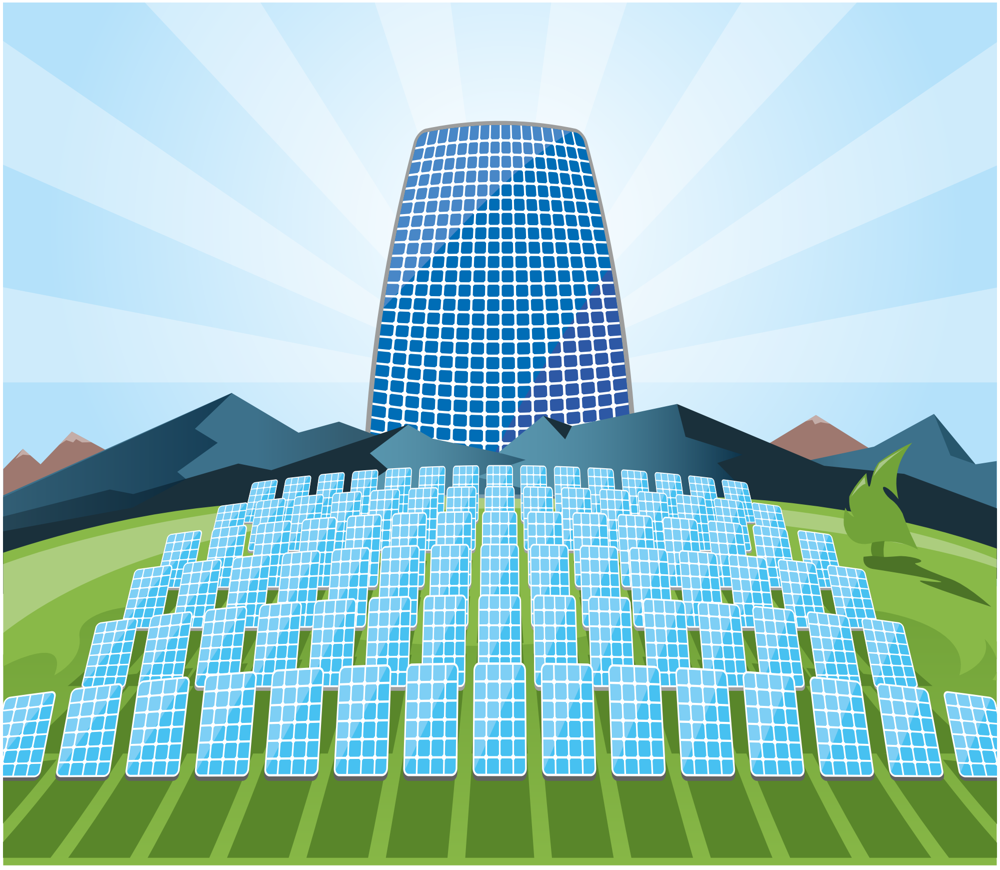
Is solar ready for the high-power era?

Module technology | The rapid evolution of photovoltaic technology has continued, as modules with peak power outputs in excess of 550W are emerging fast. Driven by a thirst for more power and increasingly larger cells, developers and EPCs now face tougher procurement decisions than ever before. But is the industry ready for such a jump? Liam Stoker investigates



Credit: Adrian Cartwright, Planet illustration

There can be no questioning the pace of technological evolution in solar PV, but recent advancements have caught even the most optimistic of industry stakeholders by surprise. Not long ago, solar modules with outputs of up to 450W hit the shelves and left project developers drooling at the prospect of squeezing more power into each hectare of a prospective utility-scale project. And yet, the industry has barely had time to blink and modules with peak outputs in excess of 550W are here, with outputs climbing higher even still.

A new dawn of high-power, ultra-efficient panels has broken. R&D from module manufacturers has produced various series of bigger, better panels, featuring larger, more efficient cells and refined approaches to panel-level technologies. The premise is clear: high output per panels means lower levelised cost of electricity (LCOE), which means more economic solar for all. In a time of contracting subsidies and merchant business models, this stands to be a potentially game-changing development for the entire power sector.

But it's not quite that simple. Bigger does not always equal better, and the introduction of such panels is not as seamless as it may seem. The entire solar supply chain now needs to match the frenetic pace set by module manufacturers.

The industry has quickly leapt from panels with outputs of 450W, to 550W and beyond

Technology driving change

This year's SNEC exhibition in China, rearranged as a result of the COVID-19 pandemic, was perhaps the best example of the industry's rapid advancement. The show floor was littered with modules boasting outputs in excess of 550W, indicating they could quickly become the industry standard. JA Solar even exhibited a module with an output of 810W, alongside Tongwei which had a 780W module on show, even if it is anticipated that it will be a while yet before these particular products hit the shelves.

Exhibitors at the show were quick to describe the next generation of panels on display as falling under 'Solar 5.0', a new era of modules each with an output of 500W and beyond. Journalists from this publication counted 500W+ modules from no fewer than 22 separate manufacturers on the show floor, and analysis of those on display reveals some key technological trends playing a critical role in this evolution.

Most panels on display at SNEC featured mono passivated emitter rear cell (PERC) architecture, while half and triple-cut cells were also prominent. Panels of this kind also boasted multibusbar technologies, the highest-output panels including anything from nine to 12 busbars. The chart (featured) provides a detailed breakdown of the panels, outputs and technologies on display.

But the overwhelming point of discussion when it comes to the technologies behind the new era of panels is wafer size. At the start of 2020 there was much discussion around the emergence of new, larger sizes of wafers and the role they would play in more powerful panels. While this debate almost petered out, with some manufacturers reflecting on it afterwards as a "distraction", it has become clear

Company	Product	Technology	Module Output (W)	Conversion Efficiency (%)	Wafer Size (mm)
Jinko Solar	Tiger Pro N-type 78-cell bifacial module	Tiling ribbon, MBB	610	22.31	182
JA Solar	JumboBlue	1/3 cut, 11MBB, PERC	800	20.50	210
Tongwei	PERC, mono shingled module G12	Shingled module+G12, Large wafer	760-780	21.90	210
Trina Solar	Vertex	MBB, non-destructive cutting, high-density encapsulation	660	21.20	210
LONGi Solar	Hi-MO 5 super-high module	Gallium doped wafer+half-cut+9BB	540	21.1	182
Canadian Solar	HiKu6	Mono PERC	590	21.30	182
Risen	TITAN 600W+	PERC, half-cut, 12BB	615	21.2	210
GCL-SI	GCL-M12/50GDF	1/3 cut, non-destructive cutting+ high-density encapsulation	505	20.8	210
Suntech	Ultra	PERC, MBB, 1/3 cut	605	21.30	210
Yingli Green	Bifacial Panda	1/3 cut, 9BB	550	21.6	210
Seraphim	SII all-black half-cut	Half-cut, MBB, PERC	530	20.30	210
LDK Solar	Mono 210, large size	1/3 cut, PERC+SE, MBB	500	22.40	210
Jinergy	Super-high, mono PERC	Half-cut, MBB, HJT	510	/	166
SPIC	156 cell, half-cut, white backsheet	IBC 6BB half-cut	505	21.6	158.75
ZNshine Solar	150 cell, 10MBB, mono PERC	10MBB, anti-PID degradation	520	21.79	210
DZS Solar	G12-66P bifacial	Shingled module+G12 large wafer	635	22.1	210
Jolywood	Niwa® Super615W high-efficiency bifacial	Topcon, 11BB	615	22.10	210
EGing	Gallium doped MBB SE+PERC high-efficiency module	Gallium doped MBB, SE+PERC, 1/3 cut	545	21.20	210
HT-SAAE	78 cell, half-cut, mono, single glass module	Half cut, 9BB	595	21.3	182
Talesun	BISTAR PRO	Half-cut+10BB	590	21.0	182
HT Solar Group	Mount Tai 6.0	Interconnection, PERC, MBB, high-density encapsulation	600	21.71	182
CECEP	182-cell large size wafer	MBB, half-cut, PERC, non-destructive cutting	540	21	182

A list of all the modules with outputs of 500W and above on display at SNEC this year

that wafer size, and more specifically the emergence of two very distinct camps, looks set to decide the course of the solar industry for the immediate future.

As the chart illustrates, aside from a select few modules still using the existing industry standard-size 158-166mm wafers, most modules belonging to the new class use either the 182mm (M10) or 210mm (M12) wafer size. Most of the upstream solar manufacturing industry has fallen into either of these two class sizes, with the likes of JinkoSolar, LONGi, Canadian Solar and others electing to use M10 wafers, while Trina Solar, JA Solar and a raft of other manufacturers very much walking down the M12 path.

For LONGi, the notion that 'the bigger, the better' does not always ring true, with the manufacturer arguing that module sizes should have a 'sweet spot'. Before throwing its weight behind M10 wafers, Hongbin Fang, director of product marketing at LONGi Solar, says his company analysed conditions relating to not just ingot, cell, wafer and module manufacturing, but system applications, ranging from shipping logistics to electrical parameters that modules operate in. "The natural progression for modules should consider reducing the BOS cost and LCOE instead of only seeking a bigger module size," he says.

Tino Weiss, head of global purchasing at German developer BayWa r.e., concurs, stressing that more power is not always the best course of action, and that balance of system costs should be paramount when it comes to selecting modules for a project. The impact throughout the system of choosing more powerful panels, from both an electrical and physical perspective, can have significant impacts on LCOE. "That's exactly what we need to take into consideration, by what is the right module in the market, what is the impact on production costs of the module and what is the impact on LCOE of the system," Weiss says.

Other industry stakeholders, however, disagree, arguing that increasing outputs per panel can contribute significantly to the LCOE of projects, helping make solar more economical. Pushing boundaries with regards to wafer size and panel output could indeed usher in a new era of ultra-cheap solar developments.

But how much is too much, and at what point do panels become too big or, indeed, too powerful? Technical issues, it would appear, are already arising.

Pushing boundaries, moving goalposts

Technical issues arise as a result of the much larger wafers used in the manufacturing process. The M12 triple-cut and M10 half-cut cells used in some of the next generation of panels operate with a current of somewhere between 11-13A, similar to that of most panels on today's market. This means that they can effectively slot straight into today's system design and be installed alongside other components available today. Voltages of around 50V present in these modules are also something the industry can handle, Weiss says.

The prevalent issue is when panels feature a half-cut M12 cell. The size of the cell, much larger than those featured in modern panels, results in a markedly higher current, around 16-18A depending on the module. This, according to Weiss, is a step too far, causing a ricochet of effects throughout the system design. Furthermore, as Fang says, with wider adoption of bifacial modules and a bifacial gain of 5 - 15%, the working current across such a panel could be more than 20A. "In this case, there is a significantly higher risk of failure due hot-spot or junction box issues," he says.

Not only are thicker cables – up from 6mm to around 10mm – needed to facilitate a current that's 40% up on what's being used today, but system design principles that underpin much of modern utility-scale solar farms also face changes. Combining two strings of panels results in a current higher than 30A, a current which modern inverters cannot handle on a single maximum power point tracker (MPPT).

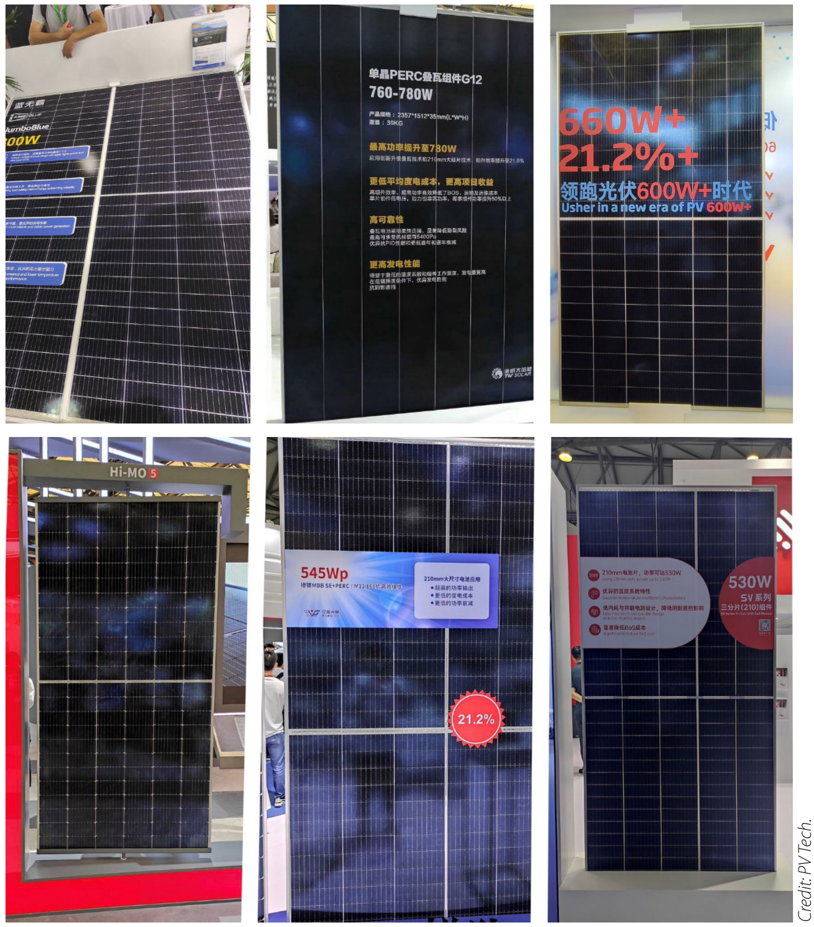
This is likely to place new strains on the supply chain. Cables of that diameter are not commonly used in the industry and will be more expensive, while there is a dearth of inverters on the market capable of being used in conjunction with these higher power outputs. Weiss says the introduction of such inverters will almost certainly be at a higher price point, a factor which again must be taken into account when designing the overall system.

Using costlier components throughout the system will obviously increase system prices, impacting the BOS and LCOE of any given project.

But advocates of the M12, 210mm wafer size argue for the benefits of cells using them, professing that their adoption opens the industry up to more significant cost reductions further down the line. Trina Solar's new Vertex range of panels, which boast power outputs of 550W up to 660W, all use M12 wafers and the manufacturer has adopted the mantra of "low voltage, high current" for its marketing. Trina's 550W Vertex panel has a current of 18.39A and a voltage of 38.1V, while the 600W version has a current of 18.42A and a voltage of 41.7V. Dr. Franck Zhang, head of product strategy and value management at Trina Solar, says by opting for a lower voltage than other panels on the market today, more can be connected per string.

Detail provided within a recent webinar co-hosted by Trina Solar and *PV Tech Power's* sister website *PV Tech* showed that in lowering the voltage, as many as 36 Vertex 550W panels could be connected per string, an increase on the 27 pieces of an undisclosed module with a 540W output used as a reference. This meant that the total power per string using Trina's Vertex series equated to 19,800W, an increase of nearly 36% on the 14,580W from the reference string. This, in turn, reduced the number of modules needed to produce each megawatt of installed capacity, the volume of steel needed for racking, the length of cable necessary for each megawatt and savings on other hard costs associated with a completed project. The end result is a saving on BOS costs which, albeit relatively minimal per watt – equivalent to around RMB0.05 (US$0.007) – extrapolated over the course of each megawatt installed, could mean the difference between a project being rendered economical or not.

Selecting any particular panel can evidently have sizeable impacts on not just the components used elsewhere in the project, but on expected returns and the way any project is designed and developed. Weiss says the introduction of 550



A selection of the high-power modules on display at this year's SNEC exhibition in China.

and 600W+ panels promises to be a significant change for developers with proven and reliable design methods. "If you look at the last 10 years, project development in regard to system design was quite easy because we didn't have too many changes on the module class. Power class went up, but the size never changed, and the technical specifications never changed like they have now," he says.

But technical issues are not the only elements of a module to change with the evolution of cell technology and sizes. As currents increase, so too do module sizes and weights, yet another modification which poses significant change for the industry.

Size, use and weight

Not withstanding the sizeable challenges in adapting systems to the electrical output of panels, the actual physical differences of these panels compared to previous generations cannot be overlooked. In upsizing to 550W and beyond, the panels themselves are increasing in physical size and weight, resulting in challenges right the way through from shipping and handling to deployment and site management.

While panel sizes and weights vary, those featuring M12 wafers are usually upwards of 2.2 metres long and 1.3 metres wide, some weighing in excess of 35 kilograms, beyond the current industry norm. BayWa r.e.'s Weiss says this is to be felt throughout the supply chain. "Handling, weight, transportation… how will pallets be loaded, how do they fit into the container – these are the questions in regard of the size [of the panels]," he says. LONGi Solar's Fang is equally dubious of shipping constraints caused by increasing module sizes, pointing in particular to the height of standard 40HC shipping containers used in global logistics.

The combined weight of panels during shipping and distribution will also pose questions. As Weiss notes, a standard shipment of some 30 panels each weighing 45 kilograms means a total pallet weight in excess of 1.2 tonnes. "How do you want to drive these through mud on a construction site?" he asks.

Getting the panels to any particular site is one thing; actively deploying panels that weigh upwards of 40 kilograms is another issue entirely. European law states that labourers lifting anything heavier than 25 kilograms cannot do so alone, meaning either lifting equipment or a second – or any other number – of additional workers must help, which in turn has a direct impact on either build times or the number of workers needed on site, adding to labour costs. The same regulations exist in other established solar markets, creating an issue for developers actively pursuing such modules. The matter is, however, further complicated by the absence of such protective legislation in key markets such as China, India or Mexico, prompting a potential split in terms of module adoption.

The combination of size and weight must also be considered in system design and build, especially in relation to the use of mounting structures and trackers, in particular. BayWa r.e. typically installs its solar panels in portrait – with modules typically increasing in width – this minimises the impact from increased weight on mounting structures, Weiss says. Those installing in landscape, however, could see more strain placed upon structures, resulting in a need for a change in design or strength. This is no major problem for the industry to circumvent, with the benefits of increased power/output from each structure providing an impetus to overcome it, but it's a factor of design that must nevertheless be taken into account.

Trackers, however, may be more complicated. As panels get larger and heavier, the notion of clamping a module and tilting it throughout the day becomes more complex, with potentially serious consequences at the panel level. "We're now talking about modules with a length of 2 metres 20 centimetres, and if tracker suppliers want to clamp these kind of modules in the middle with a 400 millimetre clamp, this might cause microcrack issues after five or ten years due to wind or snow pressure," Weiss says.

Tracker manufacturers are answering the call, with the likes of Soltec releasing products specifically geared towards modern 72- and 78-cell modules.

It's not just hard costs associated with components that are at risk of changing significantly with the advent of high-power modules, but soft costs too. And as the cost of solar components continues to decline, it's soft costs which are quickly becoming the focus of developers and EPCs.

What is clear is that while modules have evolved drastically in such a short timeframe, the rest of the industry needs to catch up for the next generation of panels to realise their full potential.

Collaboration is key

"In the last few years the industry has proved that not only increasing efficiency but increasing power by increasing wafer and module size brings tremendous value addition to the customers, especially in reducing the BOS costs," LONGi Solar's Hongbin Fang says, acknowledging that his company had indeed assessed the potential for M12 wafers. "We made a very detailed technology analysis for 210mm wafers all along the value chain – from wafers, cells, modules and PV systems. The 210mm wafer and related module will bring limited benefits to the value chain, but require heavy capital investment throughout the manufacturing process and compromise many aspects of module deployment," he says.

It's evident the entire ecosystem must evolve alongside the modules. Trina Solar's Franck Zhang says that Trina has turned to the likes of NexTracker and Huawei, collaborating with them to help bring forward a new wave of trackers and inverters that can support this new wave of modules. It's been a central cornerstone of and key motivation behind the 600W+ Photovoltaic Open Innovation Ecological Alliance, which Trina Solar unveiled in mid-July. The alliance brings together a total of 39 companies from the solar supply chain with the intent of fostering greater collaboration between them and establishing an ecosystem that can facilitate the introduction and adoption of 600W+ panels.

But, according to Weiss, module manufacturers will need to broaden their horizons even further, and collaborate with those actively deploying modules – the world's developers and EPCs – to determine just what they need from a next-generation panel.

"There have been a lot of discussions in the market beforehand, with EPCs. And, of course, if you ask an EPC 'Do you do you prefer modules with a higher power class?' Then they will say yes. But the question was wrong; they should have asked, 'Would you like to have a module which has a higher power class, and it's definitely much larger than the one before and would have a much higher current?' If they would have raised the question like this, they would have gotten a different answer," he says.

Weiss says BayWa r.e. will, for the time being at least, be sticking with what works for the company's system design principles. Modules featuring half-cut M10 and triple-cut M12 cells will suffice, with Weiss adding that his company "doesn't really need" to go beyond those modules and outputs. He does, however, admit this is not a universal approach. "I know there are other players in the market which don't look into the balance of system. They just look for specific module prices. And of course, the M12 modules will have the highest potential to get the lowest specific module price," he says.

Manufacturing economics and selling prices, set against a race for scale, are set to play a critical role. With production costs per module falling, and module selling prices calculated in price per watt peak, producing more powerful modules at scale makes for much more attractive margins. It's what Weiss describes as an "interesting phenomenon" for the solar market.

Manufacturers are bringing significant scale too. Trina Solar aims to have 10GW of manufacturing capacity for its Vertex series operational by the end of this year, followed by 21GW by 2021 and 31GW by the end of 2022. Others are expected to follow. Meanwhile, manufacturers in the M10 camp – including the likes of LONGi and JinkoSolar – are being equally ambitious with expansion plans.

The solar PV ecosystem would therefore appear somewhat split at what is undeniably a critical juncture. Technology is evolving rapidly and facilitating significant increases in power outputs, but the sector itself cannot – and most likely will not – agree on the best path to take. But there is every opportunity for the two sidest to coexist as project developers worldwide select the module that is best suited to their specific project or pipeline, and design and procure other components accordingly. What is clear, however, is that for the sector to truly embrace panels of 600W+ outputs, it cannot be just the panels themselves that evolve. The entire supply chain must move together, ensuring that each component matures to deliver the kind of LCOE and balance of system benefits that developers are looking for. If that can be achieved, then the next generation of panels will unquestionably usher in a new era of project economics.

Sooner or later though, the industry will have to decide on how large is too large. "Somewhere, the end is reached," Weiss says, commenting that the only way this message will resonate is with improved communication and collaboration throughout the ecosystem. ■