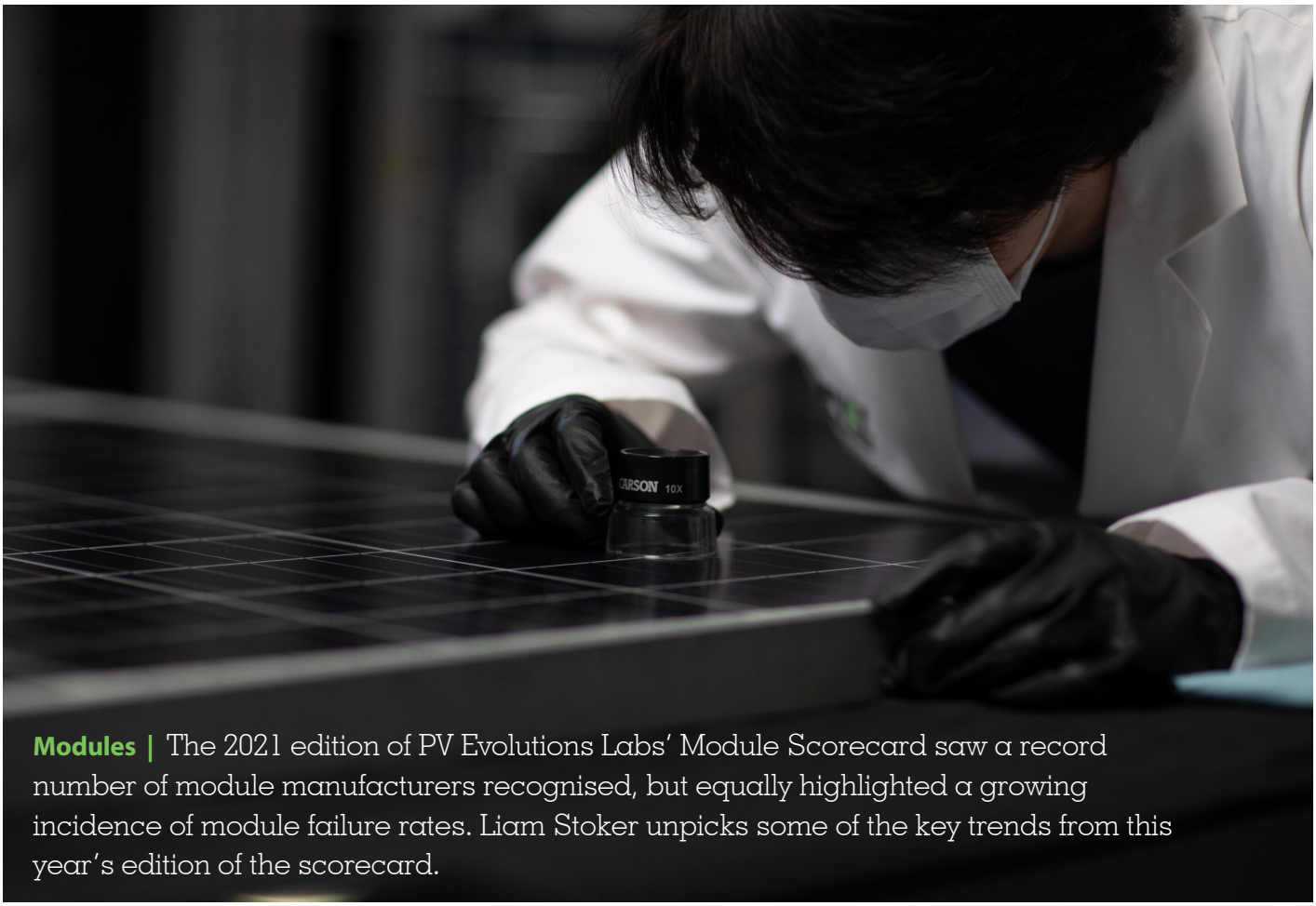
Junction boxes and BOMs: Takeaways from the 2021 PVEL Module Scorecard



Credit: PVEL

Modules | The 2021 edition of PV Evolutions Labs' Module Scorecard saw a record number of module manufacturers recognised, but equally highlighted a growing incidence of module failure rates. Liam Stoker unpicks some of the key trends from this year's edition of the scorecard.

Solar PV has a performance problem. Numerous studies have found operational solar projects to be performing below expectations with a plethora of problems proposed as the leading cause. While solar's underperformance against forecasts in certain cases is no doubt the result of many different issues, it is equally undeniable that some solar modules do not stand up to scrutiny.

The 2021 edition of PV Evolution Labs' Module Reliability Scorecard, published earlier this year following the testing organisation's Product Qualification Program (PQP), has highlighted a number of the most pressing issues for the industry to address as it stands on the cusp of a significant growth in scale and size.

The seventh edition of PVEL's scorecard celebrated a record number of manufacturers having been granted 'Top Performer' status. A total of 117 modules from 26 manufacturers received such status, with JinkoSolar and Trina Solar recording the "tremendous accomplishment", as PVEL head of module business Tristan Erion-Lorico described it, as having received 'Top Performer' status in all seven editions of the reliability scorecard to date. As in each of the last six editions of the PQP, in order to be recognised as a 'Top Performer' modules must have less than 2% degradation following each reliability test sequence, while in the PAN file performance sequence Top Performers must finish in the quartile for energy yield according to PVsyst simulations.

Inspections underway during the 2021 Product Qualification Program.

Alongside regular testing sequences such as thermal cycling, damp heat and both potential-induced degradation (PID) and light and elevated temperature-induced degradation (LeTID) sensitivity, this year's PQP added a mechanical stress test sequence in response to durability concerns relating to extreme weather.

Junction box failures and BOMs

Perhaps the leading conclusion from this year's scorecard was that more work must be done by the industry to tackle

Inaugural entrant	2x Top Performer	3x Top Performer	4x Top Performer	5x Top Performer	6x Top Performer	7x Top Performer
DMEGC, ET Solar, HHDC Xining Solar, Jolywood, Risen, VSUN	Hyundai Energy Solutions, LG, Talesun Solar	Boviet Solar, First Solar, HT-SAAE	Adani, SunPower/ Maxeon, Phono Solar, Seraphim, Silfab Solar, Vikram Solar	Astronergy, GCL-SI, LONGi Solar	JA Solar, Q CELLS, REC Group	JinkoSolar, Trina Solar

The history of Top Performers charted from 2014 – 2021, indicating in how many years the named module manufacturers have received 'Top Performer' status.

the increasing prominence of junction box failures, the incidence of which rose from one in five in 2020 to one in three in the 2021 edition of the scorecard. This rise in junction box failures is an ongoing trend, with the number of manufacturers experiencing such issues rising each year.

Erion-Lorico says one of the issues of most concern regarding junction box failures is the number of junction box lids that have fallen off during transit. Furthermore, junction box manufacturers are also failing wet leakage testing – which examines the insulation resistance of the module – a core certification test that would prohibit a module from being certified for use if it failed during testing. "Seeing the number of manufacturers that are struggling with that basic test, which has been part of certification for, frankly, over a decade... That's significant, and that is something that we would have hoped the industry would have solved by now," Erion-Lorico says.

The issue with junction box failures could lie in the manufacturing process. In a standard solar module assembly line the junction box step remains manual, meaning that it is an individual's job to manually put the junction box lid into place. In most facilities, Erion-Lorico says, they do the potent dispensing too, however there is growing automation in this particular step. This leads to potentially greater room for human error in a module assembly process which is becoming increasingly automated.

> "The scale is just going to keep increasing, and we can't sacrifice quality for scale."

In addition, the evolution from largely monofacial modules using full cells, which had just the one large junction box, to bifacial modules featuring half- or triple-cut cells that require three junction boxes has increased the potential for failure even more. Those manual workers are now having to fit three times as many junction boxes just to complete a module's assembly. "When you think of the scale of this manufacturing, just on a multi-gigawatt scale, there's a bigger opportunity for error," Erion-Lorico says.

And it's this increase in scale which stands to increase the rate of module-level failures in the years ahead. As it stands, Erion-Lorico says, around 100 million solar cells are being soldered each day, and this is to cater for demand of around 170GW. To hit ambitious climate targets more than a billion solar cells will need to be soldered each day. "The scale is just going to keep increasing," Erion-Lorico says, "and we can't sacrifice quality for scale."

Also on the rise was failure rates within the bills of materials (BOMs) used in modules, with around 26% of BOMs eligible for this year's scorecard recording at least one failure. This was up on last year, when one-in-five BOMs recorded a failure. The growing failure rate of BOMs should be of interest to the industry, Tara Doyle, chief commercial officer at PVEL says, because many buyers still do not currently request BOM details during the procurement phase. "Between supply chain instability and the ever-present push for lower prices, one cannot assume that every module sold under a given model type uses tested BOM components. Buyers must specify their desired BOM in supply contracts to achieve this," she says.

Weather factors and large-format modules

For the first time in this year's PQP modules were put through their paces in a mechanical stress load sequencing, testing modules' susceptibility to cell cracking under pressures designed to replicate the kind of weather extremes an increasing number of projects are having to contend with. This sequence generated more failures than any other testing sequence in this year's PQP.

The PQP uses IEC61215 static mechanical load requirements as the basis using conservative mounts and, as a result, PVEL recommends batch testing or conducting qualification testing using chosen mounts for those intending to mount modules in a more extreme or less than ideal fashion. This year's testing discovered that microcrack susceptibility can significantly increase when using non-ideal mounts, but also that modules can still experience significant cell cracking using ideal mounting standards.

Some modules did, however, perform better than others in the PQP. Notably, half-cut cells performed better than full cells, while modules featuring 120-cell designs performed better than those designed in 144-cell formats. Multi-busbar cells performed better than those using three, four or five busbars, and interdigitated back contact, cadmium telluride (CdTe) thin film and double-glass module technologies exhibited minimal degradation.

As an extension of what was seen in this year's PQP, some developers have noted concerns that large-format modules could be more at risk of microcracks as a result of clamping larger, heavier modules using traditional systems that would place the module under greater pressures during wind or other mechanical load events. Erion-Lorico says that while PVEL does have a number of BOMs of large-format modules undergoing stress tests, the results have yet to be compiled. Nevertheless, it is an area of concern for PVEL given the results of this year's PQP.

"We have seen, and we've already reported on an increase in microcrack susceptibility between identical BOMs of 60-cell and 72-cell [modules] using smaller format cells. With 158.75mm and 166mm [cells] we see a pretty significant difference in microcracking between two identical modules of different sizes, so by extension, it stands to reason that going to even larger modules is going to result in more microcracking," he says.

The real crux of the matter is if that greater microcracking actually results in increased power loss. As the results of this year's mechanical stress sequence identified, modules with multiple busbars demonstrated less power degradation, meaning a large-format module with multiple busbars could still perform well despite microcracks. "Microcracks aren't always a bad thing, I don't think they're a

PVEL 2021 Mechanical Stress Sequence 'Top Performers'

Manufacturer	Model Types
Boviet Solar	BVM6612M-xxxL-H-BF (BVM6610M-xxxL-H-BF); BVM6612M-xxxL-H-BF-DG (BVM6610M-xxxL-H-BF-DG); BVM6612M-xxxL-H-HC-BF-DG (BVM6610M-xxxL-H-HC-BF-DG)
ET Solar	ET-M672BHxxxTW (ET-M660BHxxxTW)
First Solar	FS-6xxxA
JinkoSolar	JKMxxxM-7RL3-V
LG Electronics	LGxxxN1C-N5 (LGxxxN1C-V5)
LONGi Solar	LR4-60HPB-xxxM; LR4-72HBD-xxxM (LR4-60HBD-xxxM); LR4-72HPH-xxxM (LR4-60HPH-xxxM)
Maxeon/SunPower	SPR-Axxx-G-AC (SPR-MAX5-xxx-E3-AC, SPR-Axxx, SPR-MAX5-xxx)
Phono Solar	PSxxxM4GFH-24/TH
Q CELLS	Q.PEAK DUO L-G5.2 ;Q.PEAK DUO BLK ML-G9+
Seraphim	SRP-xxx-BMA-BG

good thing, but they don't always lead to significant performance loss," Erion-Lorico says.

Further sequences to replicate weather events such as hail are under consideration, however the lessons for the industry from this year's mechanical stress sequence are that PQP reports per module are used as a guide, rather than any definitive example of performance under stress. If the mounts used by PVEL aren't representative of those intended for a particular project, then more significant failures could be expected in the field. "We have seen modules break and we have seen broken glass in mechanical stress sequence testing… and I think we're going to see more of that as modules get larger, particularly because… the frames aren't necessarily getting thicker, the glass isn't getting thicker, it's using the same module BOMs just on a larger format, and there's inherently some risk involved there," Erion-Lorico says.

Looking forward, Erion-Lorico also notes that the trend for larger-format modules to have smaller distances between each cell – utilising novel approaches such as gapless or seamless soldering or tiling ribbon, but all in a bid to bolster module efficiencies – could result in thermal cycling results deteriorating in future PQPs. Module performance under thermal cycling has improved in recent years, however PVEL is concerned that this could reverse as larger-format modules become more common. "We haven't yet finished the thermal cycling test sequence on large-format modules with gapless soldering. I think until we've tested a number of BOMs through that and gotten more comfortable, that's still quite a question mark," Erion-Lorico says.

For the full details of PVEL's 2021 Module Reliability Scorecard, visit **modulescorecard.pvel.com.**

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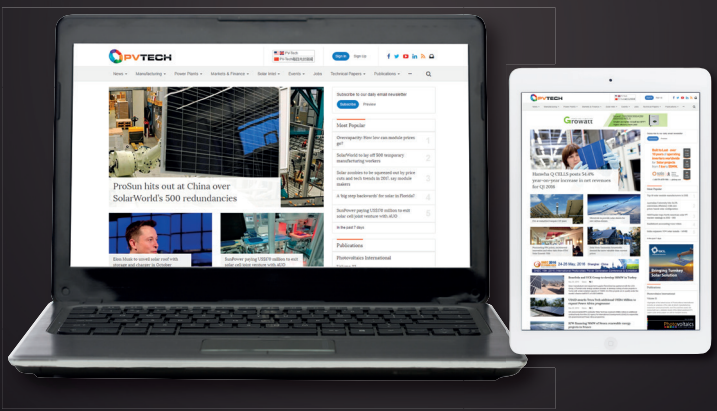

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