone testing in our Product Qualification Program (PQP) for PV modules.

PVEL's test results from the lab and field demonstrate that individual PV module components can dramatically affect product quality. PV modules with the exact same model type can be manufactured from completely different BOMs. Suppliers are free to mix-and-match integral materials - even cells - so long as all the components are listed in the model's IEC certification report.

While individual BOMs are not marketed to buyers, PQP reports clearly document the BOMs of each model that performed well in testing. PVEL's downstream partners can leverage PQP reports to specify BOMs in supply agreements.

Scorecard Eligibility

To be eligible for the Scorecard, manufacturers must have:

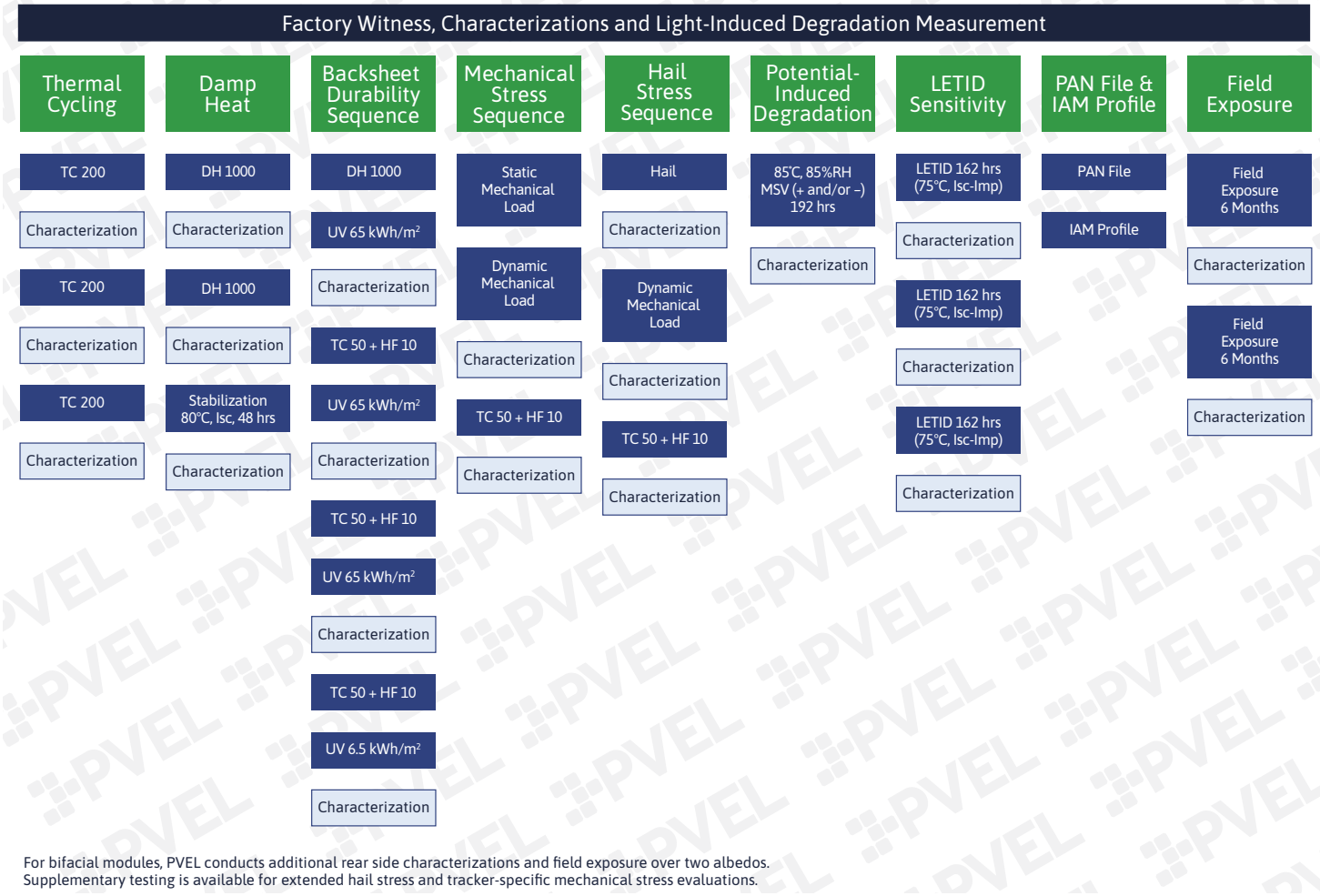
- Completed the factory witness within 18 months of 2022.
- Submitted modules to all reliability test sequences in the PQP.
- Submitted at least two factory-witnessed PV module samples per test sequence.

Scorecard Scoring

The 2022 PV Module Reliability Scorecard shows Top Performers for six PQP test categories. Not all products or model types are represented in every test.

Manufacturers with top-performing results can choose not to be listed in the Scorecard. In some cases, test results were not available at the time of publication.

PVEL's PV Module PQP



For bifacial modules, PVEL conducts additional rear side characterizations and field exposure over two albedos.
Supplementary testing is available for extended hail stress and tracker-specific mechanical stress evaluations.

Four Principles Guide the PQP

Empirical data
The PQP provides empirical metrics for revenue and energy yield modeling.

No hand-picked samples
Auditors witness production of all test samples and record BOM details.

Standard processes
The PQP tests all BOMs in the same way with calibrated equipment and in consistent test environments.

Regular program updates
Test sequence updates provide data on new technologies and manufacturing techniques.

Thermal Cycling

PVEL's thermal cycling (TC) test assesses a PV module's ability to withstand changes in temperature. While ambient temperatures vary daily and seasonally in most solar markets, top-performing TC results are most critical in locations where temperatures are much lower at night than during the day, such as desert environments and high-altitude regions.

Key Takeaways

- This year's TC results are the best in PVEL's history: 90% of BOMs tested degraded by less than 2%, with a median of 0.72% and average of 0.97%.
- Over 70% of BOMs tested were multi-busbar (MBB). BOMs with MBB cell interconnections achieved better test results than older busbar designs on average, indicating that MBB soldering issues can be addressed.
- Two BOMs that passed IEC 61215's TC 200 requirements ultimately degraded by more than 5% after PVEL's TC 600 test, which demonstrates that accelerated testing remains necessary for risk mitigation.

Go to https://www.modulescorecard.pvel.com for content available exclusively online:

- A searchable database of all Top Performers.
- A graph of 2022 and historic test results.
- An example from PVEL's lab testing.
- A case study of a module warranty claim.
- Background information about PVEL's TC test and procedure.

Note about Top Performers:
Manufacturers are listed in alphabetical order. The tested products are listed first. Variants for which the test results are representative are listed in parentheses. In some cases, test results were not available at the time of publication.

Thermal Cycling Top Performers

MFR.	MODEL TYPES
Adani Solar	ASB-7-AAA-N; ASB-7-AAA-P (ASB-6-AAA-N; ASB-6-AAA-P)
Astronergy	CHSM66M(DG)/F-BH-xxx; CHSM72M(DG)/F-BH-xxx; CHSM72M-HC-xxx (CHSM60M(DG)/F-BH-xxx; CHSM60M-HC-xxx)
Boviet	BVM6612M-xxxS-H-HC-BF; BVM6612M-xxxS-H-HC-BF-DG; BVM7612M-xxx-H-HC-BF-DG (BVM6610M-xxxS-H-HC-BF; BVM6610M-xxxS-H-HC-BF-DG; BVM7610M-xxx-H-HC-BF-DG)
DMEGC	DMxxxM6-G72HST (DMxxxM6-G60HST)
ET Solar	ET-M660BHxxxBB; ET-M672BHxxxGL; ET-M772BHxxxTW (ET-M660BHxxxGL; ET-M760BHxxxTW)
HHDC/SPIC	SPICN6(MDF)-72-xxx/BIH (SPICN6(MDF)-60-xxx/BIH)
HT-SAAE	HT72-18X-xxx (HT60-18X-xxx)
JA Solar	JAM72S10-xxx/MR; JAM78S10-xxx/MR (JAM60S10-xxx/MR; JAM60S17-xxx/MR)
Jinko	JKMxxxM-6RL3; JKMxxxM-72HL4-BDVP; JKMxxxM-72HL4-TV; JKMxxxM-72HLM-TV; JKMxxxM-7RL3-V (JKMxxxM-60HL4-BDVP; JKMxxxM-60HL4-TV; JKMxxxM-60HLM-TV; JKMxxxM-6RL3-B; JKMxxxM-6TL3; JKMxxxM-6TL3-B)
LONGi	LR4-72HBD-xxxM; LR4-72HPH-xxxM (LR4-60HBD-xxxM; LR4-60HPB-xxxM; LR4-60HPH-xxxM)
Maxeon/ SunPower	SPR-MAX5-xxx-COM (SPR-Axxx-COM)
Phono Solar	PSxxxM4GFH-24/TH (PSxxxM4GFH-20/TH)
Qcells	Q.PEAK DUO BLK ML-G9+; Q.PEAK DUO BLK-G6+; Q.PEAK DUO G8+; Q.PEAK DUO L-G5.2; Q.PEAK DUO L-G6.3/BFG; Q.PEAK DUO L-G8.3; Q.PEAK DUO L-G8.3/BFG (Q.PEAK DUO BLK-G5; Q.PEAK DUO-G5)
REC Group	TP3M Black
Risen Energy	RSM144-7-xxxBMDG (RSM120-7-xxxBMDG)
Seraphim/ SEG Solar	SRP-xxx-BMA-BG (SRP-xxx-BMB-BG)
Suntech	STPxxxS-C72/Vmh (STPxxxS-C54/Umhm; STPxxxS-C54/Umhb)
Talesun	TD6G72M-xxx (TD6G60M-xxx)
Trina Solar	TSM-xxxDE06X.05(II); TSM-xxxDE09.05; TSM-xxxDE15M(II); TSM-xxxDE15V(II); TSM-xxxDEG15VC.20(II); TSM-xxxDEG19C.20; TSM-xxxDEG21C.20 (TSM-xxxDE09.08; TSM-xxxDEG20C.20)
VSUN	VSUNxxx-144MH (VSUNxxx-120MH)
Waaree	WSM-AAA (WSM-AAA)

Damp Heat

PVEL's damp heat (DH) test evaluates the impact of heat and humidity on PV module reliability. We assess susceptibility to moisture ingress, delamination, and corrosion. Projects in hot environments with high humidity require PV modules with top-performing DH results.

Key Takeaways

- There was a wide range of performance in DH: 50% of BOMs achieved top-performing results after the full test sequence, but one BOM degraded by 54%, the worst DH result in PVEL history.
- There was a 67% decrease in BOMs requiring boron-oxygen (BO) stabilization: Only 23% of top-performing BOMs required BO stabilization to achieve <2% degradation versus 70% in 2021. This reduction in destabilization makes DH test results much easier for buyers to interpret. These improvements resulted from increased use of gallium dopants during crystalline cell manufacturing.
- Many BOMs with concerning DH results came from manufacturers that are listed as Top Performers for other model types. This proves small component changes can severely impact reliability.

Go to https://www.modulescorecard.pvel.com for content available exclusively online:

- A searchable database of all Top Performers.
- A graph of 2022 and historic test results.
- A case study of a successful module class-action lawsuit claim.
- Background information about BO destabilization and PVEL's DH test and procedure.

Damp Heat Top Performers

MFR.	MODEL TYPES
Adani Solar	ASB-7-AAA-N* (ASB-6-AAA-N*)
Astronergy	CHSM72M(DG)/F-BH-xxx (CHSM60M(DG)/F-BH-xxx)
Boviet	BVM6612M-xxxS-H-HC-BF-DG; BVM7612M-xxx-H-HC-BF-DG (BVM6610M-xxxS-H-HC-BF-DG; BVM7610M-xxx-H-HC-BF-DG)
DMEGC	DMxxxM6-G72HST (DMxxxM6-G60HST)
ET Solar	ET-M672BHxxxGL*; ET-M772BHxxxTW* (ET-M660BHxxxGL*; ET-M760BHxxxTW*)
HT-SAAE	HT72-156M(V)-xxx (HT60-156M-xxx)
Jinko	JKMxxxM-72HL4-BDVP; JKMxxxM-7RL3-V (JKMxxxM-60HL4-BDVP)
LONGi	LR4-72HBD-xxxM (LR4-60HBD-xxxM)
Maxeon/ SunPower	SPR-MAX5-xxx-COM (SPR-Axxx-COM)
Phono Solar	PSxxxM4GFH-24/TH (PSxxxM4GFH-20/TH)
Qcells	Q.PEAK DUO BLK ML-G9+*; Q.PEAK DUO L-G8.3*; Q.PEAK DUO L-G8.3/BFG; Q.PEAK DUO XL-G10.3/BFG
REC Group	Alpha Black*; TP3M Black
Risen Energy	RSM144-7-xxxBMDG (RSM120-7-xxxBMDG)
Seraphim/ SEG Solar	SRP-xxx-BMA-BG (SRP-xxx-BMB-BG)
Talesun	TD6G72M-xxx; TD7G66M-xxx (TD6G60M-xxx; TD7G72M-xxx; TD7G78M-xxx)
Trina Solar	TSM-xxxDEG15VC.20(II); TSM-xxxDEG19C.20 (TSM-xxxDEG20C.20; TSM-xxxDEG21C.20)
Vikram	VSMDHT.72.AAA.05 (VSMDHT.60.AAA.05; VSMDHT.78.AAA.05)

***Top-performing result achieved after BO stabilization.**

Note about Top Performers:
Manufacturers are listed in alphabetical order. The tested products are listed first. Variants for which the test results are representative are listed in parentheses. In some cases, test results were not available at the time of publication.

Mechanical Stress Sequence

PVEL's mechanical stress sequence (MSS) has two primary objectives: to determine whether cells in PV modules are vulnerable to cracking under pressure and if cell damage is likely to cause power loss or lead to hot spots (a potential safety risk) in the field. Strong MSS results are most important in project locations with extreme weather events and conditions, including heavy snow and high winds.

Key Takeaways

- While 72% of BOMs are Top Performers in MSS, PVEL observed a significant number of failures during this sequence in 2022 Scorecard testing. The most common failure mode was broken glass, not power loss.
- More than 80% of modules greater than 2100 mm tall are Top Performers, compared to just 68% of modules less than 2100 mm. This indicates that larger modules can be optimized for mechanical strength.
- Glass//glass BOMs only failed because of glass breakage, not cell-level damage. Glass// backsheet BOMs were more susceptible to cell cracking, but less susceptible to glass breakage.

Go to https://www.modulescorecard.pvel.com for content available exclusively online:

- A searchable database of all Top Performers.
- A graph of 2022 and historic test results.
- An example from PVEL's lab testing.
- Insights into the pros and cons of large-format PV module designs.
- Background information about PVEL's MSS test and procedure.

Mechanical Stress Sequence Top Performers

MFR.	MODEL TYPES
Adani Solar	ASB-7-AAA-N; ASB-7-AAA-P (ASB-6-AAA-N; ASB-6-AAA-P)
Astronergy	CHSM66M(DG)/F-BH-xxx; CHSM72M(DG)/ F-BH-xxx; CHSM72M-HC-xxx (CHSM60M(DG)/F-BH-xxx; CHSM60M(DG)/ F-BH-xxx; CHSM60M-HC-xxx)
Boviet	BVM6612M-xxxS-H-HC-BF-DG (BVM6610M-xxxS-H-HC-BF-DG)
DMEGC	DMxxxM6-G72HST (DMxxxM6-G60HST)
ET Solar	ET-M672BHxxxGL; ET-M772BHxxxTW (ET-M660BHxxxGL; ET-M760BHxxxTW)
JA Solar	JAM72S10-xxx/MR; JAM78S10-xxx/MR (JAM60S10-xxx/MR)
Jinko	JKMxxxM-6RL3; JKMxxxM-6RL3-B; JKMxxxM-6TL3; JKMxxxM-72HL4-BDVP; JKMxxxM-72HL4-TV; JKMxxxM-7RL3-V (JKMxxxM-60HL4-BDVP; JKMxxxM-60HL4-TV; JKMxxxM-6TL3-B)
LONGi	LR4-60HPB-xxxM; LR4-72HBD-xxxM; LR4-72HPH-xxxM (LR4-60HBD-xxxM; LR4-60HPH-xxxM)
Maxeon/ SunPower	SPR-MAX5-xxx-COM (SPR-Axxx-COM)
Phono Solar	PSxxxM4GFH-24/TH (PSxxxM4GFH-20/TH)
Qcells	Q.PEAK DUO BLK ML-G9+; Q.PEAK DUO BLK-G6+; Q.PEAK DUO G6+; Q.PEAK DUO G8+; Q.PEAK DUO L-G5.2; Q.PEAK DUO L-G8.3/BFG; Q.PEAK DUO XL-G10.3/BFG; Q.PEAK DUO XL-G10.c
REC Group	TP3M Black
Seraphim/ SEG Solar	SRP-xxx-BMA-BG (SRP-xxx-BMB-BG)
Suntech	STPxxxS-C72/Vmh (STPxxxS-C54/Umhm; STPxxxS-C54/Umhb)
Talesun	TD6G72M-xxx (TD6G60M-xxx)
Trina Solar	TSM-xxxDE06X.05(II); TSM-xxxDE09.05; TSM-xxxDE09.08; TSM-xxxDE15M(II); TSM-xxxDE15V(II); TSM-xxxDE19; TSM-xxxDEG15VC.20(II); TSM-xxxDEG19C.20; TSM-xxxDEG21C.20 (TSM-xxxDEG20C.20)

Note about Top Performers:
Manufacturers are listed in alphabetical order. The tested products are listed first. Variants for which the test results are representative are listed in parentheses. In some cases, test results were not available at the time of publication.

PID

Potential-induced degradation (PID) is triggered by high PV system voltages on ungrounded systems. PID is more likely to occur in projects that use transformerless inverters, especially in high temperature and high humidity environments. While PID is sometimes reversible, severe and permanent PID can decrease energy yield by as much as 30%.

Key Takeaways

- PID results improved markedly as compared to 2021, when PVEL reported the highest mean and median PID rates in its history. Yet PID remains unsolved: 5% of BOMs tested for this Scorecard degraded by >8% after PID testing.
- While BOMs with EVA encapsulants were Top Performers, BOMs with POE encapsulants were generally less susceptible to PID. 93% of POE BOMs are 2022 Top Performers vs. 72% of EVA BOMs.
- Average power loss for monofacial modules was slightly lower than the average front-side PID rate for bifacial modules. In contrast to 2021, front- and rear-side PID rates for bifacial modules were tightly aligned this year.

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- A searchable database of all Top Performers.
- A graph of 2022 and historic test results.
- An example from PVEL's lab testing.
- A case study of PID in the field contributed by Kiwa Moroni.
- Background information about PVEL's PID test and procedure.

Note about Top Performers:
Manufacturers are listed in alphabetical order. The tested products are listed first. Variants for which the test results are representative are listed in parentheses. In some cases, test results were not available at the time of publication.

PID Top Performers

MFR.	MODEL TYPES
Adani Solar	ASB-7-AAA-N (ASB-6-AAA-N)
Astronergy	CHSM60M(DG)/F-BH-xxx; CHSM60M-HC-xxx; CHSM72M(DG)/F-BH-xxx (CHSM60M(DG)/F-BH-xxx; CHSM66M(DG)/F-BH-xxx; CHSM72M-HC-xxx)
Boviet	BVM6612M-xxxS-H-HC-BF-DG; BVM7612M-xxx-H-HC-BF-DG (BVM6610M-xxxS-H-HC-BF-DG; BVM7610M-xxx-H-HC-BF-DG)
DMEGC	DMxxxM10-B72HSW; DMxxxM6-G72HST (DMxxxM10-B60HSW; DMxxxM6-G60HST)
ET Solar	ET-M672BHxxxGL; ET-M772BHxxxTW (ET-M660BHxxxGL; ET-M760BHxxxTW)
First Solar	FS-6xxxA
Heliene	144HC-M10-Bifacial (120HC-M10-SL; 120HC-M10-Bifacial; 132HC-M10-SL; 132HC-M10-SL-Bifacial; 144HC-M10-SL- Bifacial)
HHDC/SPIC	SPICN6(MDF)-72-xxx/BIH (SPICN6(MDF)-60-xxx/BIH)
JA Solar	JAM72S10-xxx/MR (JAM60S10-xxx/MR; JAM60S17-xxx/MR; JAM78S10-xxx/MR)
Jinko	JKMxxxM-6RL3; JKMxxxM-72HL4-BDVP; JMxxxM-72HL4-TV; JKMxxxM-72HLM-TV; JKMxxxM-72HL-TV; JKMxxxM-7RL3-V (JKMxxxM-60HL4-BDVP; JKMxxxM-60HL4-TV; JKMxxxM-60HLM-TV; JKMxxxM-60HL-TV; JKMxxxM-60H-TV; JKMxxxM-6RL3-B; KMxxxM-6TL3; JKMxxxM-6TL3-B; JKMxxxM-72H-TV)
LONGi	LR4-72HBD-xxxM; LR4-72HPH-xxxM (LR4-60HBD-xxxM; LR4-60HPB-xxxM; LR4-60HPH-xxxM)
Phono Solar	PSxxxM4GFH-24/TH (PSxxxM4GFH-20/TH)
Qcells	Q.PEAK DUO BLK ML-G9+; Q.PEAK DUO BLK-G6+; Q.PEAK DUO G8+; Q.PEAK DUO L-G5.2; Q.PEAK DUO L-G8.3; Q.PEAK DUO XL-G10.c (Q.PEAK DUO BLK ML-G10+; Q.PEAK DUO BLK-G5; Q.PEAK DUO ML-G10+; Q.PEAK DUO-G10; Q.PEAK DUO-G5)
REC Group	Alpha Pure; TP3M Black
Risen Energy	RSM144-7-xxxBMDG (RSM120-7-xxxBMDG)
Seraphim/ SEG Solar	SRP-xxx-BMA-BG (SRP-xxx-BMB-BG)
Suntech	STPxxxS-C72/Vmh (STPxxxS-C54/Umhm; STPxxxS-C54/Umhb)
Talesun	TD6G72M-xxx; TD7G66M-xxx (TD6G60M-xxx; TD7G60M-xxx; TD7G72M-xxx; TD7G78M-xxx)
Trina Solar	TSM-xxxDE06X.05(II); TSM-xxxDE09.05; TSM-xxxDE09.08; TSM-xxxDE15V(II); TSM-xxxDEG15VC.20(II); TSM-xxxDEG19C.20 (TSM-xxxDEG20C.20; TSM-xxxDEG21C.20)
Vikram	VSMDHT.72.AAA.05 (VSMDHT.60.AAA.05; VSMDHT.78.AAA.05)
ZNShine	ZXM7-SHLDD144-xxx/M (ZXM7-SHLDD108-xxx/M; ZXM7-SHLDD120-xxx/M)

LID + LETID

Light-induced degradation (LID) and light-and-elevated temperature-induced degradation (LETID) are cell-based phenomena triggered by light exposure that should be considered in energy yield models. LID rates vary by cell technology and typically stabilize within a few days or weeks of field operation. LETID mainly affects PERC cells. Research suggests it is most severe in hot climates.

Key Takeaways

- Almost all BOMs tested in this category were Top Performers this year, and only one BOM had a degradation rate over 3%.
- Improved LID+LETID test results were largely driven by advancements in cell doping, a key step of the manufacturing process for crystalline cells.
- Commercially available products sold under the same model type as LID+LETID Top Performers may behave differently in the field. Manufacturers often offer several BOMs to clients with varying performance and cost, so buyers should refer to PVEL's reports to specify their desired BOMs in module supply contracts.

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- A searchable database of all Top Performers.
- A graph of 2022 and historic test results.
- An example from PVEL's lab testing.
- Insights from Avangrid on the value of utilizing LID and LETID testing in performance models.
- Background information about PVEL's LID and LETID tests and procedures.

Note about Top Performers:
Manufacturers are listed in alphabetical order. The tested products are listed first. Variants for which the test results are representative are listed in parentheses. In some cases, test results were not available at the time of publication.

LID + LETID Top Performers

MFR.	MODEL TYPES
Adani Solar	ASB-7-AAA-P (ASB-6-AAA-P)
Astronergy	CHSM60M-HC-xxx; CHSM72M(DG)/F-BH-xxx (CHSM60M(DG)/F-BH-xxx; CHSM72M-HC-xxx)
Boviet	BVM6612M-xxxS-H-HC-BF-DG; BVM7612M-xxx-H-HC-BF-DG (BVM6610M-xxxS-H-HC-BF; BVM6610M-xxxS-H-HC-BF-DG; BVM6612M-xxxS-H-HC-BF; BVM7610M-xxx-H-HC-BF; BVM7610M-xxx-H-HC-BF-DG; BVM7612M-xxx-H-HC-BF)
DMEGC	DMxxxM6-G72HST (DMxxxM6-G60HST)
ET Solar	ET-M660BHxxxBB; ET-M772BHxxxTW (ET-M760BHxxxTW)
First Solar	FS-6xxxA
HHDC/SPIC	SPICN6(MDF)-72-xxx/BIH (SPICN6(MDF)-60-xxx/BIH)
HT-SAAE	HT60-18X-xxx; HT72-156M(V)-xxx (HT60-156M-xxx; HT72-18X-xxx)
JA Solar	JAM72S10-xxx/MR (JAM60S10-xxx/MR ; JAM60S17-xxx/MR ; JAM78S10-xxx/MR)
Jinko	JKMxxxM-72HL4-TV; JKMxxxM-72HLM-TV; JKMxxxM-72HL-TV; JKMxxxM-7RL3-V (JKMxxxM-60HL4-BDVP; JKMxxxM-60HL4-TV; JKMxxxM-60HLM-TV; JKMxxxM-60HL-TV; JKMxxxM-60H-TV; JKMxxxM-6RL3; JKMxxxM-6RL3-B; JKMxxxM-6TL3; JKMxxxM-6TL3-B; JKMxxxM-72HL4-BDVP; JKMxxxM-72H-TV)
LONGi	LR4-72HBD-xxxM (LR4-60HBD-xxxM; LR4-60HPB-xxxM; LR4-60HPH-xxxM; LR4-72HPH-xxxM)
Phono Solar	PSxxxM4GFH-24/TH (PSxxxM4GFH-20/TH)
Qcells	Q.PEAK DUO BLK ML-G9+; Q.PEAK DUO BLK-G6+; Q.PEAK DUO G8+; Q.PEAK DUO L-G5.2; Q.PEAK DUO L-G6.3/BFG; Q.PEAK DUO L-G8.3/BFG; Q.PEAK DUO XL-G10.3/BFG; Q.PEAK DUO XL-G10.c (Q.PEAK DUO BLK ML-G10+; Q.PEAK DUO BLK-G5; Q.PEAK DUO ML-G10+; Q.PEAK DUO-G10; Q.PEAK DUO-G5)
REC Group	TP3M Black
Risen Energy	RSM144-7-xxxBMDG (RSM120-7-xxxBMDG)
Seraphim/ SEG Solar	SRP-xxx-BMA-BG (SRP-xxx-BMB-BG)
Suntech	STPxxxS-C72/Vmh (STPxxxS-C54/Umhm; STPxxxS-C54/Umhb)
Talesun	TD6G72M-xxx; TD7G66M-xxx (TD6G60M-xxx; TD7G60M-xxx; TD7G72M-xxx; TD7G78M-xxx)
Trina Solar	TSM-xxxDE09.05; TSM-xxxDE15M(II); TSM-xxxDEG15VC.20(II); TSM-xxxDEG19C.20 (TSM-xxxDE06X.05(II); TSM-xxxDE09.08; TSM-xxxDE15V(II); TSM-xxxDE19; TSM-xxxDE20; TSM-xxxDEG20C.20; TSM-xxxDE21; TSM-xxxDEG21C.20)
Vikram	VSMDHT.72.AAA.05 (VSMDHT.60.AAA.05; VSMDHT.78.AAA.05)
VSUN	VSUNxxx-144MH (VSUNxxx-120MH)

PAN Performance

PVEL's PAN files simulate PV module performance in different temperature and irradiance conditions and are used as data inputs for energy models. Using empirical performance data improves energy yield forecast accuracy for all projects, but it is most impactful for extreme environments (e.g., high-temperature or low-irradiance conditions) that are poorly represented by default performance assumptions.

Key Takeaways

- All PAN Top Performers are bifacial. The average bifacial model type had a 7% higher specific energy yield than the average monofacial model type for the Las Vegas simulation.
- The biggest impacts on bifacial energy yield are a combination of the module temperature coefficients, the manufacturer's bifacial flash testing/nameplate rating accuracy, and the module bifaciality, which measures rear-side output relative to front-side output. In general, power class, wafer size and rear-side material are not drivers of specific energy yield, defined here as energy produced per watt installed.
- PVEL's analysis of PAN test results over time reveals that low-light performance is becoming more predictable across a range of manufacturers due to increased consistency in cell and module designs.

Go to https://www.modulescorecard.pvel.com for content available exclusively online:

- A searchable database of all Top Performers.
- A graph of 2022 and historic test results.
- Data from kWh Analytics on trends in performance model accuracy over time.
- Background information about PVEL's PAN test and procedure.

PAN Performance Top Performers

MFR.	MODEL TYPES
Astronergy	CHSM60M(DG)/F-BH-xxx; CHSM72M(DG)/F-BH-xxx
Boviet	BVM6610M-xxxS-H-HC-BF-DG; BVM6612M-xxxS-H-HC-BF-DG; BVM7610M-xxx-H-HC-BF-DG
ET Solar	ET-M772BHxxxTW
HHDC/SPIC	SPICN6(MDF)-72-xxx/BIH
HT-SAAE	HT60-18X-xxx; HT72-18X-xxx
Jinko	JKMxxxM-72HL-TV (JKMxxxM-72H-TV)
LONGi	LR4-72HBD-xxxM
Qcells	Q.PEAK DUO L-G6.3/BFG
Risen Energy	RSM144-7-xxxBMDG
Seraphim/ SEG Solar	SRP-xxx-BMA-BG
Talesun	TD7G66M-xxx

Note about Top Performers:
Manufacturers are listed in alphabetical order. The tested products are listed first. Variants for which the test results are representative are listed in parentheses. In some cases, test results were not available at the time of publication.

The Top Performers listed are module types whose PVsyst simulations for the Las Vegas or Boston site resulted in a kWh/kWp energy yield within the top quartile of all eligible results. The data presented here is only from PVEL's PAN testing as part of a PQP where the samples are factory witnessed.

Historical Scorecard

The table below shows the history of top performance for all manufacturers featured in the 2022 Scorecard. Manufacturers are listed by the number of years they have been designated a Top Performer, in alphabetical order.

	2022	2021	2020	2019	2018	2017	2016	2014
Jinko	■	■	■	■	■	■	■	■
Trina Solar	■	■	■	■	■	■	■	■
JA Solar	■	■	■	■	■		■	■
Qcells	■	■	■	■	■	■	■	
REC Group	■	■	■	■	■	■	■	
Astronergy	■	■	■		■	■		■
LONGi	■	■	■	■	■	■		
Adani Solar	■	■	■	■	■			
Maxeon/SunPower	■	■	■		■	■		
Phono Solar	■	■		■	■		■	
Seraphim/SEG Solar	■	■	■	■		■		
Suntech	■		■	■	■			■
Vikram Solar	■	■	■	■		■		
Boviet	■	■	■	■				
First Solar	■	■	■		■			
HT-SAAE	■	■	■		■			
ZNShine	■			■				■
Talesun	■	■				■		
DMEGC	■	■						
ET Solar	■	■						
Heliene	■		■					
HHDC/SPIC	■	■						
Risen Energy	■	■						
VSUN	■	■						
Waaree	■							

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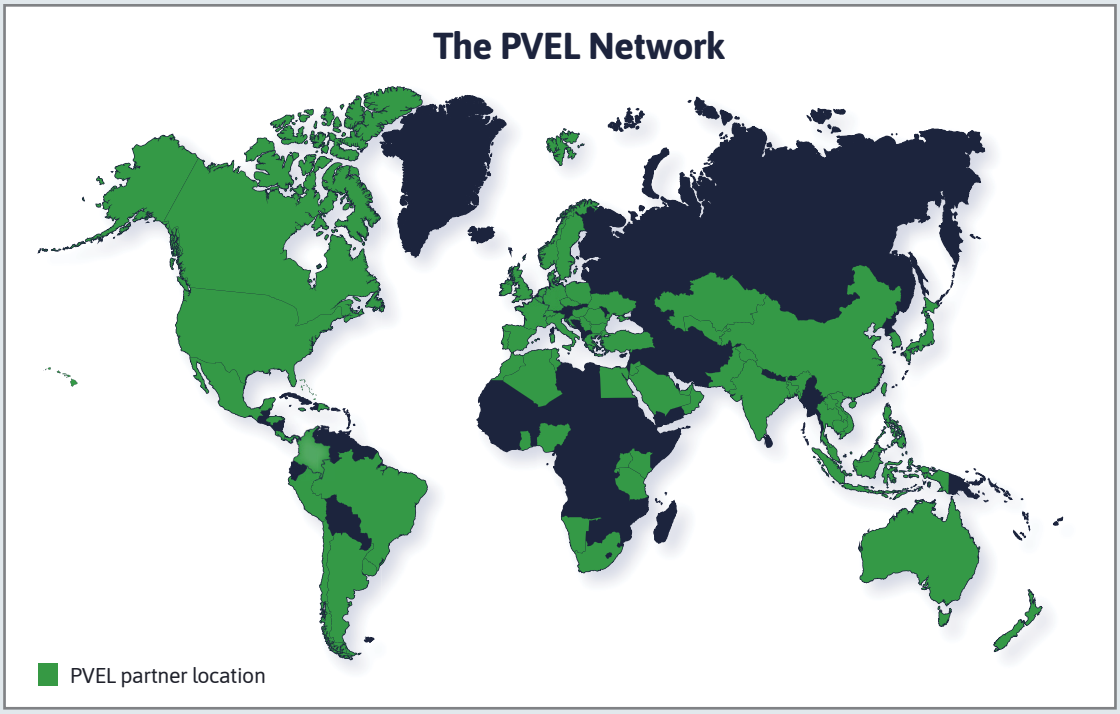

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