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pv magazine

PHOTOVOLTAIC MARKETS & TECHNOLOGY

Trade barriers spoil solar's party

Crude instruments like tariffs and duties skew PV markets and the global supply chain.

Pages: 20 – 25

Wafers go big

Larger crystalline silicon wafers are boosting power output, but is there a natural limit?

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Solarpraxis AG, Karl-Heinz Remmers.

Enabled by trade

Photo: pv magazine/Dave Tacon

The story of the modern PV industry is one defined by international collaboration and partnerships. Fundamental research, production tool development, manufacturing know-how, financial innovation and supportive policy measures have all taken place in certain parts of the globe, to be deployed, tweaked, improved upon and mastered in others. And the cumulative effect is the highly competitive, if not leading, LCOE that solar projects large and small can achieve in 2019.

So, why the trade barriers (pp. 20-25)? Solar PV and battery storage are considered future-focused industries, and ones in which job creation will occur for many years into the future. Given this, policymakers look to support solar jobs – often in the form of relatively crude measures such as import tariffs, duties or domestic content provisions. And they, in turn, frequently have unintended consequences.

One of the more recent such consequences of this apparently new era in which trade barriers are being erected, rather than torn down, has been the inclusion of climate change considerations into wider trade negotiations. Brazil appears to be feeling the pointy end of such measures, with various EU member states making action on climate change, or rather the prevention of harmful behavior, a part of free trade negotiations. So, what goes around, in a sense.

In the face of this instability and ever-changing trade dynamics, it's pleasing to see the solar industry continue to innovate and find ways to move forward. And it's innovation right across our industry.

In installations, floating PV (pp. 52-53) is making space for solar where none exists on land, and co-located solar+wind systems are boosting capacity factors and project economics (pp. 40-42). Where grid constraints exist (pp. 106-109), battery storage can increasingly lend a hand (pp. 110-112). And BIPV, long largely dormant, may be finally finding its place (pp. 44-50).

In manufacturing, there's a sense that change has never occurred so quickly. Heterojunction (pp. 68-71) is coming into wider production, and perovskites appear on the horizon (pp. 82-84). And in today's modules, larger wafer formats are already making a powerful impression (pp. 72-75).

This month sees two of the most prominent events take place: Solar Power International in Salt Lake City, and the Renewable Energy India Expo in New Delhi. No doubt these innovations will be under discussion, and one hopes, they'll offer a way to get around disagreements over solar trade.

Jonathan Gifford, Editor in Chief

"Recent developments in solar have made the impossible possible on many fronts"

The return of BIPV

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"PAYG models are constantly improving, leading to better and more affordable services"

A bump in the road

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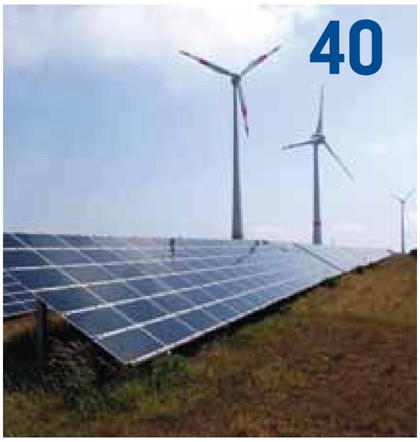
A wide-ranging look into solar tariffs, duties and trade barriers.



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A new duo faces a lack of subsidies ahead.

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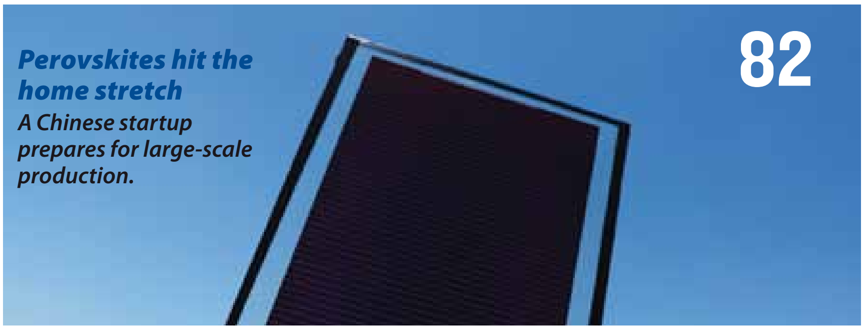
Bigger and bigger is the order of the day amid a lack of wafer standards.



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A Chinese startup prepares for large-scale production.

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First the agreements get shorter. And before you know it, everything turns merchant?

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Photo: Walmart

Walmart vs. Tesla

Walmart has filed a lawsuit in the United States against Tesla over fires, which it alleges originated at PV installations that were designed, installed, owned and maintained by Tesla/SolarCity at its stores in three states.

Walmart counts seven fires in total, but only four that are under contract with Tesla, and not SolarCity before the acquisition. These four occurred from March through November 2018, and include a supposedly de-energized array that still caught fire in November.

The retail giant is asking for Tesla to remove all 240 of the systems it installed at its stores, in addition to other damages, including paying for its consultants. These represent more than half of the sites where Walmart has installed solar and would damage its enviable ranking among corporations that have gone solar.

Perhaps the most interesting part of this case so far are the grave allegations that Walmart is making about the installation, as well as operations and maintenance practices at Tesla. "Properly designed, installed, inspected, and maintained solar systems do not spontaneously combust, and the occurrence of multiple fires involving Tesla's solar systems is but one unmistakable sign of negligence by Tesla," the company said. "The number of defects, however, is overwhelming and plainly indicative of systemic, widespread failures by Tesla to meet the standard of care, as set forth in the governing contracts, as to the solar systems installed at Walmart's stores."

Walmart says that inspections of the installed systems revealed "widespread, systemic negligence and [failure to] abide by prudent industry practices in installing, operating, and maintaining its solar systems," which significantly increased the risk of fires. Among the pieces of evidence for this, Walmart says it found a large amount of microcracks, hotspots and backsheet damage, which suggest the installation of already damaged solar panels.

Another allegation is that Tesla's inspection teams did not have the necessary skills to do their job:

"Walmart quickly discovered that Tesla routinely deployed individuals to inspect the solar systems who lacked basic solar training and knowledge. Tesla's personnel did not know, for example, how to conduct inspections or how to use simple tools, such as temperature-measuring 'guns' used to detect hotspots, and a Tesla employee failed to identify multiple hotspots that Walmart's consultants observed."

Tesla had not yet responded to **pv magazine**'s request for a public response to these allegations at the time of going to press. It also remains unclear how much these headlines will work to tar the overall solar industry. The larger question is whether or not the solar industry is effectively policing itself against bad actors who are cutting corners, and whether or not these problems are confined to only one company.


Photo: SolarEdge

Solar world pays tribute

The world of solar has lost one of its main driving forces with the death of Guy Sella, the founder and co-chairman of Israeli-headquartered inverter giant SolarEdge.

The former venture capitalist founded the company in 2006 and subsequently stated: "We wanted to make solar energy smarter and more affordable to help mankind meet a justified growing energy demand in a sustainable way that reduces our global carbon footprint."

"Guy has left an incredible legacy"

SolarEdge issued a statement in memory of Sella, its founder and co-chairman, which reads: "It is with a very heavy and sad heart that we notify of the passing of our dear friend and inspiration, Guy Sella. All of us who had the privilege to work with Guy and be witness to his unwavering drive and infinite levels of energy and passion for what he did, know what a huge loss this is, not only to SolarEdge. Guy has left an incredible legacy and his spirit will live on forever in SolarEdge. The entire SolarEdge family mourns his loss. On behalf of our board of directors, management team and employees, we extend our deepest sympathies to Guy's family." pv

Solar+storage boost for the Caribbean

The government of the Federation of St. Kitts and Nevis has awarded Swiss battery manufacturer Leclanché with a 20-year power purchase agreement for a large-scale solar-plus-storage project it plans to build.

The 35.6 MW solar array will be paired with 44.2 MWh of storage capacity. The project will be located near the capital city of Basseterre, which is situated on the island of St. Kitts. It will be built close to a power station owned by local state-run utility Skelec, to which the facility will sell electricity.

"The system will provide between 25% and 30% of the nation's current power generation needs, while displacing the same amount of diesel-generated capacity," Leclanché stated.

The construction of the plant is currently scheduled to begin in the middle of October, with completion scheduled for September 2020. Leclanché did not disclose any additional technical or financial details about the agreement or the project. pv

"The system will provide between 25 and 30% of the nation's current power generation needs"


Photo: mickfromsvg

China's H1 installs

China deployed around 11.4 GW of new PV generation capacity in the first six months of this year, according to new statistics from the country's National Energy Administration (NEA).

Around 6.82 GW of the new capacity consisted of large-scale PV plants, with the 4.58 GW balance coming from distributed-generation PV arrays.

Northwestern China boasted the largest share of new PV plants, with 3.43 GW of new grid-connected capacity, followed by the northern provinces of the huge nation, with 3.29 GW. In the more populous east, a total of 2.28 GW was installed.

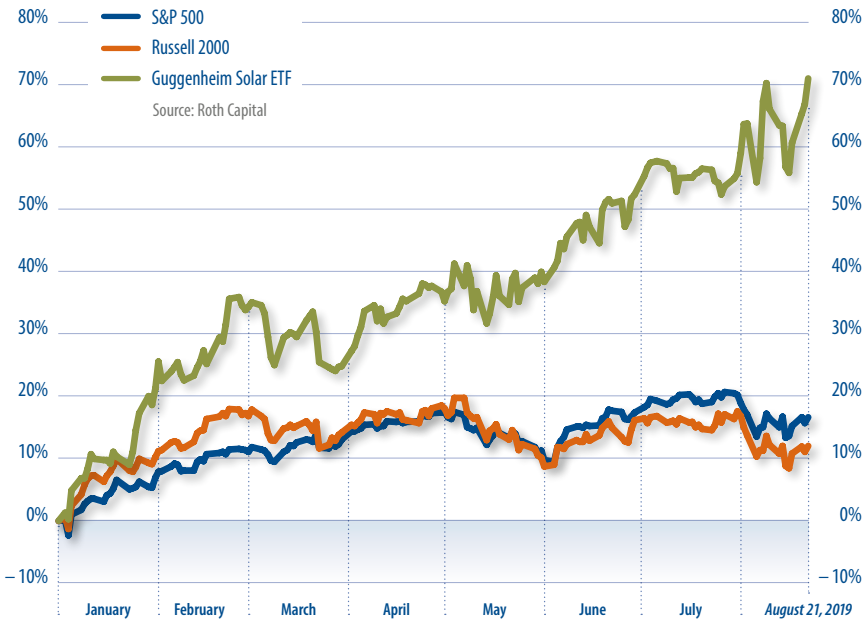
These relatively modest new additions took China's cumulative installed solar capacity to 185.5 GW. The country is expected to experience a deluge of new installations beginning in September, as developers of projects that qualify for state subsidies rush to get them connected by Dec. 31, in order to receive their full subsidy payouts. pv


Photo: Datong

Trade war shadows all but solar

Solar stocks outperformed the broader market in August. The Guggenheim Solar ETF (TAN) increased 2.0% vs. the S&P 500 and Dow that decreased 0.9% and 1.1% respectively. Canadian Solar (CSIQ), Azure Power (AZRE), First Solar (FSLR), SolarEdge (SEDG) and Enphase (ENPH) all delivered a strong Q2 and strong guidance for Q3.

Guggenheim Solar ETF – TAN Holdings



Company	Ticker	Month close price August 21, 2019	% change August 01–21, 2019	% change year to date
SolarEdge Technologies, Inc.	NasdaqGS:SEDG	80.94 USD	+21.7%	+130.6%
Daqo New Energy Corp.	NYSE:DQ	50.57 USD	+18.8%	+116.1%
Sungrow Power Supply Co., Ltd.	SZSE:300274	12.15 CNY	+18.0%	+36.2%
Tianjin Zhonghuan Semiconductor Co., Ltd.	SZSE:002129	11.86 CNY	+15.1%	+64.0%
Enphase Energy, Inc.	NasdaqGM:ENPH	33.84 USD	+12.4%	+615.4%
Xinyi Solar Hold. Ltd.	SEHK:968	4.73 HKD	+10.8%	+72.0%
TerraForm Power, Inc.	NasdaqGS:TERP	16.95 USD	+9.0%	+51.0%
Canadian Solar Inc.	NasdaqGS:CSIQ	23.93 USD	+7.6%	+66.9%
Tainergy Tech Co., Ltd.	TSEC:4934	4.62 TWD	+6.0%	–9.4%
Jolywood (Suzhou) Sunwatt Co., Ltd.	SZSE:300393	12.95 CNY	+4.2%	+29.8%
LONGi Green Energy Technology Co., Ltd.	SHSE:601012	26.64 CNY	+4.1%	+52.8%
Risen Energy Co.,Ltd.	SZSE:300118	11.07 CNY	+3.6%	+94.6%
Tongwei Co.,Ltd	SHSE:600438	14.95 CNY	+3.5%	+80.6%
Atlantica Yield plc	NasdaqGS:AY	23.84 USD	+2.0%	+21.6%
PVA TePla AG	XTRA:TPE	11.28 EUR	+1.8%	–7.5%
S.C New Energy Technology Corp.	SZSE:300724	32.19 CNY	+1.2%	+13.0%
Hannon Armstrong, Inc.	NYSE:HASI	27.50 USD	+0.7%	+44.4%
Danen Technology Corp.	TSEC:3686	1.55 TWD	–1.3%	–55.7%
Beijing Jingyuntong Technology Co., Ltd	SHSE:601908	3.22 CNY	–2.1%	+2.2%
Wacker Chemie AG	XTRA:WCH	68.98 EUR	–2.3%	–12.8%
Applied Materials, Inc.	NasdaqGS:AMAT	47.15 USD	–2.7%	+44.0%
centrotherm international AG	DB:CTNK	2.06 EUR	–2.8%	+14.4%
JinkoSolar Hold. Co., Ltd.	NYSE:JKS	19.44 USD	–3.0%	+96.6%
Azure Power Global Ltd.	NYSE:AZRE	10.47 USD	–3.1%	+15.7%
Vivint Solar, Inc.	NYSE:VSLR	8.36 USD	–3.8%	+119.4%

Information upon which this material has been compiled by **pv magazine** and is based was obtained from sources believed to be reliable but has not been verified. Additional information is available upon request.

A number of upstream solar company stocks in China and the U.S. increased on expectations for greater China demand in H2 2019. NEA is expected to release a list of solar projects that secured subsidies for 2019.

The top five performers were SolarEdge (SEDG), Daqo New Energy (DQ), Enphase (ENPH), TerraForm Power (TERP) and Canadian Solar (CSIQ) that increased 22%, 19%, 12%, 9% and 8% for the month, respectively. Roth analyst Phil Shen indicated that mono PERC cell pricing could increase by a few RMB pennies/W near-term. Although there is caution around China demand in H1 2020 after an expected surge in H2 2019, selling price increases near term are expected to drive stocks higher.

China domestic multi grade polysilicon is $8.07/kg, which declined 4% from June. Mono grade poly is now $10.62/kg. Multi and mono wafers are $0.06/W and $0.09/W, multi and mono cell price is $0.11/W and $0.12/W, multi and mono module price is $0.22/W and $0.26/W.

Despite strong solar industry fundamentals, macro economic sentiment will drive the stock market. Namely decreased economic activity in the United States and globally, exacerbated by trade war with China. On 08/23, the Dow dropped more than 600 points after President Trump said U.S. companies must look for an "alternative to China".

Roth is hosting its seventh Annual Solar & Storage Symposium at Solar Power International on September 24-25, 2019 in Salt Lake City, Utah. The Symposium will include meetings with management teams of public and private companies and a booth tour visiting a variety of distributors, developers and renewable asset owners. We will focus our symposium around four main topics: (1) What to expect ahead for the global supply/demand balance; (2) Outlook for U.S. solar, especially residential; (3) The evolving competitive landscape of the inverter market; and (4) The economics of the solar supply chain.

Jesse Pichel, ROTH Capital Partners

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LONGi Solar is a wholly owned subsidiary of LONGi Group (SH601012) - the largest supplier of monocrystalline silicon solar wafers in the world with 12 GW of wafer capacity by year-end and plans to expand to 20 GW by 2019. With strong focus on R&D, LONGi is active in the entire monocrystalline silicon value chain, including solar power plants.

Germany's PV cap must go – now

Last month's column pointed out the transregional causes and trends that could lead to a year-end rally, the associated module and inverter bottleneck, and an inevitable increase in prices. This month, Martin Schachinger of pvXchange homes in on the German market to show what consequences unwise action – or rather, inaction – by the federal government could have for the further, urgently needed expansion of photovoltaics.

As the headline suggests, I am concerned with the 52 GW cap still in place under Germany's Renewable Energy Sources Act (EEG). According to the Federal Network Agency, by the end of June the total installed capacity of PV systems in Germany had reached just under 48 GW. If this is extrapolated – taking into account the current rate of build-out – the upper limit for systems up to 750 kW that are eligible for EEG funding will be reached by summer 2020.

Module prices have scarcely changed over the past month. Despite tightening supplies – especially for modules in the lower output range – all prices, with the exception of those for all-black modules, fell slightly. The summer lull could exacerbate this trend, but the euro exchange rate is also working to counteract it.

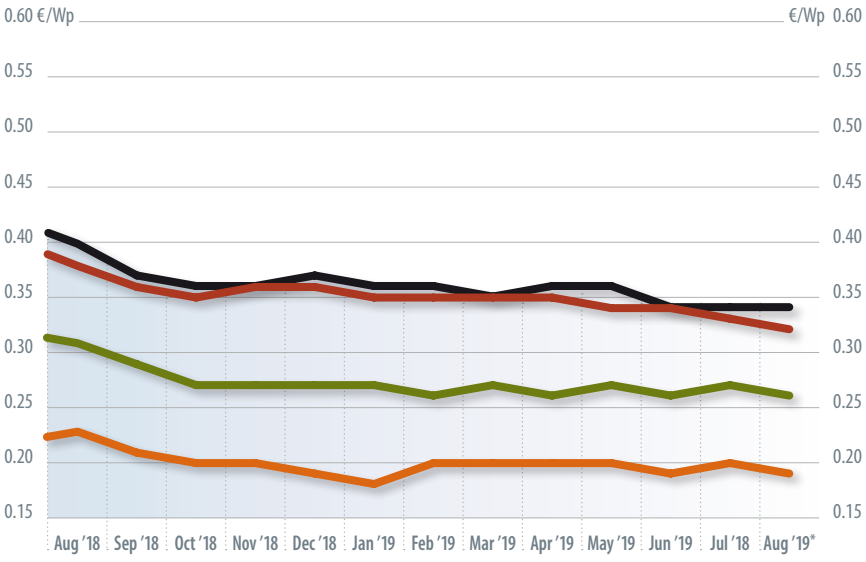
Exchange-rate losses would make products manufactured in Asia and traded in U.S. dollars nearly 5% more expensive than at the beginning of the year, if prices remain stable. This means in absolute terms that the module sector can be said to have seen slight price reductions over the past few months; we just have yet to notice them here in Europe. However, this sideways movement in prices will not last long, as the market is currently recovering – both in Germany and around the world.

Industry pressure

A number of community and industry organizations, such as the German Solar Industry Association (BSW), have been calling on the federal government to remove the 52 GW cap from the EEG, pointing to lower electricity production costs, as well as the looming failure to meet climate targets. Recently, Volker Quaschning, a professor at the Hochschule für Technik und Wirtschaft, Berlin, launched an excellent campaign with a healthy dose of humor; he sent Peter Altmaier, the German economy minister, a worn-out toilet lid inscribed with the words "The lid on PV has to go." Quaschning – who is involved in the "Fridays for Future" movement and is strongly supported by former Green Party politican Hans-Josef Fell, as well as wholesaler Krannich Solar – called on friends and customers to back the campaign. Krannich Solar asked them to send in their own statements, accompanied by a logo. All were put on cardboard lids, which were then sent to government representatives in Berlin, with all of the individually written reasons for abolishing the cap.

These activities are slowly having an effect, but there is still disagreement on the right course of action. The government has already agreed to increase the share of renewables to 65% by 2030, but this will not work without further support for PV, SPD politician Timon Gremmels told **pv magazine** recently. Debates are underway in the committees on how to proceed with the expansion of PV and wind power. The German Federal Ministry for Economic Affairs

EU spot market module prices by technology



Crystalline modules (mono-/poly-Si) average net prices (€/Wp)

- **High efficiency:** Crystalline modules **290 Wp** and above with Cello, PERC, HIT-, n-type – or back-contact cells or combinations thereof
- **Mainstream:** Modules with usually 60 cells, standard aluminum frames, white backing and **260 Wp to 285 Wp** – the majority of modules on the market
- **All black:** Module types with black backsheets, black frames and rated outputs of between **200 Wp and 320 Wp**
- **Low cost:** Reduced-capacity modules, factory seconds, insolvency goods, used modules (crystalline), products with limited or no guarantee

* Data up to August 19, 2019

More information: www.pvXchange.com

Overview of the price points broken down by technology in August 2019 with changes over the previous month (as of 19 August 2019):

Module class	€/Wp	Trend since July 2019	Trend since January 2019	Description
Crystalline modules				
High efficiency	0.33	-3.0%	-8.6%	Crystalline panels at 290 Wp and above, with PERC, HJT, n-type or back contact cells, or combinations thereof
All black	0.34	0.0%	-5.6%	Module types with black backsheets, black frames and rated power between 200 and 320 Wp
Main-stream	0.27	-3.7%	-3.7%	Modules typically with 60 cells, standard aluminum frames, white backsheets and 260 to 290 Wp — this represents most modules on the market
Low cost	0.20	-5.0%	+5.6%	Factory seconds, insolvency goods, used or low-output modules (crystalline) and products with limited or no warranty

***Notes**: Only tax-free prices for PV modules are shown, with stated prices reflecting average prices on the European spot market (customs cleared) **Source**: pvXchange.com*

and Energy has maintained a low profile so far, but Andreas Feicht – the state secretary responsible for the energy transition – has at least recognized the need for action: "We have to do something!" But it is anyone's guess when these words will be followed by deeds.

The consequences of keeping the cap in place have been the subject of ongoing speculation among the state governments of Bavaria and Baden-Württemberg, the two German states where PV is strongest. The fixed upper limit, which – according to current legislation – would abruptly cut off incentives once reached, could have a negative impact on investment decisions related to PV systems. For cost-effectiveness reasons, once the statutory feed-in tariffs have run out, the installation of new plants will be limited solely to systems installed to cover on-site requirements. As a result, the market for roof-mounted systems would decline dramatically. The cap therefore must be abolished – quickly. However, at the conclusion of a recent meeting, the state politicians failed to specify a concrete procedure for achieving this.

I have previously expressed doubts as to whether PV systems without EEG subsidies would be cost-effective in view of the current energy market structures and the many legal hurdles on existing buildings, especially for smaller plants. Without a government-backed compensation scheme it would be a stretch to finance medium- to large-sized plants. What alternatives can financial service providers expect from their customers that can match a legally guaranteed feed-in tariff? I can't think of any. So, if the cap is not lifted immediately, we will face the threat of a run on the last 4 GW eligible for incentives. It will be the worst kind of expansion with all the usual negatives: last-minute panic, acceleration of installations with scarce resources – manpower and materials – and the result will be higher prices and lower quality.

I therefore emphatically urge all players, both inside and outside of the PV sector, who are serious about the energy transition and a resolute approach to climate change to join one of the many campaigns and petitions in the call to scrap the 52 GW PV cap. pv

Martin Schachinger, pvXchange.com

Safety is paramount

When Sony first commercially introduced lithium-ion batteries in 1991, the industry recognized their potential to revolutionize portable electronics. Ever since, there have been countless efforts to improve the technology, with many researchers focusing on energy density and longevity, in line with demand from emerging applications such as electric vehicles (EVs) and on-grid energy storage. Julian Jansen and Youmin Rong of IHS Markit discuss the effect of safety concerns on this rapidly growing global market.

"Annual demand for Li-ion batteries from the automotive industry is forecast to reach over 700 GWh in 2025"

The technological advances that Li-ion batteries have gone through in the past decade are monumental. Lithium nickel manganese cobalt oxide (NMC), lithium nickel cobalt aluminum (NCA) and lithium iron phosphate (LFP) batteries have become the leading technologies due to improved energy density and lower cobalt requirements. While new battery technologies are crucial in enabling new end-market applications, concerns from the automotive and power industries over their safety have grown. Over the past five months, IHS Markit has noted more than six EV battery fires, mainly in China and the United States, with various technical failures identified.

Prevention mechanisms can be designed into a system at three levels to reduce the likelihood and impact of thermal runaway in EVs: cell-to-cell, module-to-module, and the whole pack. In response to recent incidents, Tesla has rolled out a software update for two of its models to improve battery safety and longevity through a revision of charge and thermal-management settings. Additional precautions include limiting the maximum speed and implementing a "cut loop" to deactivate most of the high-voltage connections in a vehicle in an emergency. Safety is also a focus for the development of next-generation battery technologies, where innovations tend to focus on improving safety pertaining to battery electrolytes.

Not every EV fire incident is the result of a battery design failure – an electric car crash and a combustion engine car crash can both lead to fire incidents, after all. Thus, while battery safety continues to be a concern for consumers, IHS Markit predicts that sales will continue to rise quickly over the coming years, and annual demand for Li-ion batteries from the automotive and transport industry is forecast to reach over 700 GWh in 2025.

Stationary storage

Stationary battery systems installed on the grid, with generation assets or at customer sites, have historically been considered safe. Over the past 18 months, several major fires – 21 of those occurring in South Korea – have raised concerns. A five-month investigation by Korean authorities, concluded in June 2019, identified the root cause of the fires as not being the batteries themselves, but poor installation and operation of systems.

While concerns in the residential sector were addressed in the early stages of market development, stricter installation and fire safety standards for larger systems are being accelerated. In South Korea new manufacturing, installation, operational and fire safety standards are to be rolled out by the end of 2019. In the United States, the Energy Storage Association launched its Energy Storage Industry Corporate Responsibility Initiative. Many leading stakeholders in the market have committed to developing best practices for potential operational hazard prevention, end-of-life recycling, and responsible supply-chain practices.

IHS Markit does not observe a significant impact on growth to date, outside of the South Korean market, where installations were halted for the period of the investigation. However, going forward it will be crucial that fire safety standards strike a balance between ensuring safe operation and not increasing system costs to inhibitive levels. pv

Julian Jansen and Youmin Rong

Photo: BYD

Li-ion batteries undergoing fire tests. Although several recent fires at battery installations in South Korea have mostly been blamed on poor installation and operational practices, battery manufacturers remain committed to developing best practices for fire prevention.

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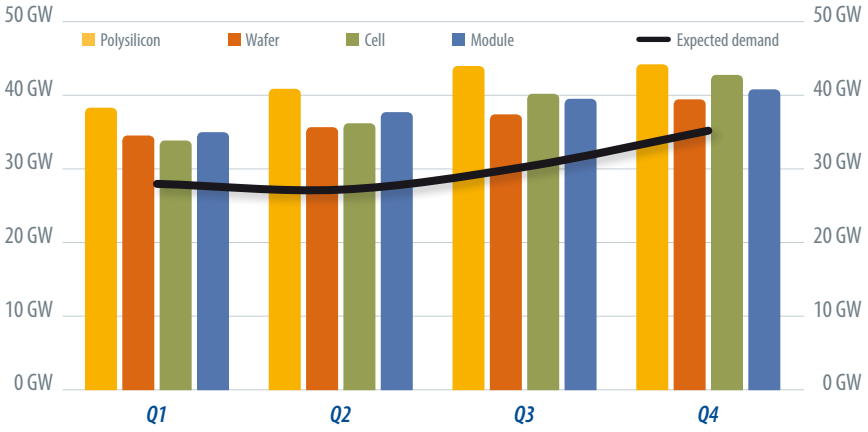
PERC cells: From shortage

After the "June rush" to complete solar projects in China – as well as the commissioning rush in Vietnam, which saw higher-than-expected demand of 4 GW in the first half – the growth of the regional solar market started to slow down in July and August, before anticipated Chinese demand picks up the slack again. With unexpectedly low demand in the third quarter, module manufacturers reacted first by marginally reducing utilization rates. Cell producers then cut production after cell prices collapsed.

In 2018, the cell segment had the lowest capacity in the supply chain, and that kept profitability of mono PERC cells above 15%. Driven by high profits, many cell manufacturers expanded capacity at a faster pace, while vertically integrated companies also ramped up existing manufacturing capacity for PERC cells. Consequently, new plans to expand PV manufacturing capacity since the end of last year have mainly focused on mono PERC lines or existing line upgrades, leading to record high global PERC capacity additions of more than 50 GW this year. Aggregate capacity is forecast to hit 100 GW by the end of 2019. Following large-scale expansion, the cell segment will accumulate the largest manufacturing capacity in the supply chain by the end of the year. Ongoing expansions and upgrades indicate that the market's elimination of excess capacity will occur ahead of time.

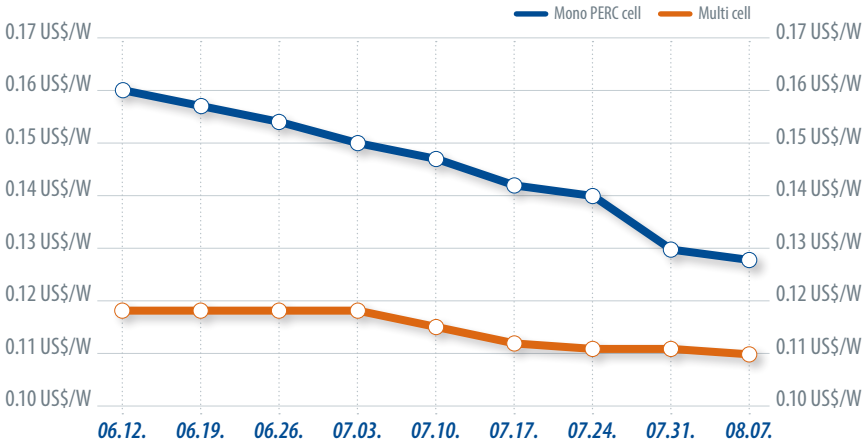
***PV supply chain capacity 2019** (tier 1)*

Source: PV InfoLink



Solar cell price trends July/August 2019

Source: PV InfoLink



Price movements

PERC cell prices trended downward in mid-June due to weakening demand, with market prices falling 20% within 45 days, from the previous level of $0.16/W to $0.12/W at the beginning of August. Calculated with mono-Si wafer prices of $0.42 for August, PERC cell prices have broken even for several older manufacturing lines, or met the cost level of small-sized manufacturers.

In the meantime, the Chinese market has been busy with auctions for grid-parity projects. To secure orders for September to December amid low demand and a slump in PERC cell prices, module makers have rapidly reduced bidding prices. Current auction results reveal that mono PERC module prices have come down to $0.252-$0.258/W in China, making the country the market with the world's cheapest solar yet again.

Demand for PERC products remains weak, despite the rapid price drop. Several manufacturers saw inventory pile up in late July and early August, pushing them to sell products below cost. Cell producers also reduced utilization rates to prevent inventory from piling up.

To remain cost effective, vertically integrated companies with in-house production capacity started evaluating the viability of outsourcing as soon as PERC cell prices broke even. In fact, a few top-tier vertically integrated companies even suspended some of their production lines and purchased cells from other suppliers.

With wafer prices going down from late July and cell prices breaking even for older production lines, profits from multi-Si cells exceeded mono PERC for the first time, driving some cell makers

to surplus

to switch mono PERC lines back to produce multi-Si cells in July. The move aggravated the excess supply situation for multi-Si amid stagnant demand, and prices have since fallen continuously as a result. The trading price of conventional multi-Si cells has declined from $0.18/W in June to $0.11/W at present. After multi-Si cell prices hit bottom, manufacturers started pushing the upstream sector to lower multi-Si wafer prices.

Based on its latest auction results, Chinese demand – which stood slightly above 10 GW in the first half – is forecast to double to 20 GW from September to December, prompting rush orders to start from the end of August and the beginning of September. Moreover, market demand in the United States and Europe is expected to rise in the high season throughout the third and fourth quarters. PV InfoLink thus projects that cell prices will rebound after hitting a low in August.

While prices were reduced further to increase sales, many manufacturers continued capacity expansions. The third quarter will see more than 20 GW of new PERC capacity from Aiko and Longi, as well as some new gigawatt-scale players coming online. Uniex and Tongwei will join the game later in the fourth quarter. Tongwei, in particular, will have new capacity coming online at the end of 2019 and the beginning of 2020. There's no end in sight for PERC cell capacity expansion.

The record-breaking volumes of commissioned PERC capacity foreshadows the elimination of older PERC production lines with higher cost structures. With an estimated 92 GW of full-year global mono PERC demand expected in 2020 – but a forecast of 113 GW and 150 GW of aggregate global mono PERC capacity in 2019 and 2020, respectively – excess PERC capacity from the end of the year to the beginning of next year will mean that PERC lines with no cost advantage may struggle to survive. Nevertheless, manufacturers have not immediately ceased activities on older lines, despite losses. The market will therefore see fierce competition on PERC cell prices over the next year.

Looking ahead, prices likely won't stabilize until demand bounces back in September. However, price increases for PERC cells will remain limited in September through the end of the year, due to large volumes of new PERC production lines and line upgrades coming online in the third and fourth quarters.

On the conventional multi-Si product side, the revival of the Chinese market in the fourth quarter is expected to drive up demand for multi-Si modules. Constrained by auction projects, module prices sit at around $0.22/W, despite multi-Si cell demand turnaround, and it will remain difficult for multi-Si cell makers to raise prices.

Overall, low demand only hit the market after the Chinese Lunar New Year holiday and the July-August period this year. However, the midstream sector will experience notable price fluctuations in the low season in the future, because of massive capacity expansion across the supply chain this year. With cell manufacturing capacity becoming excessive, the era of high profitability for PERC cells has come to an end.

Corrine Lin

All that solar jazz

As 2019 enters its final quarter, the solar industry continues to face headwinds, even as the markets for solar deployment in Europe, the United States, and Australia remain strong. Paula Mints of SPV Market Research takes us through what to expect up until 2021.

"Governments often offer tenders without exploring the capability required"

The global economy is an intricate web of alliances, and one ill-advised trade move will eventually trickle through all of it. The U.S.-China trade war continues to risk slowing down growth, not only for the two countries involved, but also for other global economies. Economies in the EU are also particularly vulnerable as the U.K.'s exit nears.

In 2019, several tenders worldwide were canceled or delayed because of inadequate transmission and distribution networks. Infrastructure concerns are high for conventional energy; solving the problem is critical for continued solar industry growth. Unfortunately, governments often offer tenders without exploring the capability required to support the deployed solar.

China, India, Europe and the United States are currently the four most significant markets for solar globally. And all four are vulnerable to market shocks.

Emerging markets in Latin America, the Middle East and Australia are currently experiencing accelerated growth; however, each market has vulnerabilities that could stall growth in the near term. For example, Mexican President Andrés Manuel López Obrador recently halted an auction for renewable technologies and stated a preference for oil and gas over renewables.

China, as it continues to stabilize its domestic market for solar deployment, is experiencing a slowing economy that is complicated by ongoing trade tensions with the United States.

India's economy and politics remain unstable and its market for solar deployment highly vulnerable to underbidding on tenders (unprofitability). It is also plagued by administrative hurdles common to all construction in India, a lack of participation by manufacturers, and low-quality components and installation practices.

Activity in the United States is accelerating in anticipation of the planned decrease of the Investment Tax Credit, even as the ongoing trade war with China pushes module and other component prices up.

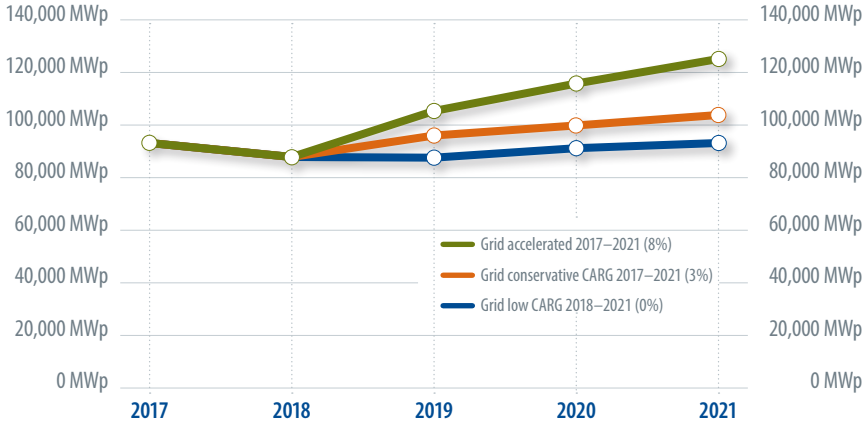
The chart below presents the global forecast for grid-connected PV deployment from 2017 through 2021. It focuses on the grid-connected market, as it is >99% of PV deployment globally. The decrease in demand in 2018 was the first market slowdown in 50 years for the solar industry. pv

Paula Mints

Paula Mints *is the founder and chief analyst of global solar market consulting firm SPV Market Research. She began her career in 1997 with Strategies Unlimited before joining Navigant in 2005, where she continued as the director of the firm's energy practice until October 2012, when she founded SPV Market Research. Her expertise includes global markets and applications for solar products, cell and module cost analysis, system and system component analysis (including inverters, trackers and other BOS components), and trend analysis.*

Grid-connected global forecast: 2017 through 2021

Source: SPV Market Research



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All eyes on the Indian government

India's total installed solar capacity touched 34.1 GW on June 30, 2019. The total was split between 27.9 GW of utility-scale PV, 4.6 GW of rooftop solar and 1.26 GW of off-grid solar. The nation's total project pipeline – projects allocated to developers and those in various stages of development – stood at 19.69 GW as of June 30. Bridge to India's Sai Nandamuri looks at the outlook for Indian solar in 2019 and 2020.

Utility-scale solar capacity additions have been slowing down in India over the past year, and the second quarter remained slow, with only 1.1 GW of capacity additions against our estimate of 1.53 GW. The slowdown is due to many reasons: land and transmission bottlenecks, tight liquidity in the financial system, and rising input costs that have affected the profitability of many projects. Distribution company (DISCOM) payment delays have also hurt the sector very badly. Rooftop solar remains a bright spot, with capacity additions of 515 MW in the second quarter.

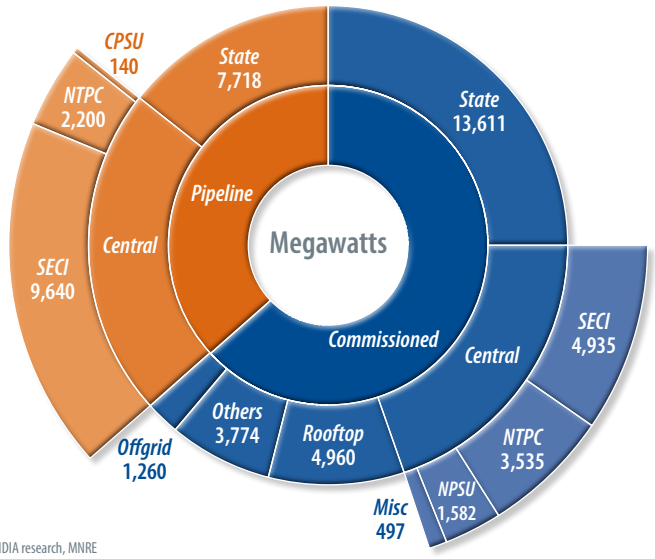
> *"India's capacity addition has been muted for over a year now, but the project pipeline looks robust for Q3 and Q4 2019"*

Going forward, installation activity should pick up significantly. A total of 13.5 GW is due for completion in the next 12 months, but we expect significant slippages due to the reasons discussed earlier. The fall in safeguard duties to 15% in January 2020, and their removal by July 2020, should ease concerns for the sector. But there is rising speculation in the market that the government is mulling further duties to protect domestic manufacturers.

Tender issuance has stayed robust, with a total utility-scale capacity of 10.3 GW issued in the second quarter, although it was down 35% from the previous quarter. However, many recent tenders have been cancelled and/or undersubscribed. Gujarat's 700 MW Raghanesda tender was undersubscribed by 100 MW in May 2019. Solar Energy Corp. of India's (SECI) 1.2 GW tender in June, as well as a 2 GW tender in March and another 1.2 GW of recent hybrid tenders, were undersubscribed by 50%, 53% and 25%, respectively. Recently, NTPC Ltd.'s 1.2 GW tender also failed to lure bidders, forcing a deadline extension.

The Ministry of New and Renewable Energy's (MNRE) decision to adopt an approved list of module manufacturers – part of efforts to address quality issues in components – is also likely to create uncertainty. All installations from April 2020 will need to comply with this policy. But there are still concerns about the MNRE's capacity to complete the necessary certification process in time, as well as the willingness of international and domestic manufacturers to hand over confidential data.

Total installed and pipeline capacity at the end of June 2019



Source: BRIDGE TO INDIA research, MNRE

Project pipeline

India's capacity additions have been muted for over a year now, but the

nation's project pipeline looks robust for the third and fourth quarters. It is up to the government to take decisive action to address issues related to land acquisition, transmission connectivity, and DISCOM bankability.

Incidents of tender cancellations and undersubscriptions have marred investor confidence. And sentiment has been further shaken up by the state of Andhra Pradesh's recent move to rescind PPAs. Overall, sentiment in the sector is highly stressed; everyone is now focusing on whether the government can announce measures to spur confidence. pv

Sai Nandamura

Utility scale solar capacity addition

Source: BRIDGE TO INDIA research

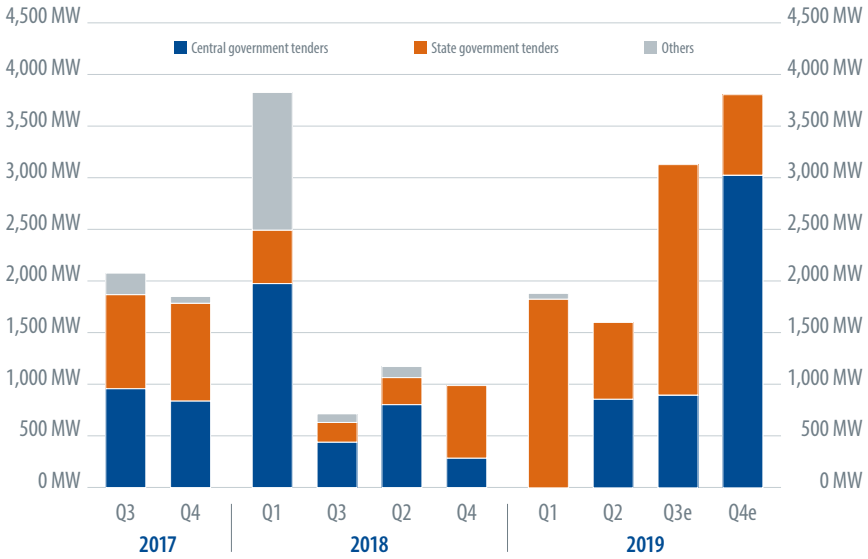


Photo: Bridge to India

About the author

Sai is a consultant at Bridge to India with five years of experience in the energy sector. He has previously worked on rating the thermal power industry in India for efficiency and sustainability. Prior to joining Bridge to India, he worked with Centre for Science and Environment. Sai holds a Masters degree in Environmental Management (MESPOM) and BE (Civil Engineering) degree from Manipal University.

The specter of PV

Trade tariffs are spreading across the global PV industry. The United States has been especially active with its sandwich of old antidumping and countervailing duties coupled with new Section 201, 232 and 301 duties. Some of these are part of the Sino-U.S. trade dispute; others impact not only Chinese producers, but manufacturers around the world. So, what will be the impact of this new era of PV protectionism on the solar sector?

"The principles of free trade and globalization have come under attack from many sides"

Frank Asbeck turned 60 years old on August 11, and many will remember him for his company SolarWorld AG, which once led German PV cell and module manufacturing before its bankruptcy in March 2018. But Asbeck also did pioneering work on another front: his efforts were critical in getting the European Union to adopt a Minimum Import Price (MIP) to protect European PV manufacturers from overseas competition, mainly from China.

Asbeck and SolarWorld were also instrumental in getting the Obama Administration to levy antidumping (AD) and countervailing (CVD) duties on Chinese manufacturers in 2012, the first round of trade measures adopted to protect U.S. manufacturers (like SolarWorld's former operation in Oregon) from cheaper modules made in China.

In both cases the aim was to protect domestic industry from what was alleged to be unfair competition from Chinese manufacturers, which were (so the claim goes) either selling below their actual costs (antidumping) or benefitting from unfair subsidies their government was providing (the gist of countervailing duties or CVD).

These cases took a rather narrow view of "domestic industry", being concerned mainly with upstream PV manufacturers and not the solar PV industry at large. On the downstream side, most consumers, installers, developers and EPCs were against putting up walls to shield domestic manufacturers. Protectionist policies, whether in the form of MIPs, AD or CVD, increase prices, making PV projects more expensive, and in some cases prohibitively so.

Since Asbeck and SolarWorld championed tariffs as the way to protect European and U.S. manufacturers, much has happened in the solar industry and for that matter, trade relations in general. The principles of free trade and globalization have come under attack from many sides, with the Trump Administration being the most vocal. In fact, the embodiment of free trade and globalization, the World Trade Organization (WTO), has been lambasted by Trump, who is blocking appointments to the WTO's Appellate Body, saying its judges have overstepped their mandate.

For the solar PV industry, which became mainstream as a globalized industry around the turn of the century, the specter of increased trade tariffs in a wide range of countries risks undermining the great strides solar has made in reducing its LCOE. On the other hand, having an extended solar value chain in place has its benefits: if a country lacks a significant manufacturing base and relies to a great extent on imports to feed its solar installations, it will suffer in terms of energy independence, especially as PV and battery storage continue to displace conventional energy generation.

Each market also has its own characteristics (environment, roof structures, etc.) and the more extensive the solar value chain, the better the country can fashion its solutions to such characteristics. Finally, there is the employment argument, which equates a more extensive solar value chain with a more diverse and technologically advanced workforce in the strategically important field of renewable energy. The employment argument can also go the other way along the following lines: the lower the cost of solar, the more projects are planned and built, which in turn stimulates employment on the downstream side.

The United States probably offers the most complex picture, since the old AD and CVD duties remain in place and have been sandwiched together with myriad other tariffs established during the Trump presidency. These Trump tariffs include Section 201, 232 and 301 duties, the final of which is part of the Trump administration's broader campaign to pressure China to change the way it handles foreign trade and investment.

Chile's open borders

Chile exempts the import of solar modules from custom duties. This has made it possible for the country to become the most dynamic PV market of Latin America over the past years, at least in the utility-scale segment, thanks to low module and project costs. As a consequence, however, zero efforts were made to create a local industry for panels, inverters, mounting structures or other components. *Emiliano Bellini*

protectionism

Photo: Mark Gunn

A container ship passes under San Francisco's Golden Gate Bridge.

Even before Donald Trump was elected, China had responded by introducing its own tariffs, with one of the victims being U.S. polysilicon producers. This was one of the last areas where the U.S. still has a significant production footprint in the PV industry. Unlike Section 301 duties, which apply only to China and cover cells, modules and inverters (at a duty rate of 25%, up from 10% starting May 10), Section 201 and 232 duties cover all countries exporting to the United States.

In India a 25% safeguard duty has not stemmed the influx of foreign modules. According to analysts at Bridge to India, one year after the tariff was imposed in July 2018, the share of foreign modules continues to hover around 90%, showing how difficult it is for governments to steer markets with tariffs.

In the European Union, the abolition of the MIP created a virtual solar renaissance, with solar installations in the EU forecast to grow by as much as 80% year-on-year in 2019, after the MIP was rescinded last September.

In both India and the EU, the lack of manufacturing depth, not only on the PV side but also with batteries, remains a central issue. And with Trump erecting barriers across the Atlantic we could see governments in the Old World consider putting up their own walls to protect and grow their technology and manufacturing base.

The concern is that such measures and countermeasures could spiral out of control and turn a truly globalized market into many walled gardens with artificially high prices. This is clearly not a scenario in line with fostering clean energy and combating climate change. On the other hand, a mega-deal between the United States and China could bring us back to the path of globalization and free trade and with it the hope of addressing climate change on a truly global level. pv

Eckhart K. Gouras

Unintended consequences in Brazil

Brazil is currently applying a 12% tariff on imported capital goods and IT/telecommunications equipment, which also includes solar products. However, in June the Brazilian government published new regulations, with which it hopes to eliminate such barriers.

The Ministry of Economics Affairs (MEA) claims that the duty can be removed, as imported panels should not be considered similar to those made in Brazil.

The local electronics and solar industries, through their respective associations, Abinee and Absolar, said domestic panels can currently already be purchased at prices that are 30% higher than imported ones, while stressing how the latter are also exempt from the Industrial Product Tax (IPI) and Merchandise and Service Circulations Tax (ICMS) and another tax under a special program for infrastructure projects, while Brazilian panel makers are subject to the payment of several purchase taxes on raw materials.

As a result of these requests, the Brazilian government decided to freeze the new regulation until August 30, with the associations urging senators to ask the MEA to include the import of raw materials in the new rules, which would exempt them from the duties. But regardless of how these new rules may be shaped, the production of solar modules in Brazil will remain quite challenging.

Emiliano Bellini

Trump's (clean energy) trade war

> *"The components affected by one or more tariffs make up more than half of the cost of a utility-scale PV system"*

The United States has developed a pugnacious trade policy under President Trump, and the solar and energy storage industries have found themselves caught in the middle of new trade wars. But while many have argued that the imposition of the Section 201 tariffs was an attempt by the Trump Administration to destroy the nation's solar market, there is as much or even more evidence to suggest that this really is about protectionism and the use of trade as a weapon in international relations.

To make sense of this, it is important to recognize that President Trump is not the only player here. Most of the important actions that the Trump Administration has engaged in have come from the desk of U.S. Trade Representative Robert Lighthizer, a veteran of the Reagan Administration and a proponent of an aggressive, protectionist trade policy.

Tariffs, tariffs, tariffs

There have been multiple sets of trade duties initiated by Lighthizer's office, often under dictates from Trump himself. The Section 201 global trade duties on solar cells and modules had the most obvious impact on the U.S. solar market, but there are also the Section 232 global tariffs on imports of steel and aluminum and several rounds of Section 301 duties on a wide range of products that include PV cells and modules, PV module components and inverters from China.

Taken together, there is essentially no part of the U.S. solar and energy storage markets that is not affected by one or more of these tariffs to some degree. As shown in the chart to the upper right, together the components affected by one or more tariffs make up more than half of the cost of a utility-scale PV system.

However, the Trump Administration has also provided two big exceptions to Section 201 – one for modules using SunPower's Interdigitated Back Contact (IBC) PV cells, and a more recent one for bifacial solar panels.

And this is not over yet; Trump is planning to impose tariffs on a range of products being imported from China at a rate of 10% as of September 1, including lithium-ion batteries.

Market effects

None of this has been good for the U.S. solar market; however the actual effects are more complicated than one may guess. Even with the Section 201 tariffs most PV systems still pencil, and solar projects are still being built to comply with renewable energy mandates, to meet corporate clean energy goals, as well as simply because they make sense economically.

What Section 201 did more than anything was to interrupt the market for a good six months or so while the U.S. solar industry knew that a change was coming but did not know what level of tariffs would be set.

And even when taken together, the various tariffs imposed by this administration did not fundamentally change the attractive economics of PV systems in most areas. However, they did have more serious effects on specific companies and even whole industry segments.

Encouraging manufacturing?

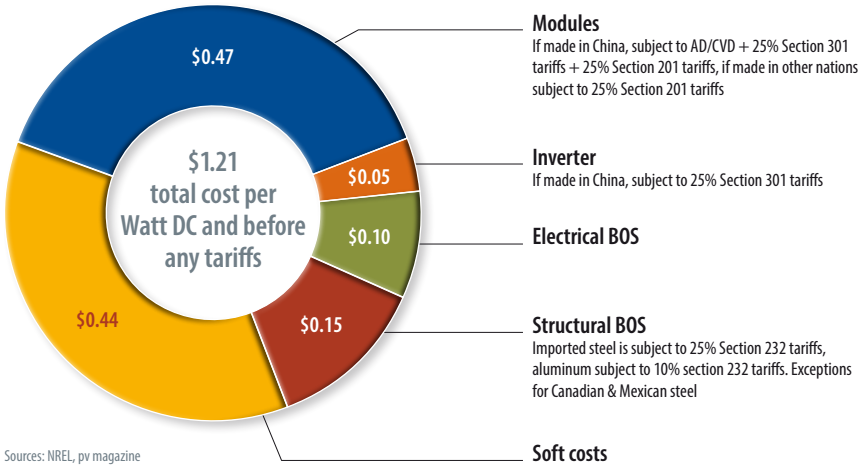
Aside from the Section 301 tariffs, which appear to have been imposed primarily as a punishment/aggressive bargaining tactic by the Trump Administration, the rhetoric behind most of these tariffs, including the Section 201 duties, is that they will protect and enable U.S. manufacturing industries.

The Section 201 tariffs were definitely a key factor in the four large U.S. solar factories totaling 3.8 GW of annual production that have either come online or are currently under construction. However, every manufacturer who **pv magazine** spoke with also identified Republican tax

U.S: President Trump and Chinese leader Xi Jinping meet at the G20 summit in Osaka in June 2019.

Photo: The White House/Shealah Craighead

Cost to build a 50 MW solar plant with single axis trackers in the United States, 2018



Sources: NREL, pv magazine

> *"Even with the Section 201 tariffs most PV systems still pencil, and solar projects are still being built"*

reform, which cut corporate tax rates, as another main factor.

Also, by raising the costs of raw materials, these tariffs are negatively affecting the very industries they are supposed to be supporting. A prime example is the racking, tracking and mounting systems makers, who were affected by higher steel prices due to the Section 232 tariffs, and U.S. PV makers have also said that their supply of aluminum frames and other materials is being affected by Section 301 tariffs on their Chinese suppliers.

Additionally, some companies, including First Solar, are now arguing that the exemptions to Section 201 – more the bifacial exemption than the exemption for SunPower's IBC – undermine the effectiveness of the tariffs as a tool to incentivize manufacturing.

So like other aspects of the Trump Administration's trade policy, the rapid and unpredictable changes created by these exemptions makes long-term business planning difficult and throws supply chains into chaos.

In the end, nothing is certain except that under the current administration the trade war isn't going away any time soon. pv

Christian Roselund

Shifting destinations

The impact of United States' removal of preferential treatment for Indian PV cell imports, whether assembled into modules or not, will be fully reflected in Q2 2019 figures, however, it is clear that India's PV manufacturers are already looking at alternative markets – and having some success.

> *"Demands are rising for the Government of India to provide incentives"*

The United States continued to be India's largest export market at INR 16,500 lakh (US$23 million) in Q1 this year – the situation may change as figures for following months become available, with the impact of 25% tariffs coming into effect – but there is a huge jump in exports to some markets.

While the figures for Denmark, India's second largest PV export market in 2018-19, are not available for the quarter, Belgium emerged as the second largest market at INR 3000 lakh (US$4 million) – more than for the full year 2018 total of INR 2400 lakh (US$3 million). Exports to South Africa stood third at INR 1100 lakh (US$1.5 million).

Topping the countries which registered significant growth in Q1 is Somalia, where India's exports reached INR 900 lakh (US$1 million) against year 2018-19's total of INR 2 lakh (US$2,800).

Market trends show the European Union (Belgium, Portugal, Sweden) and African countries (South Africa, Somalia and Ghana) – in addition to Asian countries like Korea and Pakistan – are emerging as significant markets for Indian modules.

These reported figures tend to be in line with the views of Vikram Solar's Chief Financial Officer Rajendra Kumar Parakh, who said that with the United States becoming a costly proposition, Indian solar manufacturers that have already lost the domestic market to cheaper Chinese imports, "will now target Africa, The Middle East and North Africa (MENA) region, and other rapidly growing solar markets to export."

However, given that Indian solar manufacturers are finding it challenging to match aggressive pricing of Chinese solar equipment within the global markets as well, the demands are rising for the Government of India to provide incentives on export to help them go toe-to-toe with the global suppliers.

Why exports?

In July 2018, India applied a two-year safeguarding duty on solar PV cells and modules from China and Malaysia, in order to protect domestic players from the steep rise in cheaper imports. In line with the notification issued by the ministry, a 25% safeguard duty was imposed between July 30, 2018 and July 29, 2019. The duty tapers down to 20% between July 30, 2019 and

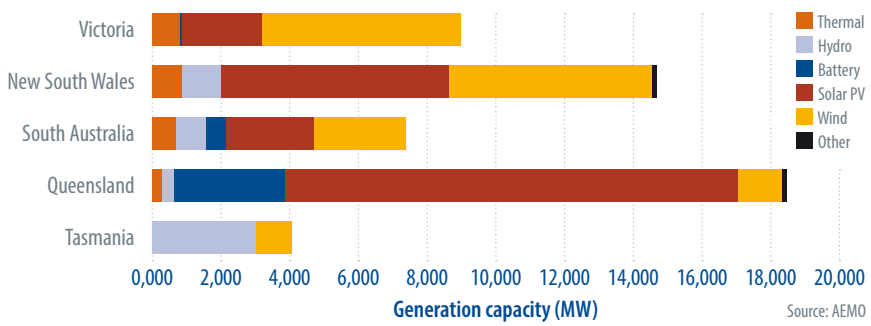
Open doors Down Under

As a country with a relatively small manufacturing sector and an economy heavily reliant on mineral and agricultural exports, Australia has few tariffs in place. With East Asian trading partners any attempts at a trade war with China would be folly. "Australia has quite a free and open market for solar power components compared to some countries such as the United States under President Donald Trump," says Darren Gladman, Clean Energy Council director for distributed energy.

Given this, Australia's ports are wide open to PV imports resulting in low system prices and healthy run rate for the rooftop segment and strong pipeline of large scale projects. Low system prices are also a credit to Aussie installers given high labor costs within the country. Installed rooftop system costs are now a quarter what they were one decade ago.

However, as PV antidumping disputes gripped other parts of the world, authorities did investigate the matter. "The Commonwealth Government's Anti-Dumping Commission terminated an investigation into the importation of solar panels into the Australian market in 2015," continues Gladman. "The introduction of additional tariffs or duties on these products would have made solar technology substantially more expensive for consumers." He adds though that there are "some complications" regarding aluminum product imports – impacting some mounting structures. *Jonathan Gifford*

Proposed Australian generation/storage projects by state, beyond those already committed



Source: AEMO

January 29, 2020, and to 15% from January 30 to July 29, 2020.

The duty, however, didn't deliver the intended results: Solar developers have chosen to shift source of import rather than sourcing higher-priced products from domestic manufacturers. So, there has been a surge in cheaper imports being rerouted though locations such as Vietnam, Singapore and Thailand, where the duty is not applicable.

In fact, a recent Bridge to India report says that the share of imported solar modules used in Indian solar projects is still around 90% – the same as before imposition of safeguard duties.

With a foothold lost in the domestic market to cheaper solar imports, Indian solar manufacturers are eyeing the untapped and emerging solar markets globally to generate revenue. pv *Uma Gupta*

One year without tariffs – alive and kicking still

The European minimum import price (MIP) came into effect in 2013. After it failed to save the upstream fleet, the EU waved goodbye to the anti-dumping measure about one year ago, to the delight of many in the European PV industry.

Right now, the market is in full steam, and to some extent, this can be attributed to the scrapping of the MIP – modules have become cheaper after all. With current installation speeds, Europe will break the 20 GW mark by the end of the year, an 80% increase compared to last year. Several new entries, like Ukraine which exploded into a gigawatt market in little more than a year, and Spain, which catapulted itself right back to the top of the pack following a change in leadership, are to be held accountable for the increase in installations. In neither case, however, could one confidently claim it was the MIP that caused the wheel to turn. It was more political will or necessity to comply with the Paris Agreement that saw many new markets turning more towards renewable energy. A few percentages off module prices were a warmly welcomed confluence.

An effect might be seen in the rise of subsidy-free projects. Severe financial tinkering and attention to detail for marginal savings allow the trick to be pulled off. Not very strong on volume yet, the segment could take off fairly soon, and cheap components will be a driver.

On the business side of things, "we are also pleased to see [that] several European companies, both upstream and downstream, in the past months announced plans to expand their business in Europe," SolarPower Europe CEO Walburga Hemetsberger told **pv magazine**.

And that is probably where the real tenet can be drawn. Put in place to protect the domestic solar industry, the MIP did little but increase component prices for European module makers. Now without the measures in place, there are first reports that Europe could be producing modules on par with China. *Marian Willuhn*

Under-the-radar US residential markets

All American residential solar markets were not created equal. While states such as California, New York and Massachusetts have legacy markets that have existed in strength for well over a decade, some have taken longer to find their footing. A look at three promising U.S. states for residential solar.

There are approximately two million residential PV systems in the United States, according to the National Renewable Energy Laboratory (NREL). These installations only represent around 1.7% of households. And while residential installations grew 7% from 2017 to 2018, future growth projections can be tricky. In the 2019 Q2 Solar Market Insight Report developed by the Solar Energy Industry Association and Wood Mackenzie (WoodMac) the U.S. residential solar market is predicted to grow by somewhere between five and 20% by the end of 2021.

Whether that forecast is reached or not will depend largely on the continued strength of those previously underserved states, sometimes referred to as "emerging markets." And these states may be primed for drastic expansion in the near future.

Decisions reached at state level regarding regulation of 'solar leasing' business models such as Sunrun's will impact overall growth of residential solar in the United States.

Photo: Sunrun

Florida

Much has been made of Florida Power and Light's (FPL) "30 x 30" plan, to bring over 10 GW to the Sunshine State by 2030. But the flashy headline numbers tend to overshadow a residential solar market that has grown in installed capacity each of the last seven fiscal quarters.

Over that period, the state has seen more than 160 MW in residential capacity added, bested only by Texas, New Jersey, Arizona and California. Looking at what is driving this performance, the state's nickname holds a clue: The Sunshine State gets a ton of sun. But beyond its natural assets, one of the most important residential segment drivers is the decision reached by state regulators in April of 2018 to allow Sunrun to lease solar systems to households.

Under Florida law, a company may lease an individual a solar system but cannot sell electricity as part of that transaction – only a fixed price on the leased hardware. In the eyes of the law, only public utilities can sell electricity. Ultimately, Florida regulators found in Sunrun's favor for the following reasons: Sunrun's residential solar equipment lease does not constitute a sale of electricity; offering its solar equipment lease to customers in Florida will not cause Sunrun to be a public utility under Florida law; and the residential solar equipment lease will not subject Sunrun or its customers to commission regulation.

Soon after the Sunrun decision, Vivint and Tesla were also approved to sell solar leases in the state. These decisions now allow Florida residents to lease entire solar systems over a fixed 20-year contract and sell back for credit the energy generated.

Net metering has also been a considerable driving force in the Florida residential market. All utilities within the state

are required to offer net metering in some form or fashion, with investor owned utilities having their net metering program overseen by state regulators.

Taxation also plays a role. Florida is well known for being one of the seven states in the Union without a state income tax – meaning that all revenue generated by selling excess PV generation into the grid is fed back to the system's owner or lessee tax free.

Florida does, however, have high property taxes – which could cause headaches for homeowners with solar PV. Fortuitously, an exemption is in place. According to Andrew Newbold of Sunrun, exemptions strengthen the market segment's backbone. "Every stable and thriving solar market in the country has property tax exemptions," Newbold told **pv magazine**. This is critical from an avoided cost perspective alone, as a more levelized property tax rate allows homeowners to pay off the loans or make lease payments on their solar systems without the financial pressure of higher property values.

"You don't tax a garden that someone adds to their house to provide them food. You don't tax a water heater someone adds to a house to heat their water. So why would you tax solar panels that are made to make a house more energy efficient," added Newbold.

Texas

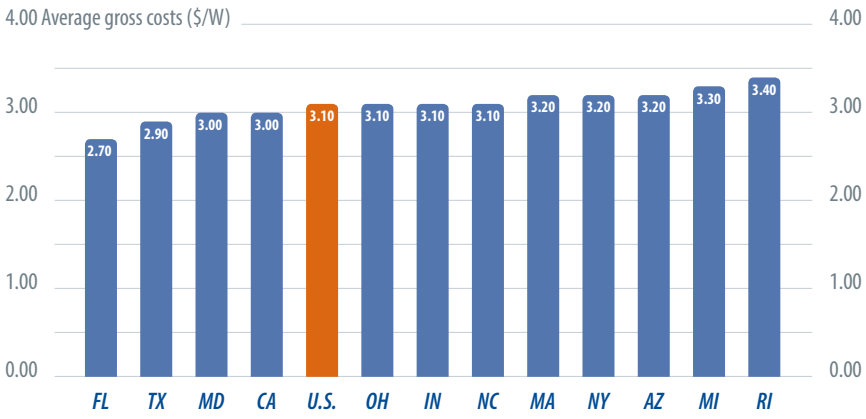
What has been said about the Texas solar industry is the same sentiment that has run true about the state since its inception: "Everything's bigger in Texas." This led to a similar situation as in Arizona and North Carolina, where utility-scale solar projects popped up quickly and were mas-

Installation figures for top 10 residential PV state markets, Q3 2017-Q1 2019

Installations (MWdc)	Q3 2017	Q4 2017	Q1 2018	Q2 2018	Q3 2018	Q4 2018	Q1 2019
California	199.8	232	232	232.6	238.7	250.4	227
Arizona	33.4	31.2	30.1	39.5	37.5	36.2	42.4
New Jersey	50.1	51.3	55.1	40.3	38.2	50.2	41.9
New York	3.8	6	11.8	17.5	20.6	25.1	31.6
Florida	13.8	15.7	21.4	23.2	26.2	32.5	31.5
Texas	32.4	35.6	31.2	36.3	34.5	35.1	31.5
Nevada	16.3	16.3	21.1	21.4	24.7	24.4	21.8
Massachusetts	24.9	24.9	13.8	18.7	16.6	16.5	16.9
Connecticut	29.3	22.1	21.2	26.8	25.2	23.6	16.2
Maryland	11.7	10.9	13.6	12.5	15.5	16.9	14.5

Residential rooftop system cost by state

Source: NREL



Texas and Florida are two of only four states in the United States to offer per watt costs under the national average of $3.1/W and are the only states period to offer costs under $3/W at $2.7/W for Florida and $2.9/W for Texas, according to researchers at NREL. With costs-over-time falling every single quarter and a national buyback period average of 7.8 years, homeowners in Florida and Texas can expect to see especially quick payoffs on their already comparatively cheap systems. This will change slightly with the upcoming ITC step down, however as that is national the state-to-state impact should be more minimal.

sive in scope, but residential development was sluggish by comparison.

However, there is one key difference that sets Texas apart from Arizona and North Carolina: Texas isn't under the thumb of a major utility. While the majority of Arizona households live under the service of resi-resistant Arizona Public Service and folks in North Carolina face the same from distributed-dodging Duke Energy, Texas is home to the Electricity Reliability Council of Texas – the deregulated energy marketplace. This provides massive variance in the Texas market, with some customers given their pick of the litter of power companies to purchase from and others under the service of their local municipal utility.

> *"Texas isn't under the thumb of a major utility"*

236 MW of residential solar has come online in the Lone Star State since Q4 2017, putting it in fourth place nationally for the market segment. The biggest anticipated hindrance to the segment appears to be the lack of net metered offerings. However, this is not universally true. The municipal utilities of three of the state's major cities (El Paso, Austin and San Antonio) as well as the state's three largest retail electric providers, which cover Dallas and Houston, all offer some sort of electricity buyback program. This means that most Texans live in an area where they're eligible for net metering in one form or another. Rebates on solar system purchases, however, are harder to come by and have more variation company-to-company.

Much like Florida, Texas has no state income tax and a solar property tax exemption, both of which allow for faster buyback times. Overall system costs also impact payback periods. Gross costs-per-watt for a residential array in both Florida and Texas is low.

Illinois

While Illinois had the best quarter for residential solar installations in its history in Q1 2019 with 6.9 MW installed, WoodMac projects the state to install only 37 MW over the next five years. Part of this is due to the headache that has been the implementation of the Adjustable Block Program (ABP).

ABP is a component of the Future Energy Jobs Act (FEJA). Passed in late 2016, one goal of FEJA was to legislate the state's 25% renewables by 2025 policy. ABP is a program which provides grants for both small and large distributed generation projects in the state.

"Illinois took this approach that every resident, in some way, should be able to be part of this clean energy future in Illinois," said Amy Heart, Sunrun's director of policy. "So, there are programs and incentives directed to provide that opportunity."

The main issue was that state regulators did not anticipate the level of demand. The ABP is ten-times oversubscribed, and even more troubling is that the renewable energy credits (RECs) given to customers to reduce the cost of a residential system are running out.

Illinois needs to issue 20 million RECs to meet its 2019-2020 RPS target of 16%. For the expanded 25% target more than 30 million will be needed. However, projections indicate that the program will run out of money in 2021-2022, well before these targets are met.

"It's a great problem to have, that there's this interest and support for renewables," said Sunrun's Heart. "We're basically taking a breath and saying 'Okay, how do we make sure this keeps going without hitting a cliff?' People support it and we need to keep up the momentum." pv

Tim Sylvia

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Diverse segments drive

In July, Bangladesh's renewable generation capacity surpassed the 600 MW milestone. A solid achievement, even though the country still lags behind the government's official plan to produce 10%, or 2 GW, of its electricity from clean sources by 2020. But with deployment rising in both the commercial rooftop and utility-scale solar segments, development could be poised to accelerate.

"Once, cost was a major barrier for solar"

While 600 MW of installed renewable capacity may not seem like cause for celebration when compared to more developed and larger economies, Bangladeshi government officials and private sector players are pleased. The milestone is a true achievement for a densely populated country in which land for PV power plants is particularly scarce.

By the middle of this year, 18.2 MW of renewables, mainly solar, had gone online in Bangladesh. About 15.4 MW of the total was connected to the grid, while 2.8 MW was off-grid. In 2018, 74.8 MW of new capacity went online, including 34.7 MW of on-grid installations and 40.1 MW of off-grid projects.

This year's additions of on-grid solar are mainly concentrated on the rooftops of industrial facilities, which are encouraged to produce power through the country's net metering scheme. Under this system, a producer can "store" its unconsumed electricity on the national grid.

The installed capacity under this net metering system has already crossed the 10.25 MW mark, and a massive boost is soon expected, as the government has decided to install solar systems on the rooftops of all educational institutions across the country.

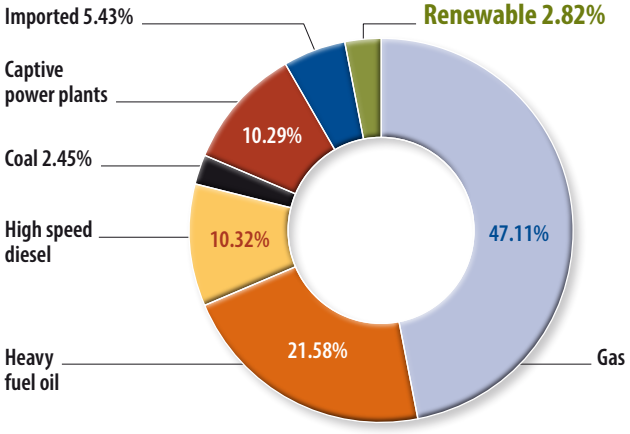
Bangladesh Railway, meanwhile, announced plans in late July to set up rooftop solar plants in its stations, office buildings, junctions and workshops throughout the country, to enhance green energy generation. Infrastructure Development Co. Ltd. (IDCOL), a state-owned financier, will provide low-cost financing to support the installations. The first phase of the railway program will add 100 MW of solar capacity to the grid.

Falling costs

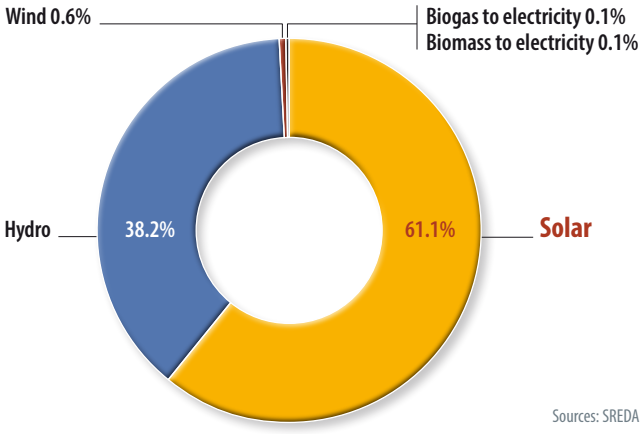
On August 4, the Bangladesh Power Development Board received proposals from five bidders to set up 45-55 MW of grid-tied solar in Rangunia, in Chittagong district. The lowest bid came from a consortium of Metito Utilities, JinkoSolar and Al Jomaih Energy and Water, with a project bid of $0.0749/kWh – the lowest ever recorded in Bangladesh's history. The second-lowest bid – from a consortium of Joules Power, WAC Logistics and Jiangsu Zhongtian – offered $0.0875/kWh, which was also much lower than anything seen in the previous tender. In the past, bids had hovered around the $0.10/kWh mark.

Siddique Zobair, a member of the Bangladeshi Sustainable and Renewable Energy Development Authority (SREDA), told **pv magazine** that solar generation costs in Bangladesh are falling due to low-cost loans from government initiatives and foreign financiers. "Once, cost was a major barrier for solar," said Zobair. "Now it is at par with fossil fuel-fired power, even in some cases cheaper."

Bangladesh electricity mix, Y1 2019



Bangladesh renewable share, Y1 2019



Sources: SREDA

deployment in Bangladesh

Photo: Parasol Energy Ltd.

This 8 MW solar plant in Panchaghar, northwestern Bangladesh, went online this year.

Big solar plants

The country's first solar IPP, a 20 MW (AC) plant, was commissioned in September 2018 by Technaf Solartech Energy Ltd. (TSEL), a subsidiary of Joules Power in the Southeastern Cox's Bazar district.

Other recent solar projects include an 8 MW plant in Panchagar and a 7.4 MW installation in Kaptai. Beyond that, most plants that have been developed in Bangladesh thus far have been below 3 MW in size.

Nuher Latif Khan, managing director of Joules Power, says that while the implementation of solar power plants has been slow, there is still a lot of optimism in the country's nascent renewables sector. "Bangladesh offers a very strong power purchase agreement and is supported by an Implementation Agreement, which makes such deals very robust from a bankability perspective. The project yields also range into double digits, which makes it a very attractive investment appraisal," he says.

Khan said that investment confidence will continue to grow, as the sector is already expanding at a much faster rate now, if the government comes forward to provide land and ensure that evacuation and transmission facilities are in place for private sponsors.

Development deadlines

The Bangladeshi government has awarded more than 1 GW of solar capacity in recent years. Of this total, PPAs have been signed for just six projects, or 532 MW.

Photo: SEPC

The location of the 15 MW floating PV site in Mongla

But private sector investors say a dearth of available land still stands in the way of Bangladesh's solar power development plans. The country's population density is 1,115 people per square kilometer.

> *"Land availability is the major constraint"*

A senior official at Exelon Bangladesh, a solar EPC service provider, agrees that land availability is the biggest constraint for solar in the country.

The official argues that the rooftop PV segment will have an excellent future if proper financing arrangements can be ensured for developers.

"The government should initiate its own bidding process, along with the RPO target for each sector, along with private carbon footprint producer. The policy should be clear and encouraging for the commissioning process," says the Exelon official.

Government and energy sector officials, however, attribute failures in securing financing as the main reason behind project delays. Power Division Joint Secretary Mohammad Alauddin said that some companies fail to arrange funds, and thus miss project development deadlines.

Floating solar

Some project developers are now working on floating solar power plants in Bangladesh. At least three such plants are under development: a 50 MW plant on Kaptai Lake in Chittagong district, a 15 MW array in Mongla, and another project on a 10-square-kilometer section of the Padma River in Manikganj, although the total capacity has yet to be decided.

The Kaptai Lake plant will be supported by funding from the Asian Development Bank (ADB), says Mohammad Alauddin, joint secretary of the power division of the Ministry of Power, Energy and Mineral Resources. The feasibility study for the plant will start soon.

Solar EPC Development Ltd. (SEPC), meanwhile, will build the 15 MW floating solar power plant at the Port of Mongla. SEPC is currently working on an additional pipeline of utility-scale, floating, and canal-related projects, with a cumulative capacity of more than 100 MW.

"As a country of scarce land, we have shifted our focus toward floating solar. Bangladesh has many rivers, a large number of [wetlands], and millions of big and small ponds, which could be an option to develop utility-scale floating solar projects," Ezaz Al Qudrat A Mazid, the founder and CEO of SEPC, told **pv magazine**. "Our 15 MW floating project at Mongla will be a new journey to a new path."

Dynamic Green Energy Ltd., meanwhile, will build the floating solar power plant in Manikganj district. Fazle Elahi Chowdhury, Dynamic Green Energy's managing director, said the project's production capacity will be finalized after the completion of a feasibility study.

More projects

In late June, the Bangladesh Power Development Board (BPDB) tendered 100 MW of capacity for two grid-tied solar power plants in Chuadanga and Netrokona districts. BPDB sought sponsors to develop the power plants on a build, own and operate basis.

In mid-June, the government also approved plans to develop a 50 MW solar power plant in Manikganj district. Bangladesh's SS Agro Complex and two unspecified German companies will build the plant. The government will buy electricity from the project for 20 years at a cost of $0.10/kWh.

Bright future

In Bangladesh, solar power was first introduced to light village homes by small-scale solar home systems. Now about 5.5 million such PV systems are providing light for millions of people, with a total cumulative capacity of about 233 MW.

To date, solar is also powering 1,392 irrigation pumps, with a combined capacity of 30.45 MW. In addition, 102,190 streetlights consume 4.2 MW of solar capacity, and 1,933 solar telecom towers provide 8 MW of capacity in total.

Dipal C. Barua, the president of the Bangladesh Solar and Renewable Energy Association, said that given the progress thus far, the future of solar power in Bangladesh is very bright. He points to the potential for rooftops to generate gigawatts of electricity to feed the power-hungry nation, he said. "The low-cost loan with 6% to 9% interest is also a plus point in investing in the solar sector," he adds. pv

Syful Islam

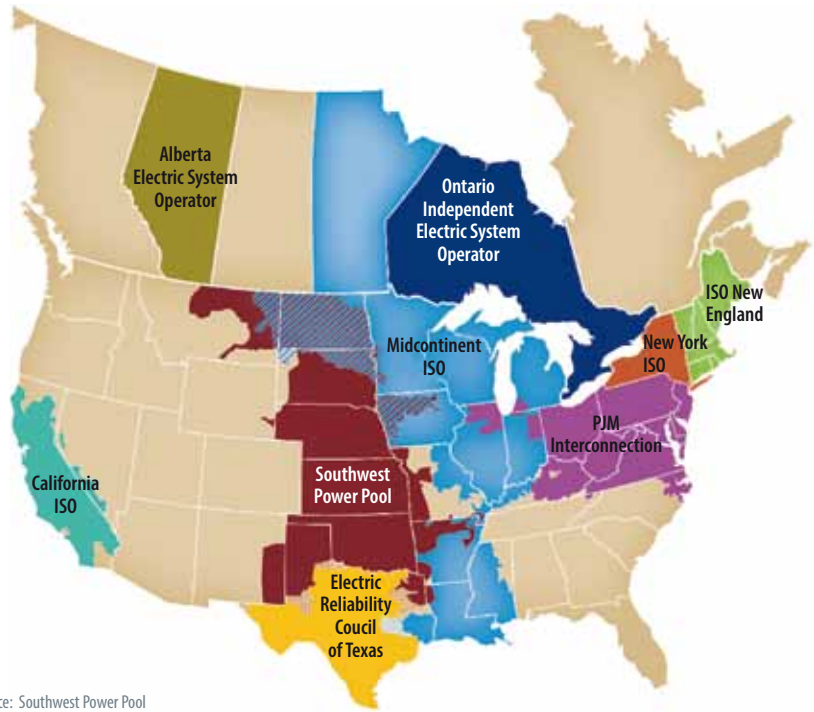
Solar tsunami

There's a lot of solar power to be built in the United States before the end of 2023, when the current "safe harbor" period for the 30% Investment Tax Credit ends. If you're reading this in September 2019, you've got four years and three full months to build large scale solar power plants under the ITC. But don't fret if you're reading later on and are afraid that you're missing out, there's development gas in the tank yet.

Since the first time **pv magazine** performed this analysis back in January 2019, the volume of solar in utility scale regional transmission organization (RTO) queues across the United States has grown from 160 GW to more than 220 GW.

Of course, a large part of this solar project volume won't be built, but the information can help guide where active companies should target resources. Looking at bright spots, Florida is looking to build a large volume of utility owned large scale solar. Additionally, there is going to be 10 to 20 GW of privately built Texas solar in the next couple of years, presenting opportunities for a host of suppliers and service providers.

Independent system operators and regional transmission operators in North America



Source: Southwest Power Pool

It is also advisable that a deeper dive is undertaken into the original sources of RTO connection data to understand their nuances, as each source is uniquely imperfect. For instance, in February 2019, there was more than 1 GW of solar power interconnection awaiting approval in Texas. But in this same state, in June 2019, 13 solar power projects cancelled, totaling 2.3 GW.

The utility scale data used to build the **pv magazine** database was downloaded from the various RTOs via public links, on July 31, 2019 in order to create the greatest level of comparable information. The data was partially cleaned. All sizes discussed are in alternating current (AC), unless otherwise noted, as this is how most utility queues communicate the information.

Electric Reliability Council of Texas

ERCOT serves 90% of the electricity demand in the state of Texas, and recently saw wind power start consistently outproducing coal. The region is also in the early construction and development stages of a massive solar boom.

Currently, 41 GW of solar power is projected "in service" at dates through the end of 2022 (with nothing listed for 2023), along with 3 GW of energy storage. Considering that at the end of the first quarter of 2019 it was estimated just under 3 GW of solar is built in Texas, this is a lot of growth.

21 GW of this volume is scheduled for 2021 – equal to what will be built across the whole of the country in 2021, not just in Texas. As a result, it likely will not be built by this date. For such a large volume of solar (and wind), the 3 GW of energy storage in ERCOT's queue seems a bit on the light side. Recent heatwave related headlines suggest there is some opportunity for energy storage, but a handful of days a year of high prices might not be enough at current low solar penetration levels.

In the press, we're seeing 100 MW+ solar deals being signed at $0.03/kWh – and even slightly lower – so the Texas market is really pushing the limits without any state incentives.


Photo: 8minute Solar Energy

The 328 MW Mount Signal Solar Farm in California. The state has seen a slowdown in utility-scale solar installations recently; but is expected to balloon to 43 GW by the end of 2023.

CAISO queue builds

California Independent System Operator (CAISO) services about 90% of California's electricity demand. While the Texas queue is front heavy and low on batteries, California shows less than 6 GW of solar power to be installed before the end of 2020, before ballooning to 43 GW by the end of 2023.

California has actually seen a utility scale slowdown in recent years as the major utilities were meeting their renewable energy goals of 33%, but now that the state has signed up for 44% renewables by 2024, and then 80% renewables plus 100% clean energy – numbers are beginning to ramp once again.

In August, it became evident that California might see a 2 to 4.7 GW energy shortfall in the evening peak hours of September, consistently the highest demand period of the year. State regulators and CAISO representatives are quite aware of solar+storage – so there might be an opportunity, if batteries can be delivered in time.

The energy storage portion of any large project in the CAISO service area is likely to be a requirement. It is also likely that in a few more years the state's duck curve will hit bottom as solar meets 100% of daytime demand.

Photo: Department of Energy

A 16.5 MW installation in Massachusetts. The state leads the ISONE region, getting 5.7% of its electricity from solar.

Southwest Power Pool

SPP manages most of the power grid in North and South Dakota, Nebraska, Kansas, Oklahoma and parts of nine other states serving a population of 17.5 million, whose more than 275,000 GWh of electricity generated in 2018 was 0.2% solar power.

"The state's duck curve will hit bottom as solar meets 100% of daytime demand"

However, now is a period of great change for the region. In a publication dated July 2019, SPP noted it has 215 MW of solar power currently in service – and as of the middle of June, had over 29 GW in various stages of study and development, along with just over 6 GW of energy storage. This 29 GW value is about double what was reported at the end of 2018.

The five main states of SPP's territory have modest renewables goals of 10 to 20%, while Nebraska has none. However, they all have massive amounts of wind power installed. The wind electricity generation values between the states range from Nebraska at 14% up to Kansas at 36.4% – compared to California's roughly 14% of electricity from solar. Of the total 29 GW, Oklahoma represents around 6 GW, north Texas sneaks 5.5 GW in, Missouri and Nebraska are both over 3 GW, and New Mexico notches 2.3 GW.

A project recently announced by NextEra Energy with Western Farmers Electric Cooperative for a combined 250 MW wind farm, 250 MW solar farm, and 200 MW / 800 MWh of energy storage in Oklahoma. NextEra has suggested many gigawatts of this combined product type in their development queues, expect many more to come.

MISO the biggest mover

Midcontinent ISO territory runs from the Gulf of Mexico to the Arctic Circle via Manitoba, Canada while connecting to the power grid in 15 U.S. states.

This region saw the greatest increase from December to July, growing from over 36 GW to 57 GW of solar power, along with 2.7 GW of energy storage. At the end of 2018, MISO's 36 GW in the queue matches ERCOT and comes close to PJM at 32 GW and CAISO at 27 GW, but now, the region is 14 GW ahead of California.

MISO managers have done an analysis of renewables grid penetration and found that once it gets past 40%, they're going to need to do a lot of upgrade work. However, they've got a long time to get there, as wind power currently represents a respectable 14%, while solar is barely

noticed. Many states within MISO's operating region, however, do have plans for solar.

Indiana leads the states with 8.7 GW in the queue, followed by Illinois, Michigan, and Wisconsin all above 6 GW. There are eight more gigawatt plus states in the region as well. The volume is back loaded in the queue with 20+ GW each in 2021 and 2022.

PJM Interconnection

Formerly known as the Pennsylvania-New Jersey-Maryland (PJM) interconnection, the RTO now touches thirteen states and Washington DC.

The region has 180 GW of generating capacity to service 65 million customers. And currently, those customers are getting less than half a percentage point of their electricity from solar power. The region did see its queue expand by about a third over the past six months, and there is now close to 7 GW of energy storage being developed.

Virginia leads the region with 14.8 GW in its queue, with many of these projects taking the form of PPAs with corporates – Amazon, Apple, Facebook, and many more – having signed up for long term power purchase agreements.

> *"Once it gets past 40% ... [MISO is] going to need to do a lot of upgrade work"*

Ohio is second at just over 8 GW, though recent legal changes might slow this market. Illinois, Indiana, Pennsylvania, North Carolina and Kentucky are all greater than a gigawatt as well. Of the states covered by PJM, nine have goals or laws pushing for 0.2% to 5.1% (for New Jersey) of electricity to come from solar power between 2020 and 2032.

NYISO behind goal

The Empire State has goals of 70% renewable electricity by 2030, and 100% carbon free by 2040. On the books, the state has goals of 6 GW of distributed solar and is

contracting about 7 TWh of utility scale solar per year – having done it in 2017 and 2018 already. On top of this, there is push to depoly 1.5 GWh of energy storage capacity by 2025. **pv magazine** recently estimated that to get to some of the state's long term renewable energy goals it will take in excess of 20 GW of new solar capacity – quite beyond what is currently being listed.

Currently, the NYISO queue lists just over 6 GW of solar power and 5.2 GW of energy storage. Recent incentives put out by the state, which could drive up to 1 GWh of energy storage have mostly been claimed already, meaning that volume will likely be deployed within the next 18 months.

Between 1 and 1.8 GW per year of solar power, from 2020 through and including 2024, is being studied. The battery volume is bunched up mostly in 2021 and 2022.

"Massachusetts has been pushing solar hard since 2008"

New England ISO

ISONE is the smallest of the RTOs, covering just over 15 million people. The northeast region of the country gets about 1.6% of its electricity from solar power, with Massachusetts – its largest state – getting 5.7% from solar.

The Massachusetts SMART program is pushing an additional 1.6 GW of solar, with a probable addition of a further 1.6 GW being considered. This volume is not counted though in the 3.6 GW in the ISONE queue, with much of that volume being sold to states with regulated markets like Connecticut and Rhode Island.

Much of the region is pushing toward various resilience efforts, with – again – Massachusetts leading. Rhode Island is currently close behind, in particular with regards to energy storage procurements on the business and residential level. The ISO's 3.5 GW of energy storage in the utility queues, relative to its small size and small solar queue number, speaks to somewhat uniqe regional considerations that are evident.

Labor costs in the region are relatively high, but so are energy prices. This allows for respectful project margins – but it should be expected that there is strong and experienced competition among developers and suppliers as Massachusetts has been pushing solar hard since 2008.

Other regions

Outside of the RTOs there are still other markets, mostly regulated and controlled by vertically integrated and privately owned utilities. The utilities control the generation and distribution of electricity – but must strongly follow state utility commissions.

For instance, Florida's largest utility plans to deliver 10 GW (DC) of solar by the end of the decade, and close to 1 GW of solar power per year – starting in 2019, and continuing through 2023. Other Florida utilities, including Tampa Electricity, Duke Energy and Gulf Power, are in on the solar development game also. These utilities do a very strong job of holding tightly to all electricity generation.

However, recent cracks have opened, with the residential power purchase agreement companies like Sunrun, Sunnova, Vivint, and others turning into solar leasing companies and moving in (see pp. 26-28).

Another recent announcement, this one from Georgia Power, puts 2.2 GW of solar by 2024 on the ground. Though again, there are very small amounts of commercial or residential solar available. Utilities in Michigan, Indiana, Oregon and other western states also have solar projected in their build outs – but mostly toward the middle and late 2020s.

And of course, all of these RTOs and privately owned utilities have states standing above them – with 11 different states having various levels of renewables requirements. New Mexico, Nevada, Hawaii, New Jersey, Maine, Puerto Rico and more are going to drive even more volume over the coming decades – but maybe only one or two of these, with earlier goals, will want that volume sooner.

There are of course, serious laggards. Duke Energy and Southern Company are the two largest utility polluters in the nation, and while Southern Company has stated a desire to be "low to no carbon by 2050", not too many expect any actions leading to respectable volumes of capacity being installed in the near future. pv

John Weaver

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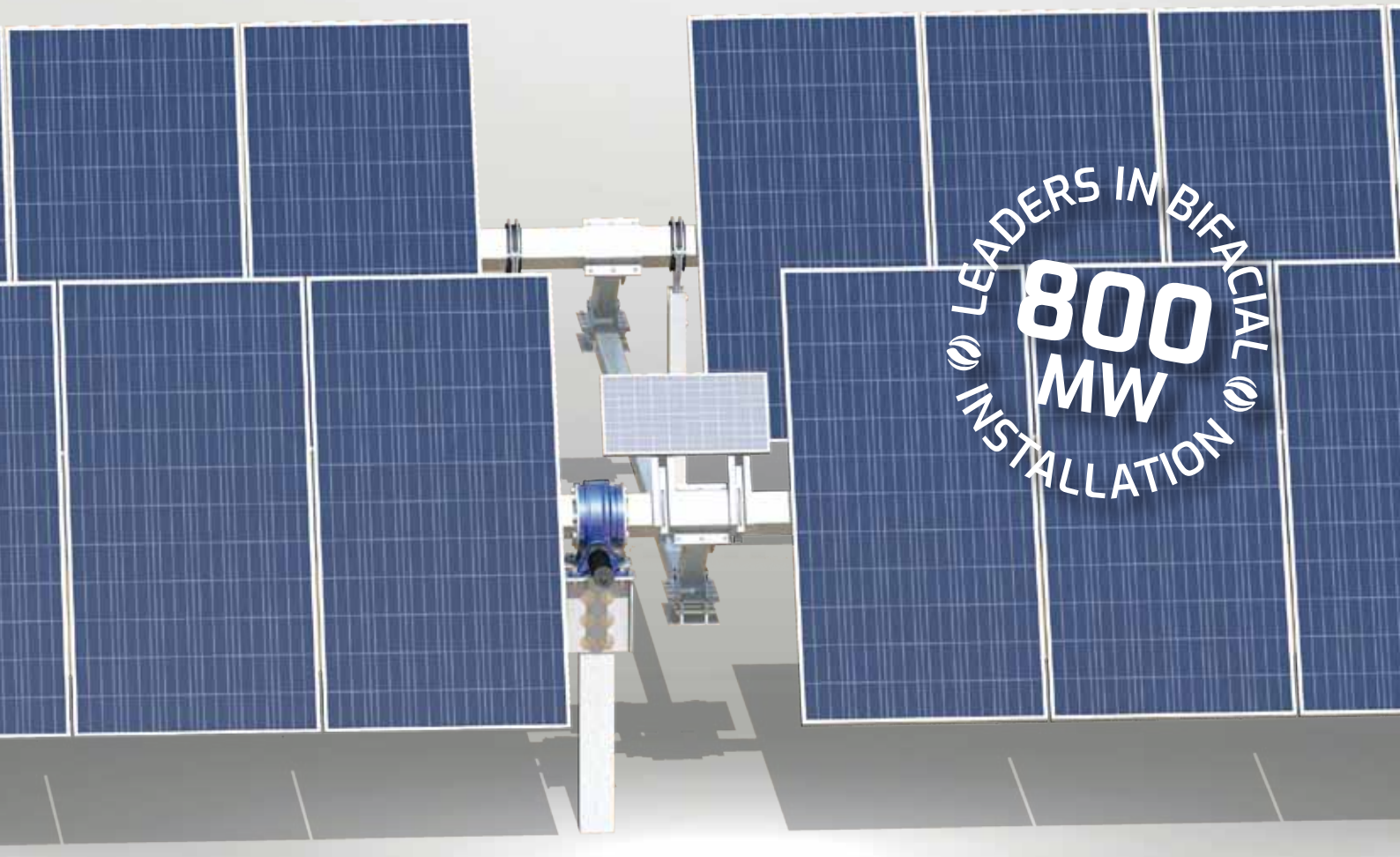

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Solar + wind, the benefits of co-location

Shared grid connections, complimentary resource availability, and more grid-friendly power are among the key advantages of pairing wind farms with solar arrays – and developers are quickly moving into the emerging space.

When subsidies for renewable energy generators were more generous, wind and solar fiercely competed for the attention of policymakers. This rivalry resulted in a fervent debate over the relative merits of each technology. In a way, it became the renewable energy version of Monty Python's Judeans People's Front – or was it the People's Front of Judea?

In recent years, however, a number of companies have started to venture into wind and solar co-location, and the trend is now picking up serious momentum. In February, U.S.-based NextEra Energy Resources signed a deal with Portland General for a 300 MW wind farm to be paired with 50 MW of solar and 30 MW of storage. Just a few months later, the company made headlines again with a new deal in Oklahoma. The project will include 250 MW of wind, 250 MW of solar and a 200 MW storage system – the largest of its kind in the United States, the company claims.

Turbine blades can cast shadows on PV modules, but this is generally accepted by project owners.

Photo: Armin Kübelbeck, CC-BY-SA, Wikimedia Commons

In early August, Adani Electricity Mumbai also launched a tender for 350 MW of wind and solar in India. Around the same time, Canberra-based developer Windlab connected 43 MW of wind and 15 MW of solar to the grid at the Kennedy Energy Hub in the Australian state of Queensland, backed by 2 MW/4 MWh of battery storage capacity. The project followed the successful integration of 165 MW of wind at Australia's 10 MW Gullen solar farm in early 2018.

The reason for this shift is primarily due to cost reductions, although developers can enjoy many technical advantages from the pairing of PV and wind. The competitive landscape has also been stirred up, as the technical barriers to entry for wind are generally higher than those of solar. Therefore, it is more likely that wind developers will venture into solar, rather than vice versa.

New environment

Hannah Staab, principal of solar and energy storage for renewable energy consultancy Natural Power, points to financial factors as the main reason for the growing interest in wind-PV projects. A small number of U.K. companies started looking at co-location a few years ago, she says. "But in a subsidy environment there weren't really any commercial drivers to seriously follow up with that," she adds.

Companies need to get creative about where to cut costs to survive in a subsidy-free market. Co-locating wind and solar capacity means that the two generators can share a grid connection, land, substation and power electronics, as well as permitting procedures and even some operations and maintenance work. All the while, the two energy sources maximize the capacity factor of the grid connection.

"Just by sharing the infrastructure you immediately have a lower capex and then we are moving toward a world where a firmer generation profile can protect you in a merchant environment, where as a pure wind or solar farm you could be more exposed to electricity price fluctuations," Staab elaborates.

The savings resulting from shared grid and civil infrastructure could translate into a 10% discount per MW of solar PV, depending on the characteristics of a project. And in a capex-heavy industry such as solar, a 10% savings on infrastructure-related outlay is no small change. "Grid-connection costs have largely remained stable or even increased over the last years, while module and other component costs have come down significantly," Staab says.

The costs of the grid connection can be shared, but overall development costs can also be driven further down because on-site roads have already been established. O&M crews can also be trained to handle both wind and solar inspections, so the additional PV is often worth the effort, despite the expectation of higher curtailment losses.

Over the past 18 months, for example, renewable energy developer BayWa r.e. has been looking at co-locating wind and solar, says Philipp Kunze, the head of global hybrid and project development for the company in Greece. "What we are trying to do is get out of government support schemes," Kunze explains. One way to do this is to enter into power purchase agreements, often with industrial off-takers. When a power plant fails to deliver the promised power due to a lack of wind or sun, the power must be bought from the spot market, which can drive up balancing costs and damage the economics of a PPA. By co-locating wind and solar, the power supply becomes firmer, as the two energy sources are complementary in many markets – that is, the sun shines when the wind doesn't blow, and vice versa.

> *"Such hybrid power plants can exceed 7,000 full-load hours in ideal places"*

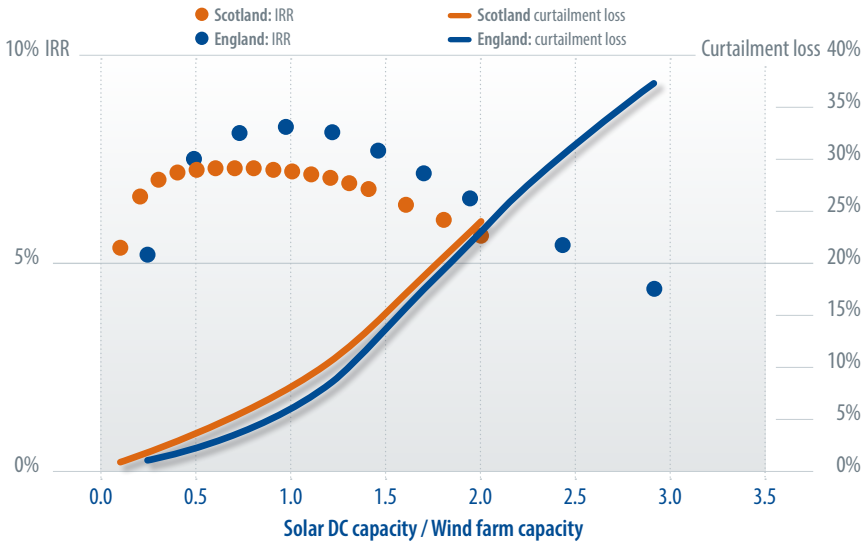
Kunze points to Wind Europe's recent "Renewable Hybrid Power Plants – Exploring the Benefits and Market Opportunities" report, which says that wind and solar are almost perfectly aligned in some markets. In parts of China, Argentina, Somalia, Australia, the United States and India, for example, such hybrid power plants can exceed 7,000 full-load hours. In particularly ideal locations, analysts have calculated the possibility of 8,000 full-load hours per year. As there are only 8,760 hours in a year, hybrid power plants in such locations almost match the capacity factor of thermal generators. But in most parts of Europe, Asia and Africa, it's easy to achieve 4,000 to 6,000 full-load hours per year. According to Kunze, solar alone would achieve little more than 1,400 full-load hours in Europe.

Sweet spot

Capturing these full-load hours is not easy, however. From a broader regional perspective, wind and solar resources tend to be complementary, but this is not always the case in a site-specific

Comparison of project economics

Source: Natural Power



context, Staab explains. "In the U.K., wind is often installed on hilly terrain, which is often covered in forests," she says. "This is not so ideal for solar. In Australia, on the other hand, there are huge open spaces that are ideal for both solar and wind."

Sizing a plant is very dependent on the type of project and its location. "There are really two kinds of projects in this field," Staab says. "One in which developers plan the co-location from scratch, which is what we see in Australia, India, or the U.S. In the other one, existing wind farms are retrofitted with additional solar arrays, which is something we see a lot more in the U.K., Germany or France."

The team at Natural Power modeled the ideal sizing ratio between solar and wind for the United Kingdom, for a wind park set to be retrofitted with solar (graph below). The two generation profiles are complementary, but there will still be curtailment losses, mainly due to the added capacity that goes beyond the grid export limit. When a wind generator produces at 100% of its grid export limit, anything that the solar array provides will be curtailed. Based on wind and solar resource profiles that are typical for the United Kingdom, if you had a 10 MW wind farm and added about 5 MW of solar capacity, curtailment losses would reach around 5%.

Kunze points to another layer of complication in sizing the generators, as one can add seasonal changes to production and consumption. He says that on many Greek islands, the production of both wind and solar peaks during the summer months. This aligns itself with the tourist season, making such hybrid plants a suitable candidate for the power supply on these islands. Yet still, this alignment has to be planned and modeled correctly. "This is considerably more complex than having a 10 MW solar plant with a fixed feed-in tariff," Kunze says.

Virtue out of necessity

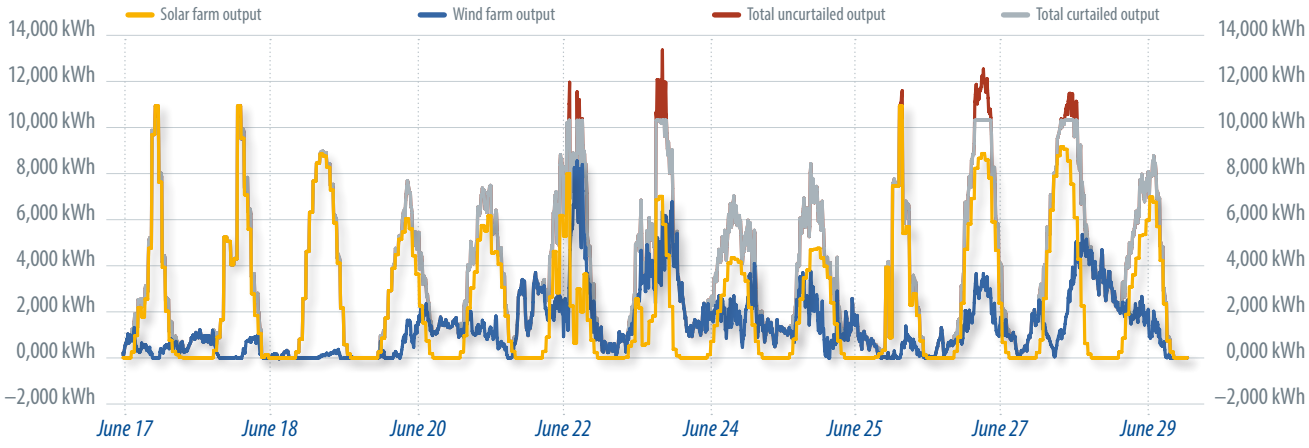
Beyond the economics, co-location offers more stable, predictable and dispatchable power output. Both wind and solar are naturally subject to cloud cover or gust changes, which alternates the power output. If the two work in tandem, they level out the effect to a certain degree. He explains that by co-locating wind and solar, one can reduce the grid capacity, because the power is more likely to be produced where it is needed. Today, power still needs to be distributed from windswept coastal lines further inland, for example.

"This is why we see markets like India or Australia with a relatively weak grid picking up on the trend," explains Kunze.

Marian Willuhn

Sample time series of generation for a 10.3MW wind farm and 12.5 MW solar farm

Source: Natural Power



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The return of BIPV

Since the beginning of 2019, many people within China's PV industry have started to get the same feeling. Not about grid parity, or about mono replacing multi, but about something more unexpected. More and more people are speaking up at conferences and meetings about building-integrated PV (BIPV), which has been little more than a niche curiosity for years. Now BIPV, it seems, is making a big comeback in China.

BIPV developed very quickly in China between 2009 and 2012, when the entire PV industry was supported by government subsidies. But since 2013, when the feed-in tariff (FIT) policy replaced direct subsidies, BIPV has been relegated to the sidelines in favor of ground-mounted PV plants, Top Runner projects, distributed PV arrays and residential rooftop installations. FITs facilitated silicon PV deployment, but BIPV technologies remained hampered by weaknesses such as high costs, low efficiency, and – most importantly – a lack of FIT support.

New hotspot

A closer look at the Chinese market reveals a number of factors that are driving a resurgence of interest in BIPV. To start, The Chinese government is requiring more and more "green architecture" to reduce energy consumption from buildings. Data from China's Ministry of Housing and Urban-Rural Development shows that 30% of the nation's energy is consumed by buildings, making them a major energy consumer alongside the industry and transportation sectors. And this figure will grow to 35% in the next two decades, with around 1.6 billion square meters of new building spaces being completed each year. BIPV will save energy and turn buildings into small power plants – bringing the goal of negative carbon emissions closer to reality.

Recent developments in solar have made the impossible possible on many fronts for BIPV. Some are related to new technological capabilities, while other changes have been economically driven. Some silicon PV products have become more flexible than ever before, making them ideal for use in BIPV installations. And the cost of thin film products has also fallen to an acceptable level.

Another major factor is the slowdown of the "traditional" PV market since China's infamous 31/5 announcement in 2018. This led to that year's annual installations shrinking by 20% – a trend that is forecast by some to continue in the coming years. The entire industry therefore needs to find other ways to consume the massive amount of surplus manufacturing capacity that exists, and the BIPV market is looking like an increasingly attractive target.

Xiao Pengjun, the deputy director of the National Solar Photovoltaic Product Quality Supervision Center, said at a recent BIPV conference that "every year China has accomplished at least 100 million square meters of new factory buildings with steel-tilt roofing that could be replaced by BIPV. The market size is around CNY 100 billion ($14 billion)." And this is without considering walls and many other types of structural surfaces that could potentially host BIPV.

Fresh opportunities

Attracted by an encouraging policy environment and clear market potential, many companies have started trying to jump back into the BIPV sector to exploit fresh opportunities.

Thin film solar cells – including cadmium telluride (CdTe) and copper indium gallium selenide (CIGS) cells – are particularly well-suited for use in BIPV products. In China, investors have mainly focused on CIGS and CdTe, rather than

Hanergy has agreed to supply more than 1 MW of CIGS modules to integrate into the aluminum roof of the Rafael Gallery, a mixed commercial and residential development in Shanghai's Pudong district. The project, which links several skyscrapers via a "sky bridge," is now under construction.

Photo: Hanergy

gallium arsenide and other non-silicon thin film cells. Given the significant required investment and high technology barriers, all of the players in this field are big companies.

China National Building Material Group (CNBM) and its thin-film PV subsidiary have outlined a remarkable plan to invest CNY 10 billion ($1.4 billion) in 1 GW of CIGS thin-film solar cell lines in Sichuan province. Its CIGS technology is believed to be coming from Germany's Avancis.

Another major state-owned company, CHN Energy – the result of the merger of power group China Guodian Corp. and mining giant Shenhua – recently invested CNY 2.75 billion ($390 million) with Shanghai Electric in a 306 MW CIGS production line. The CIGS technology and production lines come from another Germany company, Manz, in which Shanghai Electric took a controlling stake in 2016.

Hanergy, a privately held Chinese company, claims to offer the most advanced CIGS technology in China, thanks to its past acquisitions of California-based MiaSolé and Germany's Solibro, a former Q Cells subsidiary. The company claims a total CIGS production capacity of about 2.7 GW in China.

And now China is even looking at CdTe technology, which has long been dominated by U.S.-based First Solar. Hangzhou-based Advanced Solar Power (ASP) has already finished constructing a 40 MW CdTe module production line, with a mass-production conversion rate more than 14% by the end of 2018. ASP says it has plans to invest in more CdTe module lines.

"Silicon solar cells now have the opportunity to compete with thin film in BIPV applications"

BIPV vs. silicon

Following years of rapid technological progress, however, traditional silicon solar cells can now compete with thin film in BIPV applications. Thanks to diamond wire sawing, the thickness of silicon wafers has dropped from more than 200 microns to less than 130 microns, and producers may be able to go even thinner in the near future. This reduces the cost of the wafers, while also making them more flexible. And with new flexible encapsulants, silicon PV modules can be produced in curved variations to more effectively meet BIPV project requirements.

Nanjing-based Sunport Power launched its latest flexible silicon panel, the SPP Flex1.0, in late 2018. The panel is a major leap forward for high-efficiency metal wrap through back contact cells. SunMan, another company that was recently established in Shanghai under the leadership of former Suntech Chairman Zhengrong Shi, recently released a super flexible, ultra-thin solar panel for curved rooftop surfaces at the SNEC 2019 solar exhibition in Shanghai.

Beyond cells and modules, many other components have also been created and optimized specifically for the BIPV sector. For example, Arctech Solar – the largest racking and tracker supplier in the Chinese market – has developed a solar roof rack that can load standard solar panels to entirely replace the original steel-tilt rooftops of buildings. And for almost the same cost as tradi-

Photo: pv magazine/Mark Hutchins

Avancis, a CIGS module maker, showcased its new Dragon's Neck BIPV public walkway project at Intersolar Europe 2019.

tional roofing, the roof rack conforms to national construction standards for waterproofing, wind resistance and fire safety.

There are also many more ideas still in the R&D stage that could emerge in the future. Xia Aimin, a former marketing director for Longi Solar and current secretary-general of the China BIPV League, says "the BIPV market will burst in 2021 because the entire industry still needs time for lots of preparation. In 2020, we will see many more new products for BIPV."

Obstacles ahead

Despite the potential, there are few clear standards for BIPV applications as building materials. Without national standards in place, BIPV projects have to be approved by experts on a case-by-case basis, which drives up project costs.

In addition, there are still not enough mature BIPV products in the market to satisfy customer demand. This is partially due to a lack of industrial standards, but it is also early days, and market participants need more time to focus on R&D before new products can be introduced. That's why Xia says 2020 will be a big year.

Another concern is return on investment. Many Chinese investors – accustomed to "normal" solar projects such as ground-mount arrays and rooftop installations – will find the ROI for BIPV projects to be too low. But if they look at projects differently and treat BIPV costs as a construction expense, the ROI rises sharply. Of course, this also first requires the availability of new, building-certified BIPV products.

One important factor is aesthetics. PV industry experts may be very experienced in product functionality, but that doesn't mean they know what looks good. In this area, thin-film PV has a natural advantage over silicon, but with the weaknesses of higher costs and fewer suppliers.

"The governments, architectural research institutes, industrial associations and business sectors are all making efforts to push the BIPV market forward, and we already see the 'spring' of BIPV," says Xia.

He estimates that the BIPV market will grow at an unprecedented pace in the next few years: "The market will rise to CNY 20 billion by the end of 2021, from its current size of less than five billion in 2019."

Lingering concerns

Some industry experts though have expressed concerns. Aside from technological issues, the biggest fear is whether the big companies that control the upstream cell and module markets are effective or even reliable in leading the way forward. China's large state-owned enterprises are usually plagued with inefficiencies, hobbled by volatile strategies, frequent leadership changes and complex internal politics. And Hanergy is a private company, but it has long struggled with its own financial difficulties.

The PV industry may be one of the most successful business sectors in China. And one of the main reasons for this is that most of the industry's participants are privately held companies. Perhaps more private companies are needed in the nascent BIPV segment, too.

In general, China's BIPV market has a very bright future, despite some lingering uncertainties. The sector seems to be returning to the situation seen in 2013, when cooperation among a range of different parties helped to make the entire industry successful. pv

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Establishing a cost-effective BIPV sector in Europe

Why hasn't more building-integrated PV (BIPV) been installed throughout the world? The simplest answer is that a PV module does not architecture make. The nature of the building process – its methods and logic – are key factors affecting technological transfer, as seen in the steel and concrete industries, which have been the basis of modern architecture for the past century. In many cases, standardization would go against the case-by-case approach to design and the interdisciplinary nature of the field. Solar architecture therefore involves a synergic concept of constructive and functional correctness, while always engaging an "aesthetic intentionality." So how can the market segment continue to drive down costs?

We can try to resolve the actual barriers that still hold back BIPV development by changing our approach. Limitations due to shading in urban areas, or architectural and typological constraints, should no longer be seen as a no-go. Rather, they should be viewed as boundary conditions to be considered in design and technical solutions aimed at integrating solar potential with

Photo: Glassbel

This SmartFlex demo building in Klaipėda, Lithuania, features a double skin façade with semitransparent PV glass.

aspects of building design. The share of BIPV in the global solar PV market stood at approximately 1% in 2017, while in Europe, BIPV holds a share of about 2%. The EU-funded PVSites project estimates that by 2022, BIPV will account for around 13% of the total PV market. Is this forecast realistic, or is too ambitious?

The BIPV market in Europe is particularly dynamic, with a range of new products, research projects and flagship buildings emerging in recent years. Policies that push building owners to renovate, like net zero energy building programs, will be key drivers for the continent's BIPV economy. EU actors will eventually have the chance to create a unique market with a quality-based asset.

Many trends define today's routes to innovation. Both products and processes are interconnected. Thanks to industrial developments, a wide range of new products are available at competitive prices. Glass treatments that hide the solar cells – colored films or structured glazing, for example – are one path. But integration today means something more than pure cosmetics. We have to move from luxurious and costly BIPV solutions to a mass-market, cost-effective approach, with a clear focus on ordinary built stock. This involves innovation at different levels – not just with product aesthetics, but also in terms of flexibility and automation in manufacturing, creating multifunctional products for the building skin, process management based on digitalization, advanced performance assessments, and procedures that support the market to ensure quality, safety and reliability.

According to the European Commission's "SET Plan – Declaration on Strategic Targets in the context of an Initiative for Global Leadership in Photovoltaics," the way to expand the BIPV market is to set extremely ambitious cost-reduction targets: a 50% reduction of additional BIPV module costs from 2015 to 2020, and a 75% cut by 2030. But how can the industry introduce the aforementioned innovations with such ambitious cost-reduction targets?

The BIPVBOOST project, funded by the EU Horizon 2020 program, was launched in October 2018. The three-year initiative focuses on bringing down the

Photo: SUPSI

PV cladding on the southern facade of the deltaROSSO building in Vacallo, Switzerland

Photo: SUPSI

An energy-plus multifamily home in Chiasso, Switzerland

cost of multifunctional BIPV systems, by addressing the entire value chain.

After examining cost-competitiveness from a dynamic point of view – that is, looking at the entire operating lifetime and considering real additional costs when making building components active – it becomes clear that the sector is economically attractive. The BIPVBOOST project will focus on different strategies throughout the entire process, from predesign to operation and maintenance: (1) implementing a large degree of flexibility and automation in the manufacturing of BIPV modules; (2) developing a range of multifunctional, cost-competitive glass-glass modules that comply with market requests through innovations in materials and processes; (3) implementing new multifunctional solutions for building skins by enabling simplified substructures and mounting procedures, together with thermal insulation and water retention; (4) defining a qualification process that simplifies the standardization framework.

Beyond products, process innovation is also essential for tackling construction sector fragmentation. That's why BIPVBOOST is proposing new digital and data-driven solutions to enhance the collaboration of stakeholders throughout the value chain, thanks to building information management (BIM) and the implementation of advanced monitoring, as well as modelling and data analytics for automatic fault detection and predictive maintenance in BIPV operations. With energy management, everything is aligned with nZEB implementation objectives.

As legendary architect Ludwig Mies Van der Rohe once said, architecture should be a symbol of its time. To have "good buildings," we need to look at architecture within a global context. That way, even with solar, there will only ever be "good" architecture.

Pierluigi Bonomo and Francesco Frontini

About the authors

Photo: SUPSI

Pierluigi Bonomo

Pierluigi Bonomo is the head of the innovative building envelope team at the Institute for Applied Sustainability to the Built Environment at the University of Applied Sciences and Arts of Southern Switzerland. He has completed a Ph.D. in Building-Engineering/Architecture at the University of Pavia, with a thesis focusing on BIPV. He specializes in the design and envelope engineering of near zero-energy buildings, and has received a number of awards and acknowledgments for his work. He actively collaborates on different European and federal research projects related to product and process innovations for BIPV implementation. He is an expert member of the International Energy Agency's Task 15 team.

Photo: SUPSI

Francesco Frontini

Francesco Frontini is a professor at the University of Applied Sciences and Arts of Southern Switzerland and the head of the building sector at the Institute for Applied Sustainability to the Built Environment. He holds a degree in Building Engineering and Architecture from Politecnico di Milano. His research was supported by experimental work on the design of actual buildings. Early in his career, he worked in the solar facades group at the Fraunhofer Institute for Solar Energy Systems, where he gained extensive experience in building simulations and BIPV solutions. He later completed a Ph.D. in Building Engineering in 2009 and worked with different manufacturers to develop new multifunctional BIPV facades for solar and glare control. Frontini also has broad experience with energy and lighting simulations and is a member of the European Committee for Electrotechnical Standardization. He has worked on the European BIPV standard EN50583 and is now working on international standards.

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Feathered friends turn foe

A floating PV array in the Netherlands has brought a community together while highlighting the value of module lever power electronics on water.

In 2013, Frans van Herwijnen and his fellow project proponents began work on what they thought was a world first: a 2 MW solar array installed on a body of water. While during the course of the project he realized that floating PV systems had already been installed in China and Japan, the project team deployed a number of innovations to help the project rise to the top.

The Lingewaard floating array has a capacity of 1.845 MWp, and comprises 6,150 modules from Hanwha Q Cells. The project features Ciel et Terre's floating structures, as well as 27.6 kW of SolarEdge inverters. The project was completed in mid-2018 and came with a total price tag of €2.2 million.

The town of Lingewaard itself has 46,000 inhabitants and is also the location of numerous expansive greenhouses. A large freshwater reservoir stores water alongside the greenhouse buildings. And it was on this body of water that van Herwijnen and his project partners saw an opportunity to install large-scale PV.

While the greenhouses are big consumers of heat and electricity, they are supplied by on an onsite gas-fired combined heat and power plant, so the floating PV instead supplies the community of Lingewaard.

Radiation and convection cooling, along with diffuse light, combine to exceed expectations at the 1.845 MW Lingewaard Energie floating array.

Photos: Lingewaard Energie

Community focus

The Lingewaard floating array is owned by the local energy cooperative, Lingewaard Energie. Part of the project finance was crowdfunded by the locals themselves. "We have a lot of visitors to the project from the Netherlands and abroad and the community is very happy and very proud of the project," says van Herwijnen.

Beyond the crowdfunding effort, the project's proponents obtained financing through a combination of a grant from the Gelderland (Guelders) provincial government and a €1.7 million loan from Dutch lender ING Group. Ongoing revenues come in the form of the Dutch government's SDE+ program, secured for a period of 15 years.

While the financing might be small change for a large, institutional lender such as ING, the process was not straightforward. "Despite the small size of the loan, it was a complex transaction," wrote Eva Parro de la Paz, director of sustainable project finance for ING Structured Finance, in a recent blog post featuring the project on the ING Group's website.

Given the project's unique blend of crowdfunding, a government grant, and the relatively new technology of floating solar, ING Group's due diligence took almost a full year to complete, explains van Herwijnen. "We learned a lot, but also ING learned a lot," he adds.

Floating MLPE

The general assumption behind the use of module level power electronics (MLPE), such as power optimizers or microinverters, is that they are best suited to arrays in which shading is an issue. However, the Lingewaard Energie reservoir is not shaded by the adjacent greenhouses or the trees. "That is a question we often get – why optimizers?" The answer to this question came into focus once the array was in operation for several weeks, and the new reservoir feature attracted a number of feathered friends.

"At the moment, we have problems with birds on the panels," explains van Herwijnen. "And they produce a lot of – what can I say? Shit."

The issue turned up on the module-level monitoring used at the Lingewaard

Lingewaard project team members pose in front of their new array.

site. Customized alerts can be added to the monitoring systems, and they indicated to the operators that module cleaning and bird deterrent strategies were required.

"We cleaned the panels, of course, but after several weeks there was again a lot of shit," says van Herwijnen.

Lingewaard Energy has since installed a laser deterrent. The device, commonly used for this purpose at airports, periodically activates a green laser to scare the birds away. Since its installation it has been effective, and van Herwijnen is now trying to determine how long it should remain in place – or whether the birds will return.

Bruno van Bost, the director of commercial sales in northwest Europe for SolarEdge, says that it's not just birds that MLPE can assist with in floating PV arrays. He also notes how the impacts of module mismatch – the result of reflected and diffuse light from the water's surface – can be resolved by the power optimizers. Additionally, DC cabling is kept to a minimum, with arc fault detection built in, to make work on the array – as well as O&M-related tasks such as bird waste removal – much safer.

"If you are placing PV on water, there are a few key benefits that SolarEdge brings that cannot be neglected," says van Bost.

In terms of performance, Lingewaard Energie is exceeding expectations. It included plans for a 5% increase in power output, in comparison to a ground- or roof -mounted system, in its business case because of the cooling effects of the water. After one year of operation, the project is already exceeding this, with a 9% boost having been observed. Van Herwijnen believes this is because heat is radiating from the backside of the module, along with convection cooling – as wind travels underneath the modules, they are cooled by the water. "There is also a lot more diffuse light, reflected from the water surface, on the panels," says van Herwijnen.

Jonathan Gifford

Floating PV will be in focus at the Future PV Roundtable event, which is part of the 2019 Renewable Energy India Expo. Now that a number of tenders have been launched in India, the country is experiencing challenges in finding suitable land for large-scale PV projects. Floating PV applications are becoming more common, but arrays on water – as the Lingewaard array illustrates – present new challenges. These issues will be discussed by the Future PV panelists. For more information, please see page 121.

Sun King tackles age-old challenge

Rooftops that are unsuitable for conventional glass-backsheet PV modules present a clear opportunity, but the right solutions remain elusive. SunMan, under the leadership of an industry veteran – a man who is no stranger to revolutionizing PV – believes it has the answer.

The "Sun King" is back and he's looking to take solar PV into new areas – for the second time in his career. Shi Zhengrong is best known to solar insiders as the founder and former CEO of Suntech, once one of the world's largest PV manufacturers, and one that undisputedly changed solar cell and module production forever.

Not content to bask in former glories, Shi is now attempting to address an industry challenge that has long plagued project developers and building owners – replacing solar glass to take the weight out of PV panels. Five years ago, Shi founded SunMan, which is introducing frontside module glass with a composite polymer material. Its SunMan eArche modules shave the weight off rooftop installations from 20 kg/m^2 to less that 5 kg/m^2.

And now, the company is making headlines with a new installation. In August, Shi welcomed media, guests and solar luminaries – including his former mentor, UNSW Scientia Professor Martin Green – to SunMan's high-profile Australian project – a 235 kW lightweight rooftop array on the Australian National Maritime Museum's Wharf 7 building, on Sydney's Darling Harbor. Winter sun greeted the guests and pointed to a bright future.

This 235 kW lightweight rooftop PV installation on top of the Australian National Maritime Museum's Wharf 7 building is just the beginning of the museum's adoption of solar.

Photo: pv magazine/Natalie Filatoff

Museum array

"Five years ago the technology was simply not available to overcome the many challenges that particular building posed for us," says the museum's director and CEO, Kevin Sumption. Wharf 7's lightweight construction, for example, couldn't support traditional glass panels. The 30-degree pitch of the roof presented an additional hurdle, and the developers needed to consider the unacceptable glare the glass would have projected into adjacent buildings.

"We're very lucky that Dr. Shi has made a remarkable innovation in solar technology – yet another in a number of his pioneering accomplishments – with the invention of the eArche lightweight, non-glass solar panel," says Sumption.

The installation is expected to pay for itself within about seven years of operation. It will drive down electricity costs by 25% for the building, which was constructed in 1991 to house a maritime library, exhibition venue and commercial space.

"The load-bearing capability of roofs is a critical issue," says Dean Travers, general manager of Engie Renewables Australia. Engie is currently developing three large-scale solar farms in Queensland and New South Wales, but the company also installs smaller-scale systems. Travers says that eArche – at 20-30% of the weight of conventional systems – offers "a significant advantage" for developers of large rooftop solar arrays.

There are plans to expand the Australian National Maritime Museum's solar array with the additional flexibility of eArche ultra-thin panels on the curved roof of the main building, says Thomas Bell, sales director for SunMan in Australia.

He adds that the company may also apply white eArche panels to the facade of the museum. "We have this enabler product," explains Bell. "And we intend to expand the application of solar."

Flexible futures

Lightweight, flexible PV modules are nothing new on the market, but SunMan is taking a slightly different approach. Many companies have developed thin-film products, particularly copper indium gallium selenide (CIGS) cells on flexible substrates, but progress has been slow. A number of companies have simply failed to overcome key cost and conversion-efficiency hurdles.

SunMan, by contrast, is deploying conventional crystalline silicon technology, thus benefiting from the scale and impressive cost and efficiency improvements that have been achieved by mainstream cell producers. Shi says that in years past, the solar cell was seen as the "gold" in a PV module, as it was significantly more expensive than the "packaging," which includes the frame, frontside glass, backsheet and EVA. But in 2019, it is the packaging that is contributing most to total costs. "Now PV is cheap – people want more from it," Shi says. "We can now break the cycle of a lack of flexible products."

The solar pioneer says that recent progress in polymer materials has been dramatic. He notes how this has given rise to more affordable, flexible and lightweight encapsulants. "We are tapping into a big trend," said Shi. "Previously there were fears that polymers will crack or yellow. But polymers have progressed tremendously. Today, about 40% of a new car is composed of polymer material."

SunMan estimates that 40% of commercial rooftops are unsuitable for regular glass solar panels, which provides a significant market opportunity for its eArche range. The company has already installed around 50 MW of its modules and has achieved IEC 61215 certification.

This track record, as well as the relevant certifications, will be important as SunMan rolls out its products in Europe, the United States, Japan, China and the rest of Australia, says UNSW's Green. "It's a matter of the market getting confidence that it's going to be as durable as the glass-encapsulated modules that everyone's used to," he concludes.

pv magazine

Photo: pv magazine/Dave Tacon

SunMan says lightweight polymers are part of a major technological wave.

Photo: pv magazine/Dave Tacon

Shi Zhengrong: "Now PV is cheap – people want more from it. We can now break the cycle of a lack of flexible products."

Photo: pv magazine/Dave Tacon

Thomas Bell: "We have this enabler product and we intend to expand the application of solar."

A bump in the road for PAYG and self-sustainability

Two high-profile bankruptcies this year could serve as a warning for the potential pitfalls of the pay-as-you-go (PAYG) solar segment. However, Marcus Wiemann and David Lecoque of the Alliance for Rural Electrification say that PAYG business models can lead to long-term success, and they have a key role to play in providing power to the 1 billion people throughout the world who still live without electricity.

On the one hand, PAYG offers an unprecedented opportunity for private companies to step in and provide tailored solutions to a wide portfolio of customers with extremely limited budgets. On the other hand, it stimulates the integration of innovative business models that are flexible enough to constantly adapt to the abilities and urgent needs of their customers, who are usually in isolated, rural areas that are otherwise unreachable. These unique characteristics are clear enablers of the attention and growth the off-grid sector has experienced in recent years. More specifically, PAYG models have attracted more than $600 million of funding so far, and growing interest from big, reputable corporate investors such as ENGIE, EDF, EDP and Total.

However, it is the very same dynamism and uniqueness of the PAYG system that can backfire when companies are confronted with difficult market circumstances, especially in the case of fierce competition and unsupportive legal and political frameworks, as access to finance remains a challenge. These contextual disadvantages can threaten the long-term

Despite recent insolvency declarations from Mobisol and Solarkiosk, the pay-as-you-go solar segment has attracted interest from major corporate investors and is expected to continue to play a key role in rural electrification throughout the world.

Photo: Mobisol

sustainability of PAYG business models, as shown by the bankruptcy cases of Mobisol and Solarkiosk, two high-profile players in the rural electrification universe that each filed for self-managed insolvency this year.

For this reason, it is extremely important that private and public agents join forces to create the business frameworks needed to turbo-charge the off-grid industry, so that it can effectively deliver on the goal of achieving universal access by 2030, for the remaining 1 billion people in the world who still lack electricity.

But what are the exact characteristics that make PAYG systems different from other business models? How can governments and development organizations take those matters into consideration when designing new policies, in order to ensure positive impacts through the scaling-up of the energy-access sector?

High scalability

The PAYG system is an innovative approach that allows electricity end-users to pay for their energy consumption and solar technology in small instalments – thus avoiding the initial upfront investment. While the company provider is typically the one that finances the purchase of the necessary equipment, its ownership is fully transferred to the customer at the end of the repayment contract. Payments are usually done through a simple mobile app and allow customers to lower their risk profile by "behaving" through timely payments. As a result, a positive credit history helps them access lending at better rates on future occasions. Examples of successful and ongoing PAYG models include Angaza, BBOXX, d.Light, M-Kopa, and Off-Grid Electric, as all of them have contributed to ramping up PAYG investment to $550 million over the past two years.

One of the main advantages of PAYG models is that they are highly scalable. They reduce investment barriers for customers through flexible payment schemes, lower energy costs, better technology prices and improved solutions, while also providing the necessary margins that companies need to maintain and expand their operations. Due to its flexibility and ability to adapt to different customer profiles, PAYG models are constantly improving, leading to better and more affordable services for end-users.

Moreover, these models allow customers to save money while accessing more valuable energy services for production and household use. As PAYG systems are less costly and more energy-efficient than traditional fuel-based energy production systems, customers often improve revenues from their businesses, as well as their quality of life. For instance, they achieve this through increased connectivity services and studying, recreation and income-generating activities in the evening. Productive use in turn enables the interlinkage of essential sectors such as energy and agriculture or water, thus laying the foundation for long-term, local economic development.

Mobisol and Solarkiosk

As in every sector – especially relatively young and highly dynamic ones – pitfalls exist. To fully understand the how and why of the Mobisol and Solarkiosk bankruptcies, one needs to first look at the wider context. The off-grid sector as a whole – and the market for solar home systems (SHS), in particular – still lacks the necessary economic and political conditions to unlock its full scalability. That means that the legislation and financial instruments the industry needs to take more action are often nonexistent, or inadequate at best. This not only complicates the development and implementation of off-grid solutions, but also makes it difficult for companies to access suitable finance, which in turn drives operational costs up in the highly competitive environments that PAYG models operate in. Only big companies like Mobisol have shown they are able to showcase positive impacts and therefore obtain the best portion of the off-grid financing pool. This grants them an ever-increasing share of the market and greater access to available resources. In other words, the off-grid sector is becoming a self-reinforcing spiral that sends an urgent signal to the PAYG market – companies must scale up at a faster pace.

> *"The off-grid sector still lacks the necessary economic and political conditions to unlock its full scalability"*

Mobisol is a clear victim of this vicious circle. In order to keep up with ever-decreasing prices, fast product development and the expansion of its competitors, the company has

had to rely heavily on impact investments and public funds, as commercial financing methods for PAYG startups are fairly expensive. For Solarkiosk, this would have seemed like a sensible way – at least, in principle – to reduce financial risks, as it builds trust among private investors. However, the business models and full-speed commercial activities of both companies proved to be unsustainable in the end.

> *"The business models and full-speed commercial activities of both companies proved to be unsustainable in the end"*

Even with established first movers such as Mobisol and Solarkiosk, the pressure to scale up can have a pernicious effect that can eventually lead a company to bankruptcy. This is due to the strategic advantages of second movers, which can benefit from passing realized lower technology costs in the meantime onto their customers. Consequently, in markets with short product cycles, second movers are often able to increase their market share in the short term, while incumbents remain tied to older technology purchase contracts, which makes it difficult to hold and attract new customers by lowering prices.

For first movers, this could mean two things: They either incur losses by reducing the price of their services – while financing a more costly technology – or they maintain the same prices. The latter option sets the stage for second movers to grab market share from them, however. This situation, along with Mobisol and Solarkiosk's increasing operational and technology costs amid their race to scale up, created a financial gap that public funding and impact financing alone could not fill.

Key lessons

From these experiences two important lessons can be learned. First, it is clear that the main objective of PAYG models is to become self-sustainable in terms of commercial and financial viability over the long term. Companies should also prioritize quality – that is, looking first at the stability offered by suitable finance and reliable customer portfolios – over rapid growth. As highlighted above, there are a number of successful PAYG business models in operation and in the process of scaling up. However, it is overambitious to expect full commercial viability over the short term, as the sector targets hard-to-reach customers with a low ability to pay. Companies also face markets that have been distorted by hefty fossil-fuel subsidies, and therefore they need continued support to develop properly.

This is why as a second point, in order to achieve full PAYG scalability over the long term, public financing needs to support the rural electrification transition to bring confidence to mainstream financial markets, so longer-term capital can become accessible to the key players of the PAYG sector. But regarding market size and the products that are offered, it is important to remember that the sector provides opportunities for all companies to scale up. Second movers can benefit from falling input costs, while experienced first movers are ideally positioned to improve and develop their business model to the next level.

The cases of Mobisol and Solarkiosk can teach us key lessons about the PAYG sector, in terms of scaling electrification, the commercial benefits, and the remaining challenges. They also send a clear message: While the strategic behavior of companies in highly dynamic, innovative markets offer a natural way for any sector to mature. Public and private investors should therefore adopt holistic approaches to supporting PAYG companies, so they can play a leading role in charting the path to sustainable electrification. pv

Marcus Wiemann and David Lecoque

Photo: ARE

Photo: ARE

About the authors

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Marcus Wiemann, the executive director of the Alliance for Rural Electrification (ARE), is responsible for the operation and future direction of ARE, as well as the management of relationships with institutional partners and governments. He also managed the ARE-OFID CfP, under which three clean energy minigrids were installed in Bangladesh, India and Mali.

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Grid security on the line

The move toward a digital, distributed energy system raises several questions for those managing grid infrastructure, and not least among these considerations is security. As the managing director of investment fund Energize Ventures, Amy Francetic oversees investments in technologies that will ensure reliability and security on the grid of the future. Here she discusses the current landscape for digtitalization in the energy space, and how a recent bill passed by the United States Senate could potentially throw a spanner in the works.

Photo: Energize Ventures

Amy Francetic is the managing director of Energize Ventures, which has invested in several companies that are driving the shift to a digitalized energy system.

What are the leading risks when it comes to increasing the digitalization of the energy system?

The grid is one of the oldest assets in the country and is extremely vulnerable to cyber attacks, even without digitization efforts. Cybersecurity is certainly a risk as the grid becomes more digital, but there are companies and technologies available to address that challenge, which is why one of our first investments was in Nozomi Networks.

Are there any unique risks when it comes to renewable energy assets, and solar in particular?

On one hand, the distributed nature of these assets potentially creates more points of connection and communication that might be vulnerable to attack. On the other hand, the distributed nature of digitized renewable energy assets, along with an increasing trend toward microgrids, creates a more redundant and resilient power system. For example, if one multi-megawatt or multi-gigawatt coal, natural gas or nuclear plant were shut down due to a cyberattack or physical, such as climate-related event, the outage extent and duration would actually be worse than with a more modular, distributed and redundant system. We've seen evidence of this with the California wildfires and Hurricane Sandy in New York City.

How can these issues be effectively managed or eliminated? What types of solutions are currently available?

The risks can be managed with new cybersecurity technologies. For instance, Nozomi Networks has a cyber solution specific to this type of distributed renewable energy asset. Nozomi maps out all of the points of communication, shows where they are vulnerable, and alerts asset owners to unwanted communication flows/vulnerable points.

How good is the awareness of industry players relating to these risks? Are they already being managed?

The threat is well known, but we are still in the early days of taking action to mitigate it. Part of the issue is related to utility regulation: Since utilities in the United States cannot rate-base software, they are not as incentivized to invest in those solutions. In the age-old adage of "show me the incentive and I will show you the outcome," part of the issue here is that there has been no historical financial benefit to utilities to invest in more software solutions.

Which solutions in particular are gaining ground commercially? Do you see a standard developing for security in the digital energy space?

We haven't seen a standard yet. There are a number of organizations looking at this issue, and it is a hot topic in Washington, so we wouldn't be surprised if standards eventually surface. The North American Electric Reliability Corporation has developed a Critical Infrastructure Plan (NERC CIP) to "establish a baseline set of security measures" for electric utilities. NERC CIP is currently the only mandatory requirement with which electric utilities must comply when it comes to cybersecurity – outside of customer data privacy considerations – in relation to operations.

> *"If we find a problem with a car, no one suggests we revert to horses and buggies"*

Why is digitalization plus security preferable to simply relying on an analog system that cannot be hacked?

Changes to the grid and electric generation – the movement from centralized to distributed infrastructure and assets – requires a new set of tools. We see digitization playing a large role and having numerous benefits to both the operators and utility customers. This is not as much a technology problem (the technology to secure the infrastructure exists) as it is an implementation problem and a who-will-pay-for-this-new-technology problem.

The U.S. Senate recently passed the Securing Energy Infrastructure Act, which takes the approach of relying on analog – what problems do you foresee with this?

Adopting this approach is likely to create a far less resilient grid, with higher costs borne by ratepayers. For one thing, an analog approach could require highly qualified and experienced staff – a challenge in an industry where filling vacancies caused by retiring workers is a serious issue. Furthermore, digitizing transformers, automated switches, reclosers and other grid equipment has been shown time and again to reduce outage frequency and duration in fault scenarios – in peer-reviewed literature by leading national labs like Lawrence Berkeley National Laboratory, and the National Renewable Energy Laboratory. It also entirely ignores increasing demand from consumers for more choice, control and personalization in how they consume energy – not to mention the environmental benefits of a more flexible and digital electric system. The Act would end up achieving the exact opposite of its stated goal. It's also worth mentioning that the Act goes against the grain of technological advances in every industry over the past century. If we find a problem with a car, no one suggests we revert to horses and buggies – rather, we figure out how to apply technology to address the problem and make the car safer. That's what we should be doing with the grid.

And what would have been a better approach for policymakers to take?

We should ensure that proper policy and regulatory controls are instituted such that digitization occurs in a secure, equitable and cost-effective manner. It would be counterproductive, likely costly and cumbersome, to try to make the grid more analog. The technology exists today to protect the grid, and companies like Nozomi are actively and successfully working to secure it.

How do grid-connected, distributed assets such as rooftop solar systems fit in with this? Do customers need to take note of the cybersecurity risk?

Again, this is my point about how grid-connected distributed assets actually increase the resiliency of the grid. This is precisely why Puerto Rico is rebuilding with solar and microgrids, rather than the status quo. Customers should absolutely understand how their service provider is addressing cybersecurity protocols, and how their PV system and utility customer data are protected – but that risk is no different than using an Apple iPhone, Amazon Alexa, or Nest Thermostat. We should all seek to better protect our privacy and data in the digital era.

Interview by Mark Hutchins

Award window 3: SPI & REI

The third window of the 2019 pv magazine Award reveals competition heating up on the module front, as we head to Solar Power International and the Renewable Energy India Expo. Several different technologies are in the running, with transparent backsheets bringing a new dimension to bifacial PV, wafer sizes creeping upward and cast mono technology also making an appearance. The latest innovations in balance of systems, meanwhile, promise to push solar into new locations and bring down installation and labor costs. And the latest crop of inverters continues to earn their moniker as the "brains" of PV systems.

Into round five with less leakage

Solis-(25-50)K-5G

Ginlong (Solis) presents its fifth-generation (5G) technology platform with seven new C&I inverters, available in 25 kW, 30 kW, 33 kW, 36 kW and 40 kW at 400 V versions, and in 40 kW and 50 kW at 480 V versions. Ginlong claims that its next-generation platform ticks all the boxes when it comes to functionality. As with its previous models, the Solis inverters have a wider MPPT voltage range and lower startup voltage than before. As a result, the manufacturer promises that customers will be able to generate power for longer full-load hours per day. The startup voltage sits at 180 V, while the MPPT range is from 200 V to 1000 V. Another novelty from Ginlong's R&D labs is its improved pulse-width modulation algorithm. The feature helps to suppress leakage currents by 50-60% more than previous models. With improved string monitoring, I/V curve scanning, DC and AC side type II surge protection, and residual current detection, the company claims that its inverters will continue to supply power through more stress than has been the case before. All models are transformerless, fuseless and fanless to decrease parasitic capacitances, fire hazards and noise.

A digital doctor for utility-scale PV

Huawei SUN2000-185KTL

Squeezing every last bit of efficiency and productivity out of a solar plant is as important as ever. And with hardware inching toward the physical barriers of its development, software solutions are ready for further exploration. This utility-scale inverter comes with 18 inputs and nine maximum power point tracking channels, which the company says is ideal for the use of bifacial modules, to minimize string mismatch caused by weather effects and alternating ground albedo. This inverter's party trick, however, is its artificial intelligence-supported I/V curve diagnosis. According to Huawei, this type of I/V curve diagnosis is considerably faster than manual approaches. A 100 MW plant can be fully diagnosed for 14 different kinds of module faults, in 15 minutes, while a manual approach would take three days for 1 MW, according to Huawei. This improved diagnostic can prompt a 15-20% discount on a site's O&M bill, the company asserts.

The do-it-all off-grid hybrid solution

GoodWe A-ES & MT Series

GoodWe is expanding its offerings with a U.S.-tweaked version (with Rapid shutdown and AFCI requirements) of its ES energy storage inverters. The device comes in 5 kW and 10 kW versions, which should be enough for all home applications. It's equipped with four MPPTs, so homeowners shouldn't worry about slightly off roof angles or that neighbor's big tree. What sets this inverter apart, GoodWe claims, is its versatility in combining various power sources. The company says it is the only inverter on the market that can send DC from the PV array as DC to the battery, AC from the grid to DC in the battery, DC from one battery to DC to another battery (which it can easily accommodate, even from different manufacturers), and DC from the battery to AC loads in the house. GoodWe says this makes it a hybrid and off-grid inverter at the same time, covering all sorts of use cases. The charging current is 50A for fast cycling and the whole system is capable of UPS and zero export functions. GoodWe also rocks up with another new C&I scale inverter range from 50 kW to 80 kW. The inverter boasts efficiency of 99%, the manufacturer claims, and additionally the possibility to oversize the capacity-to-yield ratio by 50% and overloading of 15%.

Four panels now with reactive power

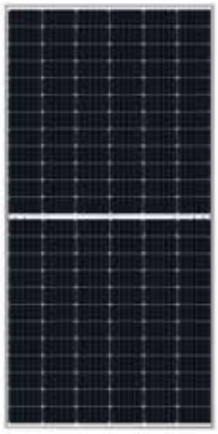
Hoymiles HM-1200

This microinverter comes close to a mini string inverter, allowing the connection of four modules to one microinverter. This keeps component costs down, while providing the benefits of microinverters. One of these would be a micro startup voltage of just 22 V, for an extra early start into the power production day, as well as module-level MPPTs, which allow extremely high-granularity power generation optimization. The company claims that thanks to such advantages, the use of its microinverters can boost an array's yield by 10-30% compared to the use of string inverters. Additionally, Hoymiles notes that its products are not only intended for the small-scale residential market, as they have been used extensively in multi-megawatt C&I applications. To top the whole thing off, the company says that its microinverter is the world's first in its class that is capable of supplying reactive power. With ever increasing shares of renewable energy in the grid, reactive power supply is already a requirement for many installations.

HJT from REC

REC Alpha Series

The Alpha Series boasts a power output of 360 W to 380 W, in a 120 half-cell, dual module configuration. Module efficiencies range from 20.6-21.7%. The HJT technology comes courtesy of Meyer Burger, REC's new partner for an initial 600 MW production line. The line includes Smartwire cell interconnection, allowing the low temperature processes required for HJT, along with additional structural support to potentially thinner n-type wafers. On durability, REC has a long track record with half-cut cells – pointing to high-quality cell separation and cut edges. The frame includes two horizontal supports, meaning that it can sustain mechanical loads of +7000/4000Pa. The n-type technology is LID-free, REC says. Alpha is covered by REC's 20-year product and 25-year performance warranty.



Bigger wafer delivers bang for buck

Longi Solar Hi-MO 4

Bigger wafers are a thing. And the power output boost speaks for itself. The M6 wafers in the new Longi Hi-MO 4 module come in about 12.2% larger than the M2. The result is 420 W output on the frontside, in a 144 half-cell, dual module configuration, with mono PERC cells and module efficiency of 18.5-19.4%. The M6 is a 166 mm wafer, produced from ingots sized up to 216.229 mm. Handling the larger wafers, Longi claims, requires cell and module equipment upgrades – a considerable barrier to entry that delivers a competitive advantage to the Chinese mono giant. But the move to larger wafers is not just about competitive positioning, says Longi. The additional output of the Hi-MO 4 results in reduced BoS and, in turn, total system costs – delivering a 3% increased RoI for investors, Longi claims.

Cast mono inside

GCL Saturn Series: M3/72GDF

It's what's under the hood that GCL is heralding with its latest module in the Saturn Series – cast mono. The switch to monocrystalline cells is well understood, and GCL is not bucking the trend, but rather adopting cast mono technology. Cast mono utilizes multicrystalline process equipment to create mono-like products – and at 370 W to 405 W, in a 144 half cell configuration, the M3/72GDF illustrates that the technology can pack considerable punch when it comes to power output. Beyond the cell, M3/72GDF includes many leading features: dual-module design, half cut cells and multi-busbar interconnection. In terms of interconnection, GCL is offering the M3/72GDF in either 5BB, 9BB or 12BB. The company has opted for glass-glass encapsulation for the bifacial M3/72GDF. The module weighs 30.1kg. GCL points to its durability, owing to its claimed lower oxygen and carbon content – resulting in reduced risk of LID.

n-type + clear backsheet

Jolywood-HT156N Series

In 2019, bifacial doesn't have to mean glass-glass with a new range of transparent backsheets making their way onto the market. Jolywood is adopting the new material in its HT-156N Series of modules, which incorporate n-type high-efficiency cells. Jolywood packs more cells into the module also, with 156 half cells, in a 12x13 configuration, dual-module design – the latter of which Jolywood describes as being a Duplex design. The outcome is that the module achieves 440 W to 460 W peak power, representing a 20.29% - 21.21% module efficiency. The HT156N Series comes framed, and Jolywood says that by virtue of the n-type technology, it does not exhibit LID.

New glass for lightweight dual-glass

Jetion Solar JeThrü JT-SSh

Glass-glass PV modules are bulky, and if frameless, prone to handling damage and failure – right? Jetion Solar says no, particularly in light of its new JT SSh module, which is part of its JeThrü series.

The module deploys 1.6 mm ultra-thin and high transmission glass – courtesy of its parent company, construction materials giant CNBM.

The result: a 144-half cell module, with 405 W front side output, at only 21.5 kg in weight. Mono PERC half cut cells are used in the module.

With a lightweight frame that doesn't shade the rear side, Jetion claims its new module is very durable. It points to the module having passed the 7,200 Pa mechanical load test as a result.

Another notable feature of the JT-SSh is its use of polyolefin encapsulant (POE) delivering additional durability. The new glass is not only thin and lightweight, says Jetion, but also exhibits high transmittance in the visible spectrum, delivering a 0.3 – 0.4% efficiency boost, or 1.99 W on the front side.

High powered plug-and-play from LG

LG NeON R ACe

"Plug-and-play" is an overused term in the PV industry, but South Korean module maker LG is bringing an AC module onto the market that appears to live up to the claim. The LG NeOn R Ace builds on the award-winning, high-efficiency NeON module series, which couples n-type high efficiency with busbarless cell interconnection, along with its in-house microinverter technology.

The NeON R Ace comes in at 21.7% module efficiency, delivering 375 W(DC) and 320 W (AC) for a power conversion efficiency of 97%. The module is set for release on Sept. 19. The value of the AC module is that it brings with it the known advantages of microinverters – less DC cabling, fast shutdown, module-level monitoring and optimization – straight out of the box, with microinverters pre-assembled to the module. LG says the solution is a demonstration of its understanding of installer "pain points," and that it requires only two components to be installed beyond the module – a gateway and extension cable. The gateway can be installed without wall drilling. This results, LG claims, in system design and installation requiring only seven steps, compared to 14 with a conventional system.

With all components coming from LG, the whole system is covered by one 25-year performance and product warranty. Systems can be expanded with more solar modules over time. LG's Enervu monitoring system is also included in the package and it can also be extended to feature energy storage.

LG highlights its sustainability track record with the NeON R ACe, including participation in module takeback schemes, such as those managed by SEIA and PVCycle, underpinned by LG Electronics' target of net zero emissions by 2030.

Cutting down on cables

Shoals Big Lead Assembly

By combining the functions of cable assembly, combiner boxes, external fuses and recombiners, Shoals Technologies Group is taking aim at both installation costs and operations and maintenance.

The system transmits power from modules to inverter without the need for a combiner box or underground cabling. And as a "plug-and-play" solution, it promises significantly faster installation, as well as high reliability and low O&M requirements.

According to Shoals, feedback from the 9 GW of Big Lead Assembly systems installed shows that some developers have been able to cover more than 60% of their initial product costs through savings in labor, before projects are even substantially completed. This shows that the solution's minimal operations and maintenance requirements bring about further savings down the line. The company notes that Big Lead Assembly allows developers to transition from a small-gauge copper connection to a DC feeder cable, allowing for further system optimizations.

Rooftop harmony

Lei Import Clearline Fusion

Clearline Fusion is an integrated rooftop PV system that aims to address the questions of weatherproofing and aesthetics – both of which are important when it comes to rooftop-integrated installations. The solution replaces the actual roof coverage with a connection method that allows for panels to simply be pushed together to create a weatherproof and secure fixing. The panels sit lower on the roofline than a standard rooftop install, with no visible brackets or racking – increasing the aesthetic appeal.

According to Netherlands-based Lei Import, the solution is cost-competitive with standard rooftop PV installations. It has been designed with ease of installation in mind, as well, and can be installed by a roofer, so one party is responsible for providing a watertight roof.

The company says that Clearline Fusion has been certified for wind resistance in even the most exposed locations, and is the only rooftop-integrated PV solution to be certified to the highest European standards for fire resistance (BRoof T1-T4).

Coating goes underground

Kern Solar Structures Solar X-Pile

X-Pile is a coating for steel substructures that aims to provide a more environmentally friendly solution for the prevention of steel corrosion caused by soil conditions, while ensuring that PV trackers and racking systems can last for at least as long in the field as the modules they hold.

By protecting steel from corrosive soil conditions, X-Pile also aims to allow for more solar installations on poor quality, polluted land. The coating utilizes low-volatility organic compound materials and is consistent with Environmental Protection Agency regulations in the United States.

Kern says this does not risk introducing higher levels of zinc into soil, as can happen with the hot-dip galvanization process that is commonly used with such steel structures. Rather than allowing for a certain amount of corrosion over a structure's lifetime, X-Pile looks to protect the steel from corrosion effects in the ground. "X-Pile minimizes the financial and engineering risk of premature foundation failure, and also has the potential to extend the residual value of the solar support structure at the end of the initial investment period," the company says.

Panasonic

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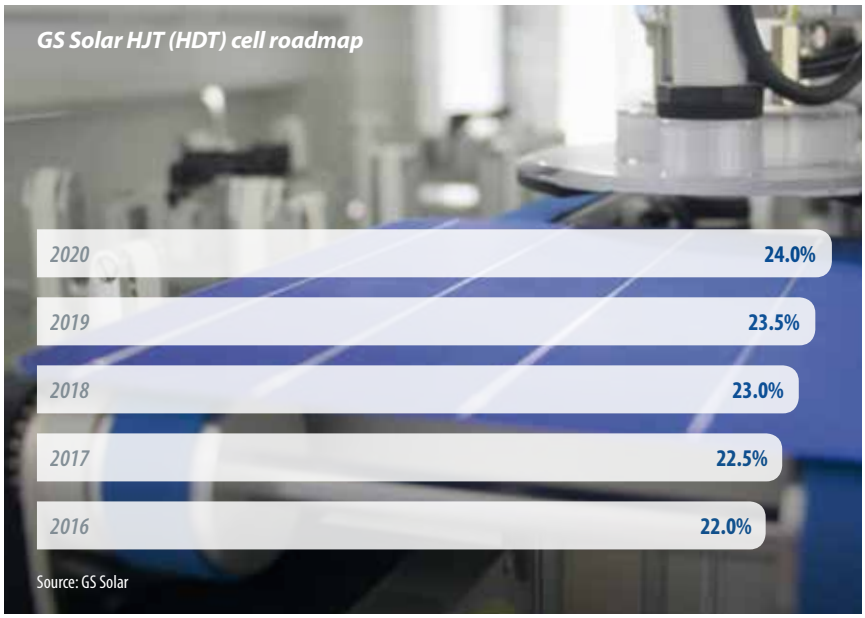
Next steps for HJT

There is movement in the heterojunction space, but will it be enough to surpass PERC's momentum? New production lines show promise, but they might also be the last roll of the dice for Swiss production equipment supplier Meyer Burger.

It is considered conventional wisdom among some in the PV production community that for technology upgrades, PERC including TOPCon is the obvious choice, while for greenfield projects, the only way is heterojunction (HJT). But as the 2019 PV market heads toward its final quarter, it remains unclear whether this technology dynamic is self evident.

One major development on the HJT front in 2019 has been REC Group's embrace of the technology. At Intersolar Europe in May, REC launched its new Alpha Series HJT module with 380 W of output in a 60-cell configuration. Alpha deploys Meyer Burger HJT deposition and Smartwire cell interconnection technology. On release, module efficiency came in at 21.7% and 21.4% for an all-black module.

REC dove headfirst into HJT, particularly from a volume perspective as a non-Chinese manufacturer. In one fell swoop, it purchased 600 MW of HJT production equipment – and it is currently ramping that up further. First shipments are expected in October and November to Europe, the United States and Australia.



"There were very interesting reactions from people," says REC Group CTO Shankar G. Sridhara. "They have been surprised because it is a bold move jumping to HJT and it is also very bold doing 600 MW in one shot. But we are confident about the due diligence that we did and the module development that we did on the side."

The Alpha modules combine HJT and advanced connection technology with REC's "Twin Panel" design, which the company pioneered back in 2014, along with half cut cells.

Sridhara sets out the thinking behind the move: "REC with its size of around 1.8 GW can't compete on the standard technology, which is now PERC. With the n-PERT which we launched last year, we are ahead, but in order for us to be a true technology leader, we have to maintain a significantly larger distance to our competitors. HJT is the right technology to do that, both from a performance and, naturally in this industry, from a cost perspective."

Cost in focus

In terms of costs, there are concerns that the capex requirements for investments in new HJT lines remain too high. Ethan S. Simon, the CTO of DuPont Photovoltaic and Advanced Materials, says that production equipment capex for an HJT line may be up to two times higher than for a standard mono PERC line. However, he notes that efforts to advance large area PECVD equipment could reduce that margin significantly. "The investment required could be a damping factor," says Simon.

PV InfoLink analyst Corrine Lin estimates that HJT capex, drawing on Chinese equipment supplier figures, is around CNY 0.75-0.85 billion ($100-120 million) for 1 GW of capacity, with PERC coming in at around CNY 0.25 billion.

On the opex side, too, there are challenges. Early HJT cells were sometimes described as being heavy on the silver paste laydown for cell metallization, although here progress has been made. "Our fourth-generation [HJT paste] ver-

sion reduces the cost of the process by offering up to one-third reduction in paste usage," says DuPont's Simon.

But indium, often used for the transparent conductive oxide (TCO) layer, does not come cheap – particularly if large volumes have to be purchased at the start of production. Indium tin oxide is favored for the TCO in HJT production.

Technological inertia

A further limiting factor for HJT adoption could simply be technological inertia, as PERC is well established and understood by manufacturers and the market, now that it has gone through a long gestation period. "They have done their homework on PERC and now they have to think what's next," says Christian Knechtel, the CEO and CFO of German production equipment supplier Von Ardenne. In PV, Von Ardenne supplies coating equipment to the thin-film segment – First Solar being a notable client, along with TOPCon and HJT crystalline silicon manufacturers – specifically for physical vapor deposition (PVD) of the TCO layer.

"We also see a lot of people understand PERC and its efficiency restrictions, which could be eliminated by TOPCon. People are a bit reluctant when it comes to technology change," says Knechtel. This reluctance may be more pronounced given the strong efficiency gains made by PERC producers, in its various flavors.

Oliver Voigt of wet chemical equipment supplier RCT Solutions asks: "If TOPCon cell efficiency of 22.5% can be achieved, then why would you go to HJT?"

24% and beyond

The promise of a potential 24% cell efficiency in mass production is what makes HJT production so enticing, along with the relative simplicity in terms of process steps. REC is an experienced PV producer and with 600 MW running at high utilization rates, presumably learnings will be accelerated. And beyond REC, there are moves by other tier-one manufacturers into HJT.

In August, Risen Energy broke ground on a 2.5 GW HJT cell and module facility in China's Zhejiang province. The company plans to invest some CNY 3.3 billion in the facility. Risen Energy says HJT's advantages are its good temperature coefficient, along with its resilience to "light and power degradation" – presumably LID and LeTID. Zengsheng Liu, director of module R&D for Risen, adds that HJT exhibits up to 19% bifacality – far superior to that achieved by PERC or PERT.

> *"It is a bold move jumping to HJT, and it is also very bold doing 600 MW in one shot"*

GS Solar, a production equipment supplier based in China's Fujian province, claims to operate 1 GW of HJT capacity, which it calls HDT technology. The company's core technological competence is in PECVD and PVD technology. But PVInfoLink's Lin says that the company pivoted from HJT equipment supply to cell and module production after experiencing limited demand for its equipment.

In May, HJT pioneer Panasonic transferred the ownership of its Malaysian HJT manufacturing facilities to GS Solar and launched a joint venture for ongoing R&D. The partnership aims to "drive further development of heterojunction photovoltaic technologies," according to a statement by Panasonic – presumably with cost reductions front and center.

Veteran solar analyst Götz Fischbeck, from Smart Solar Consulting, believes that while recent HJT deployments are encouraging, there are still considerable headwinds for the technology – most notably the capex requirements. Fischbeck understands the Meyer Burger/REC deal includes some form of profit sharing and a period of "technological exclusivity" for REC. For the Swiss technology provider, Fischbeck believes, it also "represents the last chance for Meyer Burger to survive as an equipment supplier to the solar industry." PV

Jonathan Gifford

Addressing HJT capex, opex

Heterojunction can be an attractive technology pathway for a number of PV producers, says Christian Knechtel CEO and CFO of Von Ardenne. However, the key to deployment could lie in manufacturing key production tools in a cheaper manner while continously ramping up throughput.

Photo: pv magazine/Dave Tacon

Christian Knechtel: "We are ready to support the market – and let's see if people can find the financing to move on with HJT."

How would you describe HJT's progress in the manufacturing landscape this year?

Heterojunction is slowly moving into the market, and a lot of people are looking into whether it is something that they can really use for the future. In particular for smaller startups it is quite nice because it doesn't have all the value chains that a PERC line has, so it is much easier to get started. What we see is a small success in the market – however, the big topic is bringing down the cost. What manufacturers are saying is that with HJT, "I have better efficiency on the module, but how do I bring down the capex and bring down the opex?"

And how can you, as a production equipment supplier, contribute to that?

We looked at it from an LCOE point of view and put together a strategic roadmap about how to potentially overcome that. The first thing, reducing capex: How to do that in terms of manufacturing cost and scale. We worked on two programs. One was bringing the production of the machines into China – so German-engineered, made in China. Just recently, we successfully manufactured the first machines in our Chinese subsidiary.

The second topic was to increase the throughput of our PVD machine – the XEA|nova L. If we look at what we discussed three years ago, 6,000 wafers per hour is not good enough. It has to be scaled up to 8,000 or even up to 10,000 wafers – and that is what we did. Our engineering concept is finished and we are just now promoting the 8,000 wafers/hour tool, which can even be scaled up to 10,000. That is a good balance between the wet benches in the beginning and the PECVD and metallization line at the end.

And what about on the efficiency front?

We have shown that we have a real track record with a tier one customer, and have shown the superiority of TCO layers, processed on Von Ardenne PVD machines. This applies not only to technology, but in particular from the cost of ownership point of view.

In parallel is the topic of bringing the opex down further, for example with different target materials and increasing target utilization and things like that. That is really what drives the HJT market: Capex down, efficiency up, opex down, and that is the simple algorithm for the LCOE.

Are the machines the same size?

The XEA|nova L is a bit bigger than before, with a larger carrier. The wafer can be up to M4 format. It still fits in the space on the carrier. We use every millimeter available in the machine.

But how can you make this process three times as fast? It's pretty incredible.

It is a good question – but if you challenge engineers, they become creative. In glass coating, we have established thin film machines for substrate widths up to 3.3 meters. By comparions, the XEA|nova L for PV applications is 1.6 meters in width. So the machine for the PV business is still around half of what we have done on the thin film side.

The reason why we did not apply even larger systems with 20,000 or more wafers per hour is the need to balance the PVD system in the overall PV production. You have the wet benches in the front and they have limitations, and you have PECVD in the middle and the metallization at the end.

in equipment supply

How do these other process steps compare to, say, 8,000-wafer throughput?
The throughput of conventional PECVD is less than 4,000 wafers. So you need two or three PECVD and one PVD to match the HJT vacuum equipment. The upstream wet chemistry step can be done in one machine.

Does this bring down the capex?
Of course, the PECVD and PVD require more capex investment. Another advantage of a bigger machine is that you use more of the targets. The wider the magnetrons, the higher the overall utilization rate per wafer and the lower the opex.

> *"6,000 wafers per hour is not good enough. It has to be scaled up to 8,000 or even up to 10,000"*

What would you say is the outlook for HJT?
Honestly, now we are just looking to see whether there will be more investments into HJT. Let's see what happens. We are ready to support the market – and let's see if people can find the financing to move on with HJT. pv *Interview by Michael Fuhs & Jonathan Gifford*

Size matters

The latest development on the module front sees manufacturers adopting larger wafer sizes in order to reach the industry's raised expectations for power output. Older "M2" wafers have been the standard in recent years but now appear to be on the way out. Several theories about optimal size are gaining ground, but the future direction of the standard is still far from clear.

"It's a bit of a mess, but it's part of the proceedings and the improvement of technology"

Philipp Matter from GCL Systems Integration says that only a few years ago, he did not have a precise understanding of module dimensions. "They were all the same." Today, Matter says, things are different. "It's a bit of a mess, but it's part of the proceedings and the improvement of technology, so we have to take it."

Over the past decade, the size of silicon wafers for the solar industry has slowly crept upward. Larger wafers offer the potential for savings in production, but for the most part, changes have been slow and incremental, as there is a need to minimize disruption to the downstream industry. Major changes to the size of this key component could necessitate an expensive overhaul of cell and module production lines, while also affecting installation practices, racking design and other balance-of-systems components.

From around 2010, suppliers began to move to 156 mm² as a standard size, and older 125 mm² wafers were more or less eliminated from the market by 2014. Wafer suppliers in China then adopted 156.75 mm² as a standard, and this became the M2 wafer format, which the International Technology Roadmap for Photovoltaics says represented more than 90% of the market for both mono- and multicrystalline wafers in 2018.

Scaling up

In 2019, manufacturers have again begun to diverge from this standard, as they look to maximize active space in the module to meet the industry's demand for consistently higher power ratings. Several major manufacturers have launched modules based on wafers measuring 158.75 mm², while a handful of high-efficiency suppliers are working with the M4 format, measuring 161.75 mm².

And it doesn't stop there. In June, leading wafer supplier Longi Green Energy Technology launched its new M6 wafer, measuring 166 mm². And in August, Zhonghuan Semiconductor took the trend to another level when it launched the supersized "Kwafoo" wafer, measuring 210 mm².

The rationale behind any increase in wafer size is reduced costs. In production, the aim is to produce the larger format at the same level of throughput, effecting a reduction in the cost per watt. And further down the line, the goal is to reduce balance of systems costs by fitting more watts into the same size racking system.

According to Longi, the M6 wafer has an area 12.2% larger than the M2, providing an 8.8% boost to power output. Back in May, Longi launched the M6 at CNY 3.47 ($0.49) per piece, and the price has since remained slightly above that of the smaller M2. Longi has stated, however, that with its economies of scale it expects to reduce the price premium to less than CNY 0.20 per piece.

The company estimates that its new M6 wafer brings down costs at the cell and module level by around $0.007/W, while also reducing the spend on other components including racking, foundations and cabling by around $0.01/W.

"With a larger module size, each array requires fewer brackets, and each bracket requires more steel in order to carry a larger module," explains a Longi spokesperson. "But this cost increase is lower than the bracket decrease. Therefore, the bracket cost is reduced, and the number of pile foundations is generally proportional to the number of brackets. Therefore, the cost decreases significantly with the increase of module power."

Varying sizes

With at least three different wafer sizes gaining ground commercially, it is difficult to say which, if any, will form a new standard. Longi is keen to promote its M6 as the best option. "With this size, there is no need to replace the tube furnace. And a bifacial module using 2 mm

glass+frame weighs less than 30 kg, and still can be handled and installed by two people," says the Longi spokesperson. "A smaller increase will still change the module size and require all new certifications. Therefore, Longi believes that if the wafer size should be changed, 166 mm is the right choice."

Other manufacturers appear to have settled on 158.75 mm² as the optimal size to offer the best compromise between manufacturing processes and module features. GCL Systems Integration stated earlier this year that it would work with this size in all future projects. Last year, JinkoSolar also brought its Cheetah series to the market and has now shipped more than 5 GW of products that incorporate the wafer.

"We have done our homework on this and we think we understand that this [158.75 mm] is the right size for the industry at the moment," said Gener Miao, JinkoSolar's VP for global sales and marketing. "With even larger sizes we have done the research and this would create a lot of disruption. You would have to design a whole new racking system. As a manufacturer we can do larger wafers, but I don't think the downstream sector is ready for it."

And in between these two is the M4 wafer, measuring 161.7mm. It has been available for several years, and has been mainly adopted by manufacturers offering premium high-efficiency products, including Hanwha Q Cells, REC Group, LG and SunPower. "We opted for M4 wafers with an edge length of 161.7 mm as the most cost-effective choice in the market," says Jürgen Steinberger, manager of Q Cells Product Management. "M4 wafers make better use of the ingot than M2 wafers, help increase module power by 20 to 25 watts, and thus support material and labor cost reduction during installation."

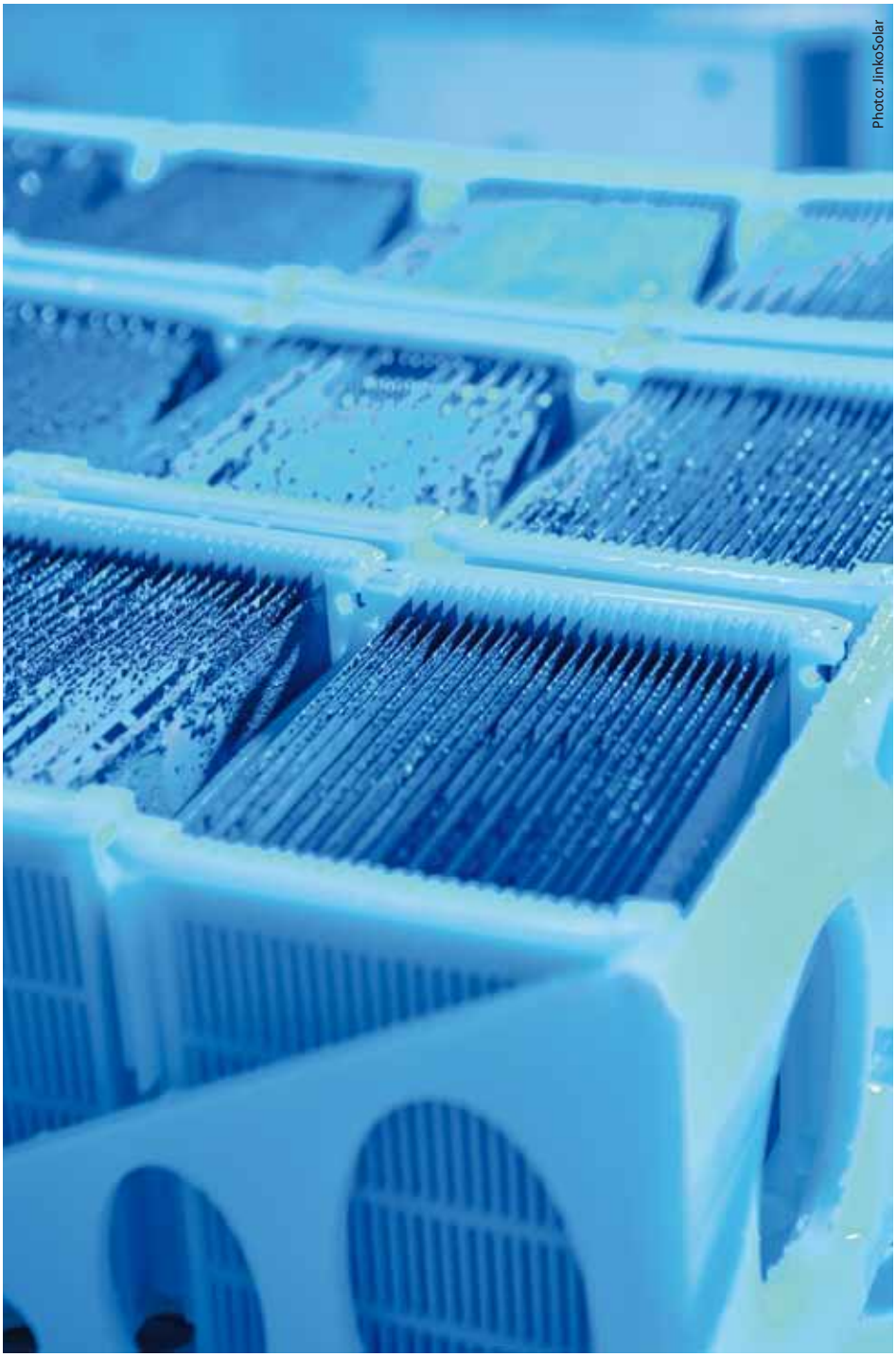


Photo: JinkoSolar

JinkoSolar's Cheetah series wafers measure 158.75 mm². While others are investing in even larger sizes, the company says this currently represents the best compromise between manufacturing processes and PV module features.

Maximum output

On the manufacturing side, where players are looking to larger wafers to maximize their module output and get the most out of their investment in machinery, it would make sense to move directly to the largest size that can be processed without major adjustments to the production line. "Adopting a wafer size such as 158.75 mm, which is only marginally larger than M2, does not offer enough LCOE benefit for our customers in order to justify the slight increase in module size," says Steinberger. "The fact that some of our competitors decided differently suggests that their existing production equipment does not support the use of M4 wafers."

Longi is keen to stress that its M6 wafer can be adopted on production lines with minimal disruption, and is already seeing widespread acceptance. "The monocrystalline furnace has plenty of room to produce thicker silicon ingots," says the Longi spokesperson. "Newer cell and module production lines only need replacement of jigs and fixtures, and the cost of transformation is not high. New factories do not need transformation,

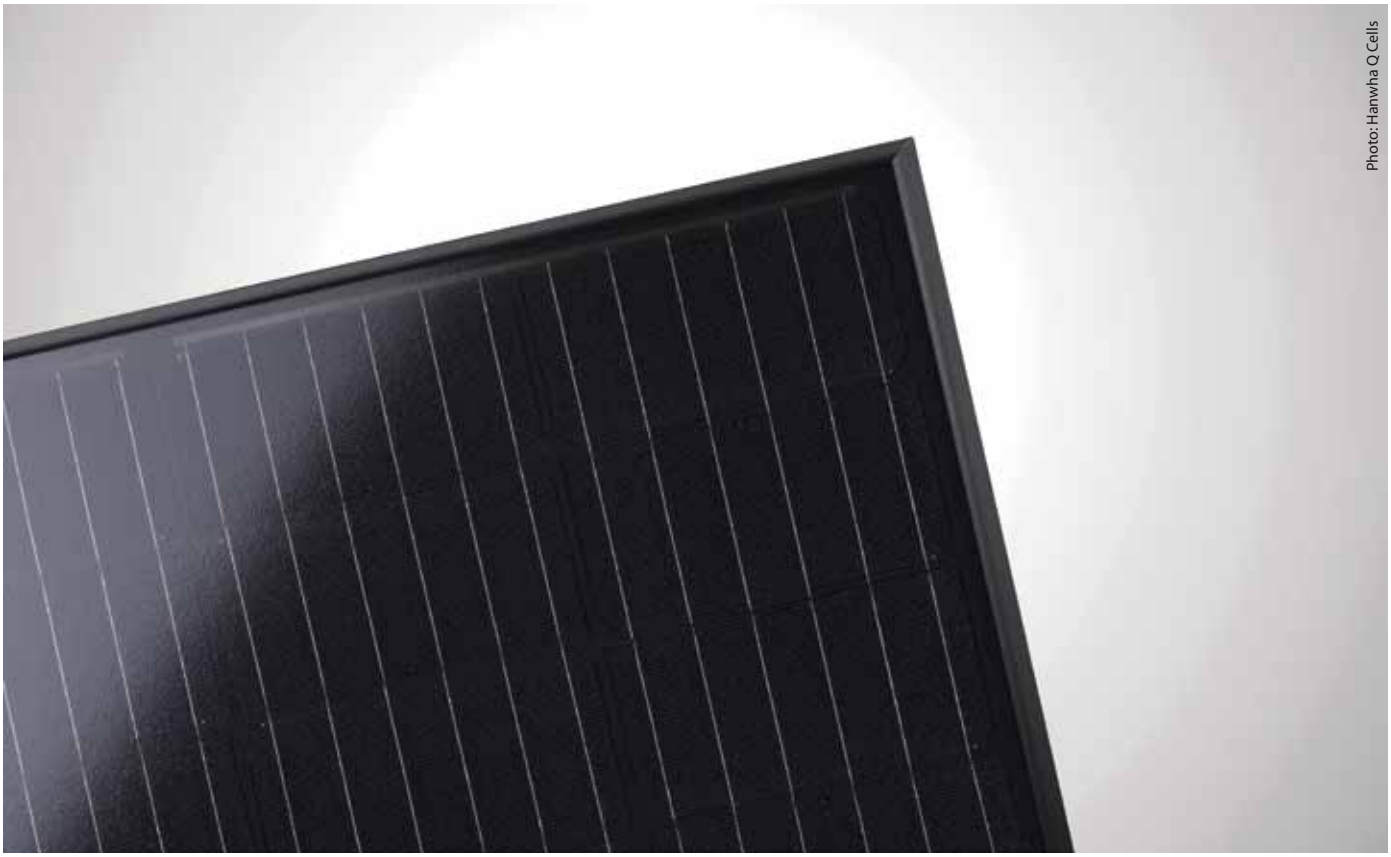


Photo: Hanwha Q Cells

Hanwha Q Cells opted for the M4 wafer, measuring 161.7mm, in its Q.PEAK DUO BLK G-6 modules, stating that this represents the most cost effective choice on the market.

and will all take the compatibility with M6 wafers into account."

Suppliers that have opted for the smaller increase to 158.75 mm², however, are keen to stress that minimizing changes to the module dimensions is a key consideration, as it avoids added costs in installation. "We chose the 158.75 mm wafer to lean in toward our EPC partners. This led us to maximizing the wafer size without changing the module dimensions significantly. It's not a case of 'the bigger the better'. The target is to optimize the cell size also considering the downstream industry" says Andrea Viaro, head of technical service for Europe at JinkoSolar. "The Cheetah module is just a few centimeters longer and larger, and that's it; it does not generate extra requirements or costs to adapt the PV array configuration. We have done much research, and with larger sizes the design of the system would create a lot of disruption."

"There are conflicting theories as to where the sweet spot lies between cost optimizations in module manufacturing and added weight or complexity in installation"

With its announcement of the 210mm² Kwafoo wafer, however, China's Zhonghuan Semiconductor looks to be inviting this type of disruption. The company says a 120 half-cell PERC module incorporating the wafer could achieve a power rating of 610 W. However, this would surely mean a much larger form factor – one that would likely make big investments in new production equipment a necessity, as well as complete redesigns at the system level. Zhonghuan Chairman Shen Haoping, however, is convinced of the Kwafoo wafer's potential to reduce project costs. The company says it will now "work closely with partners from the entire value chain to build up a lower cost and more efficient platform for the solar PV market," which may be more of a long-term goal, given the implications for customers of the new larger wafer.

"The much larger 210 mm wafer format poses some challenges along the supply

chain," says Steinberger. "Such large wafers do appear promising – especially for lowering capex per watt for manufacturing tools, from ingot to cell – but even slight negative effects on production yields or cell efficiencies could easily cancel out such benefits."

With multiple wafer sizes in use – not to mention different choices regarding the number of cells and their layout in a module – there are conflicting theories as to where the sweet spot lies between cost optimizations in module manufacturing and added weight or complexity in installation. And in practice as well, this will likely vary depending upon project specific parameters.

"The industry is now determining how to balance the equation," says Eduardo de San Nicolás, sales coordinator and product director at tracker manufacturer Soltec. "As panels grow in size, at some point, the upfront manufacturing savings of the larger panels will offset the extra cost of reinforced structures and BOS construction."

Differentiation vs. standardization

Differentiation has emerged as a major trend among module makers in recent years, as they look to make their offerings stand out in a crowded marketplace, and as technologies grow more tailored to specific applications.

Applying this to wafer size, it could be that the different sizes coming to the market are each able to find their niche – for example, many rooftops would be unable to accommodate larger, heavier modules, while ground-mount racking systems can be reinforced relatively easily.

"In the last years, module makers have introduced a variety of types of cells, frames, and technologies, thus making it harder to standardize," continues San Nicolás. "We cannot foresee a module dimension standardization in the industry in the short- nor the mid-term. Instead, the market is putting its efforts into a seamless panel-tracker integration that minimizes installation costs."

Cell and module manufacturers, however, have been more vocal in calling for standardization as a way to keep driving costs down. "The potential risk that we see with diversified module sizes on the market is an increase in the mismatches along the supply chain," says JinkoSolar's Viaro. "This might create complexity, and ultimately higher costs for the end customer."

Longi has also called for manufacturers to adopt the M6 wafer as an industry standard. "A standard size can help the whole industry reduce costs and avoid frequent changes in the product specifications," says the spokesperson, noting that the M6 wafer will be its main direction in the future, even though there is still demand for the M2.

For now, research and collaboration are needed to balance the needs of manufacturers with those of their customers. What's certain is that we won't see the market accepting lower power ratings. And since a larger wafer is a relatively simple way to push more watts out at module level, this is likely the way the industry will move – and the M2 format could soon be a thing of the past.

Whether increasing to 158.75 mm, 161 mm, 166 mm or even larger will prove the optimal strategy here remains a question the industry will soon need to answer. "There is a theoretical tipping point in which the savings in terms of Wp derived from manufacturing larger panels will not be able to balance the higher costs of manufacturing larger trackers and handling bigger and heavier panels of a PV plant's construction," says Soltec's de San Nicolás. "We are collaborating with EPC contractors and panel manufacturers to determine that threshold." PV

Mark Hutchins

Beyond mastery of mono, Longi looks toward 'solar for solar'

At this year's SNEC 2019 show in Shanghai, pv magazine had the opportunity to interview Zhong Baoshen, the chairman of Longi Group. Along with Longi Group President Zhenguo Li, Zhong is spearheading the company's exypansion on various fronts.

Zhong Baoshen, Chairman of Longi Group. The manufacturing giant envisions powering its entire production fleet using clean PV electricity.

Photo: LONGi

More than any other PV manufacturer, Longi is responsible for catapulting monocrystalline panels from a minority position in 2018 (46% market share according to PV InfoLink) to an anticipated 62% in 2019 and 75% in 2020. That alone is a stellar achievement, but Longi has also turned in stellar financial results, making it the most bankable pure play module maker according to Bloomberg NEF's Solar Module & Inverter Bankability 2019 report.

In 2018 Longi Solar generated an impressive $3.32 billion in revenue, capping a five-year CAGR of over 57%. Net profits delivered an even higher five-year CAGR at 104.8%, amounting to $386.49 million last year. 2018 shipments amounted to 3.48 billion wafers and 7.07 GW on the module side.

Zhong also highlights Longi's dedication to R&D along the entire PV supply chain. From 2013 to 2017 Longi Group invested a record $380 million in R&D. The company has invested considerable resources to improve the monocrystalline ingot casting process, increasing both ingot sizes and the speed at which ingots are pulled in the so-called recharging Czochralski process. On the cell side, the manufacturer surpassed the 24% efficiency mark earlier this year with its bifacial PERC cell, the first time this had been achieved on a commercial scale. And finally, on the module side, the company launched its latest generation Hi-MO 4 module with output levels well beyond the 400 W mark at Intersolar Europe in May.

To further boost outputs, the march to larger wafer sizes is important. According to Zhong, 30% of Longi's cells will feature larger 166 mm wafers in 2020. Bifaciality is another measure to boost module output and in the **pv magazine** test program Longi Solar's bifacial mono PERC module LR6-60BP-300M consistently ranks as top performer in the outdoor test energy yield ranking (see page 98-99).

As Zhong makes clear, the manufacturer has even bolder ambitions than being master of the mono field. The key phrase to understand this is "solar for solar." It means using clean energy to power the plants that churn out wafers, cells and modules. Longi is no newcomer here and already boasts production facilities in Yunnan, China, and Kuching, Malaysia, which mainly rely on hydropower. "Solar for solar" goes one step further and envisions PV manufacturing relying exclusively on clean PV electricity.

We also addressed the development of Longi's home market, China, and the rollercoaster it has been on in 2018 and 2019. Zhong takes an optimistic view, seeing 35 to 40 GW as realistic this year and a corridor of 40 to 50 GW emerging for 2020 and beyond. China's policy environment has moved away from outright subsidies (the initial Golden Sun program, followed by the PV FIT program) to a model where auctions are the norm, be it China's Top Runner program or the latest FIT model. In addition, the Chinese government has singled out "grid parity projects" as deserving special support, and Zhong anticipates that the first batch of these projects – amounting to just under 15 GW – will be built already by the end of next year. If Longi and other Chinese PV manufacturers (some of which have formed strategic partnerships with Longi) continue to innovate and increase efficiencies, grid parity and not auctions could become the norm not only in China, but around the world. And if these projects are also thoroughly green and sustainable, so much the better.

Eckhart K. Gouras

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Southeast Asian manufacturing, bifacial technology to drive ET Solar's resurgence

With new manufacturing facilities in Vietnam and Cambodia, a revitalized organization in the United States that is quickly racking up hundreds of megawatts in sales, and a portfolio of innovative products to serve both the on- and off-grid markets, ET Solar's resurgence is taking shape in 2019.

ET Solar has unveiled a new manufacturing strategy that looks set to position the company well to serve both established and emerging PV marketplaces. And success is already coming in the form of large orders from prestigious companies – with its stellar performance in the U.S. market over the last six months demonstrating the effectiveness of its new direction.

> *"Success is already coming in the form of large orders from prestigious companies"*

Only six months after putting a challenging period in the market behind it, ET Solar reports that it has signed more than 500 MW of U.S. module supply contracts. California-based ET Solar Inc. began making inroads into the U.S. marketplace in March.

ET Solar says it has signed more than 500 MW of module supply contracts for projects in the United States over the past six months.

Photos: ET Solar

The company reports that in the following five months, it racked up more than 500 MW in module supply contracts. This includes 400 MW to be delivered in the second half of 2020.

"We are back," stated Alex Chen, the head of sales and marketing for ET Solar USA. He says that most of the 2020 orders are for the company's half-cut mono-PERC products – both bifacial and monofacial versions. These are likely to be produced in the company's new cell and module factories in Vietnam and Cambodia, the first of which is scheduled to come online in the fourth quarter of this year.

ET's bifacial cells and modules benefit from the recent exemption for bifacial products from the Section 201 tariffs. Its Elite bifacial half-cut modules carry a 30-year output warranty, in addition to a 10-year product warranty, with power ratings of 375-395 W for its 144-cell ET-M672BHXXXGL series.

"I think the most important thing is customer service," said Chen, noting that in addition to the longer warranty, the company has an internal system for risk management in product delivery.

There could be a lot more business where this came from. With its current sales pipeline, the company expects to supply 800 MW of modules to the U.S. market in 2020. And under its current expansion plans, it also expects its factories in Southeast Asia to reach a capacity of 2 GW of cells annually in early 2020.

Made in SE Asia

ET Solar Technology (Vietnam) Co. Ltd. was established in July, and the company says it will start production at its new facility in the country by the end of this year. A new plant is also expected to come online in Cambodia later this year.

"The new facility in Vietnam will be manufacturing mono PERC, bifacial cells," said Chen. The company plans to have 500 MW of cell production online at the new location by the end of this year.

ET Solar's Elite bifacial half-cut modules feature a 30-year output warranty, in addition to a 10-year product warranty, with power ratings of 375-395 W for its 144-cell ET-M672BHXXXGL series.

In Cambodia, ET Solar is establishing 300 MW of manufacturing capacity for both cells and modules. "The module line will produce mono, poly, half-cell and dual glass bifacial," Chen explained.

Beyond modules, ET Solar is also rolling out a host of innovative end-user solar products. These range from smarthome solutions including solar and storage, having equipped more than 1,000 homes with clean energy solutions – including a 3.3 MW rooftop project in Yorkshire, United Kingdom, The company is even providing an array of off-grid kits – which are well suited in emerging PV markets such as Africa and South Asia.

From portable solar chagers through to lamps, backpacks, freezers, fans, streetlights and televisions, ET Solar has shown a willingness to embrace innovation and spread the benefits of PV far beyond the reaches of the electricity network. The company launched its African operations, based out of Kenya, this year.

In India, which along with the United States, Japan, and Europe has been selected as a strategic end market for ET Solar, the company is understood to have confirmed a 100 MW order – a significant milestone in a solar market where long lead times can be common.

Innovative and high prestige projects are a feature of ET Solar's track record. Recent highlights include a 60 MW supply deal to provide power to an Apple data center in the U.S. state of Nevada, an 80 kW (AC) module project at the Harvard Business School, and a 315 kW floating solar project in Fukuoka, Japan – where microinverters from NEF Power have ensured that DC cabling is minimized at the installation, ensuring safety.

pv magazine

"We are back," stated Alex Chen, the head of sales and marketing for ET Solar USA.

Supplying an exponential

While solar's competitive position in the global energy mix has never looked more promising, the manufacturing segment remains ruthlessly competitive. Since joining the industry in late 2018, Heraeus Photovoltaics President Martin Ackermann has come to believe that the silver paste provider needs to be close to its customers in order to find refuge from race-to-the-bottom pricing in the face of rapid technological change.

Welcome to the PV industry. Now that you've had some time to settle in, what do you make of the sector?

When I was offered the job, I took only one hour and 15 minutes to say "yes." From an industry perspective it is very exciting. I think the industry at the moment is at a phase, from a cost perspective, [where] solar power is very close to becoming "the" energy source for the planet. With all of these discussions that we are having about technology, politics, climate change and things like this, we are in a very interesting phase. The other point that I like – I am a very competitive guy, and this industry seems to be very competitive.

What has surprised you?

I would say the exponential innovation rate. In the last couple of years there has been a lot of innovation, a lot of advancements. But in the last two years alone, the rate of innovation has been almost as fast as the previous six. And it can be expected that an innovation rate like this will continue. This has also had a huge impact on us – how we needed to operate, invest in the market, and then to ask, "how can we sustain the pace and continue to collaborate with our customers?" It brings implications for our organization.

The cell production landscape is evolving quickly, requiring weekly innovation from material suppliers.

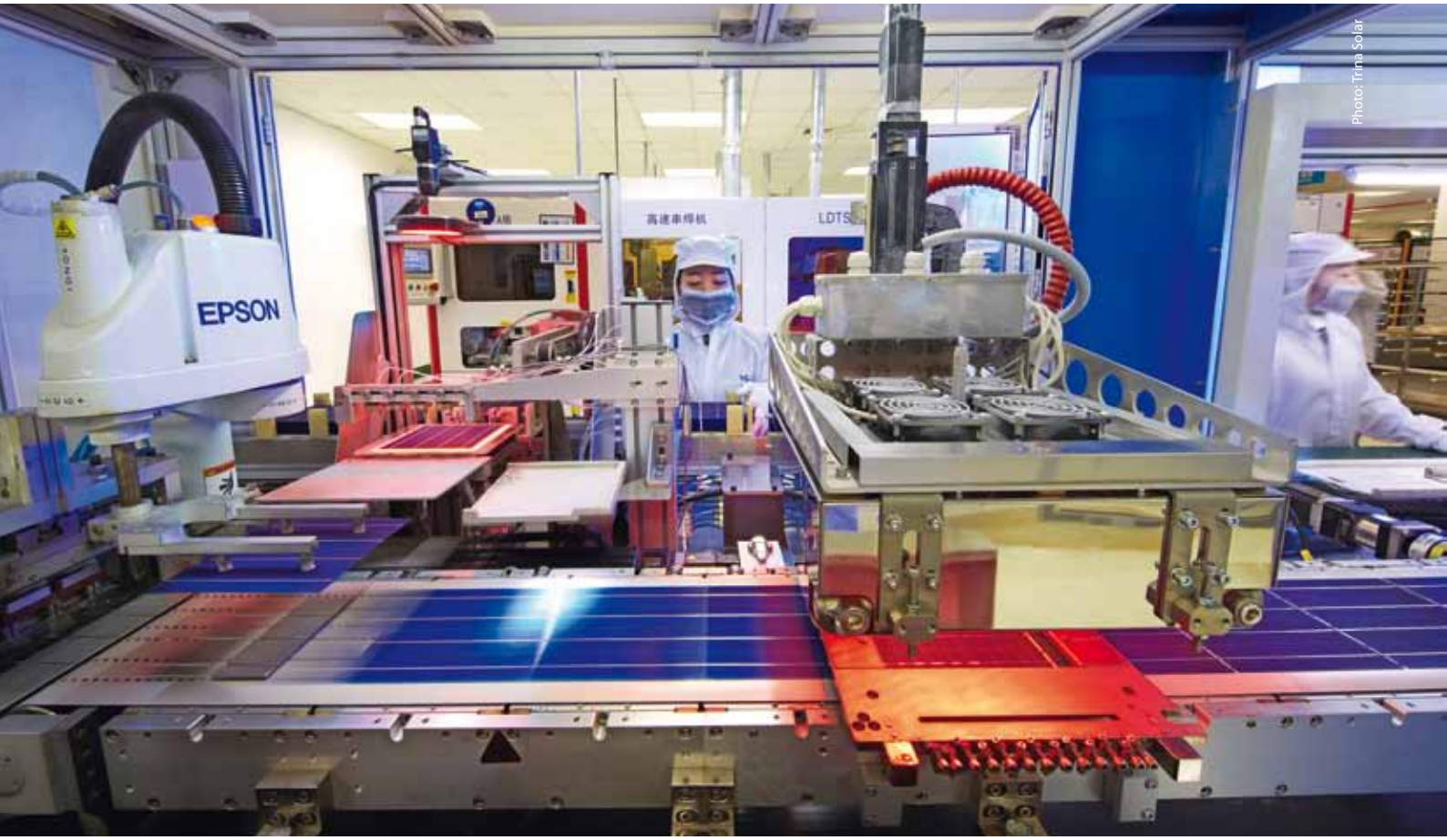


Photo: Trina Solar

rate of innovation

Before we can play that role, I had to clarify the [internal] situation and ask whether solar PV was an important pillar for Heraeus. We then got the continued commitment reconfirmed and it is really a great inspiration to take it forward. That is why you can see the smile on my face: PV is a competitive environment, a very exciting market, a very exciting technology, a market at a very interesting stage, and has good backing from the [Heraeus] group. That is actually something with which you can progressively go forward.

How can Heraeus respond to the rapid rate of technological change?

When you go back a few years and look at how Western companies operated in China, it was more like a hub. There were a lot of activities going on in Europe or in other places, and there was also something here in China. Now, 70-75% [of cell production] is here in China, 15% in Southeast Asia, and then 9% elsewhere. And in order to continue to develop you need to be very close to the customers. You can't do that as an add-on, or with some hubs in between. Discussions can't go back and forth again.

We have actively changed the company to become very much local. I employ more people in China than any local competitor. It is very much, from that perspective, about being where the markets are – and that includes Southeast Asia and places like Singapore. We have an American research center that will continue more long-term development on next-generation PV technologies such as HJT or perovskite cells.The changes that we need to make, drive and adapt to – it's not about releasing a paste at certain set times – that's not how it works today. What we need to do is release the foundation of a paste, and at that second design it in with a customer. You already start an ongoing development process with this paste, with the customer.

There are also variations that did not occur in the past. As manufacturers invest in new lines there are differences between lines. There can be a combination of old and new machinery. The paste then doesn't necessarily work on line one as it does on line two. Now what we see is that the customer demands an upgrade every week. Honestly, I am really saying every week because they really push us to try out new stuff – not on a monthly basis, but more like tomorrow or the next day.

The willingness to experiment is also changing as people in China are pragmatic in that they have an idea and are willing to try it out and then make adjustments. So, there is much more interconnection. We have changed our entire sales and interconnection approach in how we handle R&D with the customer.

Technological development is important. But can Heraeus compete on a cost level?

Now you raise an interesting point. Price is not necessarily just the fab price. Modules are still sold on performance, so on watt/peak basis. You can see the race towards higher power outputs. We are already well above 400 W on a module basis, and now everyone is racing towards 500 W. And we will get there. Talking with cell and module manufacturers, this could potentially happen already by the end of 2020.

This dynamic is actually helping on the price front. If you can help manufacturers to achieve a higher efficiency without necessarily increasing the silver component or even by decreasing by using smaller finger openings, by decreasing the laydown, then you can help your customers to compete in this business. This means that you don't have to compete purely on a price tag when it comes to volume or fab.

Nevertheless, you need to be as lean as possible. Heraeus Photovoltaics is an organization, as we have figured out, that needs to be very strong and dominant from an R&D perspective, but at the same time we have to be as lean as possible in order to stay competitive. Maybe in the past this was not so pressing. Maybe in the past it was easier to stay in the higher efficiency segment. But this is not the game that will continue in the future – you need to be very efficient and very lean in everything you do. And you still need to have a very good R&D capability.

Interview by Jonathan Gifford

Photo: pv magazine/Dave Tacon

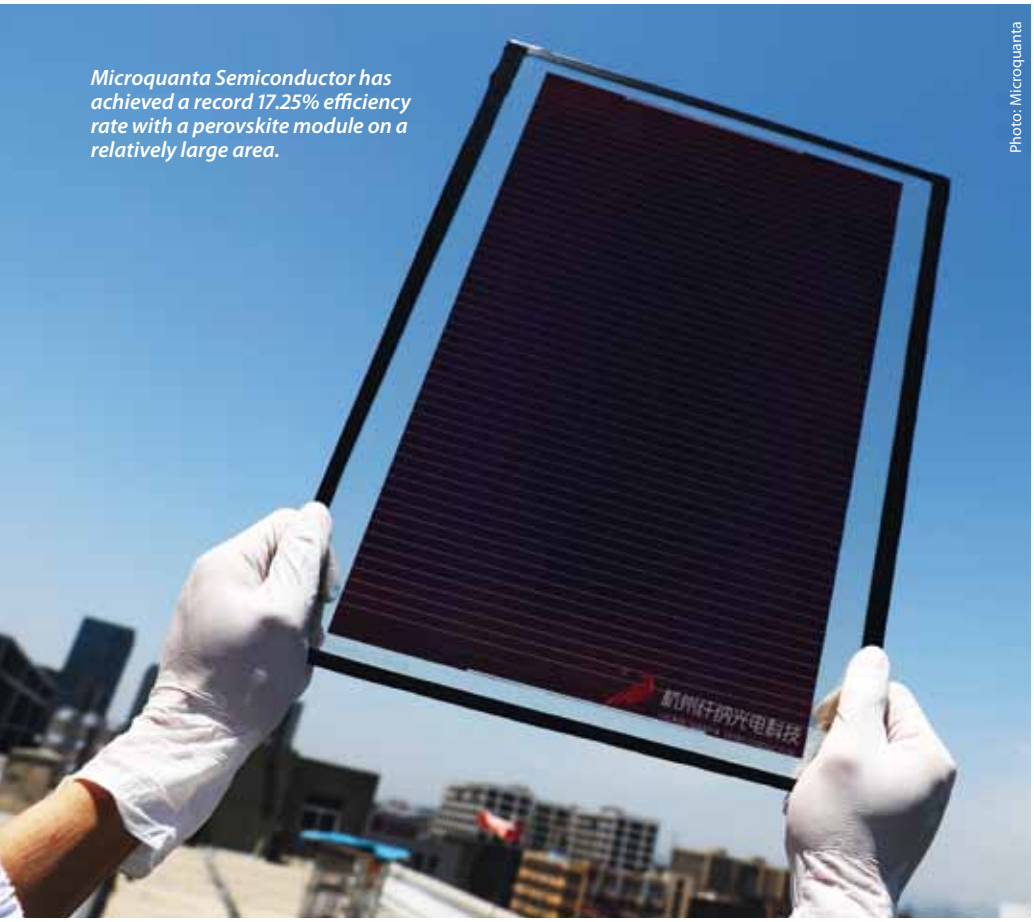
Heraeus Photovoltaics President Martin Ackermann previously served as the CEO of Heraeus Infosystems GmbH and as the chief information officer of the Heraeus Group. He joined the company in 2005.

> *"You need to be very efficient and very lean in everything you do"*

Perovskites hit the

Microquanta Semiconductor holds a 17.25% efficiency record for a relatively large-area perovskite module and wants to build a production facility with fresh capital from investors. pv magazine takes a look at the Chinese startup and some of the basic questions surrounding the technology.

Buyi Yan does not lack self-confidence, as he showed during a recent discussion at SNEC 2019 in Shanghai – and perhaps with good reason. Largely out of view of the Western world, Microquanta Semiconductor – which Yan co-founded four years ago in Hangzhou, China – has set an efficiency record for a perovskite module, and not just with a small laboratory sample. It achieved a 17.25% efficiency rate with a module that was 16 cm long – an impressive scale, as confirmed by external examiners at the Newport PV Laboratory and published in the ongoing efficiency list in *Progress in Photovoltaics: Research and Application*, a scientific journal.



Microquanta Semiconductor has achieved a record 17.25% efficiency rate with a perovskite module on a relatively large area.

Photo: Microquanta

Now Yan and his co-founders, Yao Jizhong and Yang Yang, want to take the next step: a multimillion-dollar funding round, quickly followed by a production launch – just like European perovskite startup Oxford PV. And they're going all in.

The first line is set to come online next year with a capacity of 50-100 MW. Three more lines will follow as the market develops. "Before expanding production, we have to prepare the market for this product," says Yan. "We need to realize some demonstrations – there will probably be five projects by the end of 2019."

If this occurs, perovskites will have developed into a product in just 11 years. The material began to attract attention from scientists in 2009, when a team led by Tsutomu Miyasaka at Toin University in Yokohama, Japan, achieved 3.8% efficiency with a perovskite cell. After that came rapid advances; first in efficiency, then stability, and now in production. But there are questions as to whether this pace has been too rapid, and the young technology still has challenges to face.

Learning from experience

Even when half the industry is caught up in technology fever, its assessments can often be wrong. At the end of the last decade, countless thin film silicon factories were built, amid hype that it was the technology of the future. Today, virtually all of them have ceased production, as the modules were far too expensive.

Yan believes such a failure will not be repeated with perovskite. The thin film technologies that survived, such as cadmium telluride, have managed to keep pace with the cost reductions of crystalline silicon. The less fortunate ones could not keep up, because the efficiency increases were too low and they used expensive materials.

"Perovskite was born with a much lower materials cost, unmatched by crystalline silicon, because of the way the materials are synthesized and processed," Yan says.

Another lesson he has drawn from thin film solar is that "good PV technology must not stay in the lab for too long until it's just right, it needs to hit the market

home stretch

once the major pieces are in place." And he believes that this is now the case.

In the end, production costs are crucial, of course. But Yan is reluctant to venture a public statement on this. "The figure depends a lot on production capacity," he says. "We don't have an accurate number right now because there aren't enough data from a production line."

Many other experts are also working to estimate what it will ultimately cost to successively deposit layers of perovskite, conductors and transparent conductive oxides onto glass, then laminate it and then turn it into a workable product. One such individual is Jan Christoph Goldschmidt, head of the Innovative Solar Cell Concepts group at Fraunhofer ISE. He says the estimate depends on a number of assumptions, such as efficiency and service life. "If you could achieve comparable values to a silicon module – that is, 19% efficiency and 25-year service life – a perovskite module would probably be cheaper than a silicon module today," he says.

Costs currently sit at roughly $30 per square meter, whereas silicon modules cost around $50 per square meter, Goldschmidt adds. The scientists use this unusual metric because, unlike crystalline silicon, the size of perovskite cells is not determined by wafers.

Critical questions

Anyone who makes a serious announcement about setting up perovskite production is asking skeptics to pose two further questions: Is the material stable? And how unfavorable is it that lead is needed in the layers? Microquanta has already subjected 6x6 cm mini modules to damp-heat and thermal-cycle tests, as defined in the IEC61215 standard. "And these mini modules passed each subtest accordingly," with an efficiency similar to that of the record-setting module, Yan says.

This is indeed a huge step forward compared to the stability findings that scientists were publishing a few years ago. At that time, the cells were simply destroyed by exposure to light. "This view that perovskite solar cells are not particularly stable has been shaped by cells that use methylammonium lead iodide as a perovskite absorber," says Goldschmidt.

The methylammonium iodide is very volatile. It evaporates easily, so the corresponding perovskite is a very unstable material. In addition, he notes that the solar cells had a layer of titanium dioxide. If you irradiate that with UV light, it can trigger a chemical reaction.

"Once these two materials are replaced, the solar cells are much more stable," says Goldschmidt. In addition, the electrode layers, transparent conductive oxides, and buffer layers protect the cell from the surrounding air and oxygen. So it looks as though the stability problem can be solved.

However, damp-heat and thermal-cycle tests are not the only challenges. In the end, products have to pass all of the tests of the IEC standard, while possibly accounting for new degradation mechanisms. Philippe Holzhey and Michael Saliba looked at the situation last year in an article in the *Journal of Materials Chemistry*. There are promising results for thermal-cycling, damp-heat, outdoor and UV-light tests, they write, but little work has been done on mechanical, reverse bias, high-voltage and humidity-freeze stability.

Lead content

Yan also wants to dispel concerns about the technology, since most of today's perovskite modules contain lead. "I think it is normal for people outside of the field to regard lead as a point of concern, and I think that people working in this field have an obligation to explain why such concern is misplaced," says Yan. After all, it only gets into the environment if modules are not properly recycled at the end of their service life. Yan also notes that the perovskite layers are thin, with less than 400 mg of lead per square meter of module. He claims this is significantly less than levels in soil, if one considers a square-meter layer.

This is confirmed in principle by Helmer Schack-Kirchner, a soil ecologist at the University of Freiburg. One square meter of the upper 25 cm soil layer consists of roughly 375 kg of dry matter. If we assume that a perovskite module is not recycled, the encapsulation is destroyed

"Damp heat and thermal cycle tests are not the only challenges"

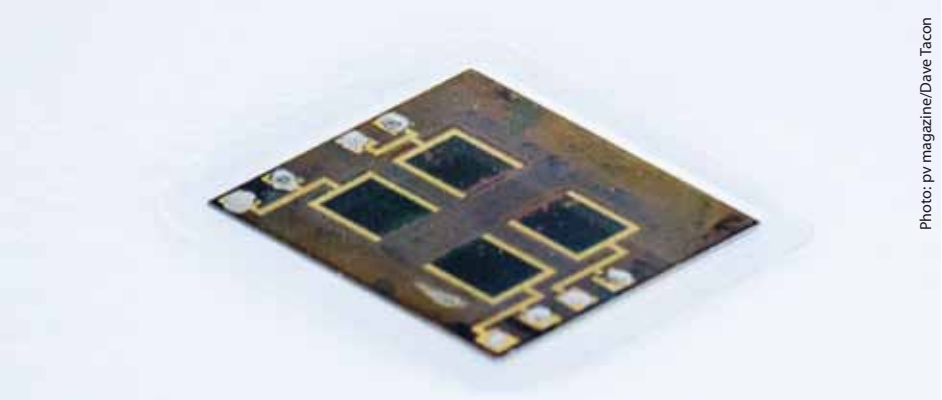


Photo: pv magazine/Dave Tacon

A perovskite solar cell developed by Fraunhofer ISE. Jan Christoph Goldschmidt, head of the Innovative Solar Cell Concepts group at Fraunhofer ISE, says that there is a good chance that perovskite modules would be cheaper than silicon panels if they both had comparable values – that is, a 19% efficiency rate and a 25-year service life.

> *"Those who think this is just a pipe dream ... would be mistaken"*

and water washes out the lead, a concentration of 1.1 mg/kg would be added to the topsoil. According to the *Geochemical Atlas of Europe*, this is 20 times less than the 22.6 mg/kg found on average in the 843 soil samples examined for this purpose across Europe. It's also below the 3-6 mg reported in the atlas for sparsely populated areas. It is also just a tenth of the threshold value for sandbox sand in Germany, which is subject to the most stringent requirements.

So is the lead harmless? Well, not exactly. Keeping lead content as low as possible is a generally accepted goal, and therefore the element may only be contained in products under the European RoHS Directive with special approval. And there are silicon modules that do not contain lead. Whether and where lead is acceptable in new technologies ultimately will be a socio-political decision that balances the advantages of a cheaper energy supply and perhaps a faster energy transition against the disadvantages that could arise in the event that the modules are not disposed of properly.

"Scientists are therefore not in a position to answer the question of whether lead should be accepted in this application," says Schack-Kirchner.

Early days

Microquanta Semiconductor can hold its own when it comes to startup stories. Yan says he and his two co-founders, who met while studying at Zhejiang University in Hangzhou, recognized the potential of perovskites as early as 2012. At the time, Yan was doing his master's degree at King Abdullah University of Science and Technology on quantum dot applications in photovoltaics, while Yao Jizhong was at Imperial College in London, working on organic and hybrid solar cells. "I called Yao and said, 'let's start something,'" Yan recalls. The local government of Hangzhou liked the idea and helped them with a startup program, by providing the company's first office and introducing them to potential investors. Yang Yang later returned from his Ph.D. at UCLA, became a professor at Zhejiang University, and joined the group.

They officially founded Microquanta Semiconductors in 2015. Two years later, Insigma – an incubator that also emerged from the university – entered the market with CNY 60 million ($8.5 million) of funding. The money that will now go into setting up production facilities comes from Three Gorges Capital. Yan has estimated the total at tens of millions of yuan.

From the outset, Microquanta has relied on inkjet printing technology, not only for the perovskite layer, but for as many of the layers that make up the cell as possible. "Because these layers are not independent, the device architecture, including all layers, is regarded as an important focus of our R&D efforts," says Yan. He considers printing technologies particularly cost-effective. Since they print at temperatures below 200 degrees Celsius, capital and operating costs are lower than with the vacuum-coating technologies used by other companies. Although the substances are more exposed to environmental factors during printing, they have been tried and tested in other industries. Microquanta Semiconductor currently prints on an area of 30x40 cm. On the production line, the size will be increased to one square meter.

To transform the coated surface into a module, the coating is separated into parts which are then interconnected, as with other thin-film technologies. The process is known as monolithic interconnection. The record-setting module consists of seven cells. But at 17.25% efficiency, the full potential has not yet been tapped, says Yan. "There is still plenty of room for improvement."

Those who think all this is just a pipe dream for perovskite afficionados would be mistaken. A number of crystalline silicon cell manufacturers are interested in the technology or are already actively working on it. They are motivated by the prospect of being able to make further advances once all the other improvements planned for silicon have been exhausted in a few years' time. pv

Michael Fuhs

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In leaps and bounds

Policies, non-government initiatives and market forces have started driving the adoption of more rigorous quality-assurance practices in Indian PV project and module manufacturing this year.

"We have seen remarkable improvements"

There is good news to report about module and installation quality in India: Things are on the up. But the work on quality never ends, and the National Solar Energy Federation of India (NSEFI) continues to work on developing and deploying best-practice quality guidelines for PV asset management and solar project development.

"For context, this is the joint project between Solar Power Europe and NSEFI," explains Subrahmanyam Pulipaka, the CEO of NSEFI. "What we are trying to do is get the best practices from an Indian context, using the SPE guidelines and adapting them. The first part is done – we have identified our reference points from the SPE report; identified the areas in the Indian context that need to be addressed; and we are now in the consultation period regarding our members."

As the guidelines take shape, Pulipaka reports that a number of quality issues that had risen to prominence in the Indian market are now being addressed. In 2018, independent engineering provider PI Berlin carried out and publicized a study of six PV projects in India. It found that a host of quality concerns were evident. In particular, problems with module quality were detected, as well as damage from incorrect handling. And component selection was rarely made with local environmental conditions in mind, leading to corrosion, failures and faults.

PV project components with materials unsuited to environmental conditions were among the faults that PI Berlin identified in 2018.

Photo: PI Berlin

"We have seen remarkable improvements, or rather increased emphasis, on particular aspects of project quality," says Pulipaka. "The wiring and cabling was one of the main things raised by PI Berlin. This can now be seen to have been improved, including the use of underground ducting ... Usually, we can proudly say [that] we are on par with our Western counterparts."

Falling prices

One of the drivers behind the improvements in project quality is tighter project revenue streams, says the youthful CEO of NSEFI. While race-to-the-bottom pricing and bids may put pressure on supply chains, less generous feed-in tariffs or PPAs mean that maximizing power output over time becomes a priority.

"Every unit [of power] matters," says Pulipaka. "When the tariffs were high, the Indian market was in a nascent stage. Today we are at a very good stage to understand and react to the importance of quality."

Improvement has also taken place with regard to quality in Indian manufacturing, reports Rajaram Pai, DuPont Photovoltaic Solutions' business leader for South Asia and ASEAN. He says that among "the larger" Indian manufacturers that DuPont works with, many are reporting high utilization rates, with project developers opting for a blend of locally produced and imported modules.

"A lot of the developers feel comfortable to lock in volumes from the Indian guys," says Pai. "The production is right in front and you can actually visit the facilities." He says that another influence on the embrace of Made in India modules is that the quality gap between homegrown and imported panels is closing.

"Years ago it was pretty different because there was a much larger differential, and there were not the safeguard duty restrictions," Pai says. "The disparity in the wattages and the quality of modules [between Indian and imported] was quite glaring."

The DuPont representative says that improvements in Indian manufacturing emanate more from a better general understanding of quality, through to upgraded equipment on lines, in-line inspection, more scrutiny of material quality and the benefits of higher line utilization.

BIS steps in

On the policy level, the development and application of Bureau of India Standards (BIS) for solar PV manufacturing and testing has played a key role in boosting quality on Indian production lines. One positive aspect, says DuPont's Pai, is that it has made manufacturers wary of switching module Bill of Materials (BOM), due to the related certification costs.

"It has deterred those people supplying sub grade materials," he explains.

On the other hand, there is still room for the BIS to more comprehensively integrate the harsh environmental conditions of India into the standards regimes, rather than replicating existing IEC regulations.

Last year, PI Berlin engineers noted that while environmental conditions such as salinity, high UV levels, humidity, heat, sand and strong winds are often experienced by PV project developers, "in several areas of India PV projects often face a large number of these factors at the same time."

There is also a need, adds Pai, for more testing facilities that are qualified to carry out BIS testing and certification. He notes that there are numerous "prestigious scientific institutes in the country" that could carry out such tests. By expanding the number of accredited testing facilities, Pai concludes, India could accelerate the certification process for new materials.

Jonathan Gifford

Photo: pv magazine

Rajaram Pai: "A lot of the developers feel comfortable to lock in volumes from the Indian guys."

NSEFI CEO Subrahmanyam Pulipaka will co-moderate **pv magazine**'s Quality Roundtable event at the Renewable Energy India Expo on Wednesday, Sept. 18 in New Delhi (Greater Noida), alongside **pv magazine**'s Jonathan Gifford. The two will lead a stakeholder discussion on NSEFI's O&M and project development best-practice guidelines, as well as a discussion of quality in manufacturing. See page 120 for more details.

High power, maximum dynamic efficiency, reliability come together

Building on a 90 GW track record in the wind sector and a growing installed base in the global PV market, Madrid-headquartered Gamesa Electric is bringing a new range of utility-scale power electronics devices to the U.S. market. Driving down LCOE with high performance and highly reliable products is the company's secret sauce, says Enrique de la Cruz, solar and storage sales director at Gamesa Electric.

Photos: Gamesa Electric

Enrique de la Cruz: "We have a strong focus on reliability… In the end, the customer benefits."

Why is it that you believe that Gamesa Electric is positioned to supply the fast-moving U.S. market with its utility-scale inverters and battery storage products?

The United States is simply one of the largest global marketplaces for PV and is probably the leading market for battery storage – as of today. It is also a fast-growing market. So, for a company like Gamesa Electric that has put in place a very ambitious strategic plan in both PV and storage, it is a must to be in the United States.

Why is it that the United States has become the leader in terms of large-scale battery storage deployment?

Based on what we know and what we've heard from customers, there are few countries in the world that are as advanced as the U.S. in terms of storage. Together with the U.K., some other European countries, and Australia, the United States is in the leading position for battery-related projects on a megawatt scale.

How are you supplying megawatt-scale storage?

Gamesa Electric's approach for the storage market considers two main sales channels and scopes for standalone or co-located businesses: The first is our battery energy storage system (BESS) turnkey solution. This option includes whole BESS procurement and scope: power conversion system (PCS) plus AC container, batteries and DC containers, and the energy management system (EMS). This supports the building and integration of whole systems. PCSs and EMS are designed and manufactured in-house, while batteries and DC containers are outsourced with different alternatives/technologies/suppliers. The second is supplying the PCS power station. Our product portfolio for energy storage has been structured accordingly. In that sense, the design of Gamesa Electric's PV inverters is flexible enough to easily turn them into a PCS. Furthermore, the inverters are bidirectional, allowing PV power plants to be configured as part of a BESS in DC (through a DC-DC converter) and AC coupling topologies.

You mentioned DC coupling through a DC-DC converter. The advantages of DC-DC storage are becoming better understood – is that the thinking behind the Gamesa Electric Stor DC-DC500?

Definitively. Gamesa Electric's product portfolio for storage applications intends to support all of our customer's necessities. Related to this point, there are several U.S. states in which using a DC-DC converter device improves eligibility for the ITC [Investment Tax Credit].

Apart from that, Gamesa Electric Stor DC-DC 500 contributes to maximizing our customers' revenues, because it allows to shift otherwise clipped PV energy, increasing overall PV plant output. Our DC-DC converter gets capex optimization by using existing PV plant hardware (PV inverter/station).

Moreover, in terms of flexibility, our DC-DC converter is fully compatible with different PV panels and battery technologies from a range of suppliers. It has a modular design which is scalable up to eight units in parallel, and it is straightforward integrated with our PV products for the U.S. market – the PV 3400U inverter and Electric PV Station 3400U.

The UL-certified PV 3400U comes in at 3420 kVA. It will be available in the U.S. market, along with the plug-and-play PV Station 3400U, in Q3 and Q4 2020.

On a slightly more technical level, my understanding is that the EMS plays an important role in optimizing the battery cell charging, discharging and cycling – to ensure that degradation doesn't occur before it should. Is that right?

Sure, this is correct. It is not a combination of different elements working isolated from each other. The added value that Gamesa Electric brings is a deep knowledge of power electronics, and the integration of systems into the electricity network.

At Siemens Gamesa Renewable Energy, our parent company, we have deep knowledge in the wind sector. We have vast experience in connecting renewable energy to the network and doing it correctly. Batteries are a new element, but the technology is well known and the optimization of the control of the different elements is one of the added values that we bring – and it's a key element for the performance of the plant and the confidence of the financiers in the end.

Looking purely at power conversion now – you'll introduce your new inverter platforms, the UL-certified PV 3400U and PV Station 3400U, at SPI 2019. What advantages will they offer project developers in the U.S. marketplace?

These two products being presented at SPI represent the same value proposition that we have had in our company for many years: optimization of the levelized cost of energy. Now we are bringing the power up to 3.4 MW, making it one of the largest central inverters in the U.S. today. That will allow customers to optimize the number of units and the capex to be improved.

Opex is also reduced by these new products. They have been designed with best-in-class components and reliability is very high for many reasons. Finally, this new PV inverter has arrived with high DC/AC ratio and the top efficiency – and not only the electric efficiency, but also maximum power point tracking (MPPT) efficiency at both static and dynamic states.

Our inverter includes an enhanced algorithm to optimize the MPPT efficiency, which is a critical element. And I am proud to say that the dynamic efficiency of our inverters is one of the best of the world – pretty close to 100% efficiency. This has been measured and certified by third-party independent laboratories.

> *"Products to be presented at SPI represent the company value proposition: LCOE optimization"*

You mentioned the DC/AC ratio – we've already begun to see projects in some U.S. states with very high DC/AC ratios. How does the 3400U meet this need?

Effectively, higher power modules and especially bifacial modules (which are nowadays the standard for the U.S. market), points to the need for higher DC/AC ratios for PV inverters. This requirement is a major constraint/disadvantage for most string inverter suppliers, in comparison to central ones.

The Gamesa Electric PV 3400U central inverter is ready for bifacial modules, providing a high DC/AC ratio up to 2 (200%) and fulfilling international standards (IEC 62109). This last part is critical to guarantee a real high DC/AC ratio and therefore a higher production/yield value.

Interview by pv magazine

Lead-free PV

Should lead still be used in solar? Are there realistic alternatives? These are the questions pv magazine is seeking to answer throughout the fourth quarter of 2019, as part of our newly launched UP sustainability initiative.

Lead (Pb) is a hazardous element which poses threats to both the environment and human health. It has been phased out of many products since its toxicity was recognized in the late 19th century. Yet the majority of solar modules still employ the heavy metal, and its usage is not set to decline any time soon.

Of the more than 500 GW of PV deployed globally, the Fraunhofer Institute for Solar Energy Systems calculates that approximately 95% comprises crystalline silicon (c-Si) modules. In 2019, another 100 GW of PV is on track to be installed, and the majority of that will again consist of c-Si technology. According to one 2011 study, presented by the European Commission for an updated Waste Electrical and Electronic Equipment (WEEE) Directive, the average c-Si panel at that time contained approximately 12,672 mg of lead.

The material is found primarily in the solder and metallization pastes of panels. But Dustin Mulvaney, an associate professor in the Department of Environmental Studies at San José State University, says the glass – which covers approximately 80% of the panels – also contains impurities like

SunPower is one of the only manufacturers to avoid using lead in its solar panels. How does it still deliver on price and performance? Are there lessons for other manufacturers to learn? These are some of the critical questions the UP initiative aims to answer.

Photo: SunPower

lead and antimony, meaning it cannot be recycled for solar use again.

While the leaching of this material in traditional c-Si panels is said by many to be of minor concern – mainly because it occurs in trace amounts – the recent popularity of lead-heavy perovskites, which are expected to enter into mass production within the next two years, has potentially more significant consequences for the industry. As Michael Fuhs writes in his article, "Perovskites from the lab, into production," (pp. 82-84), the most efficient perovskites contain lead, with levels that may be as high as 400 to 1,000 mg per square meter. Consequently, there is concern about the conditions under which it can leach out in, as well as the impact this leaching could have on the environment.

Lingering questions

It is possible to manufacture PV panels without lead, as U.S.-based SunPower, Japan's Mitsubishi and Sharp, and the now insolvent SolarWorld in Germany, have demonstrated. However, it is not common practice, with the vast majority of manufacturers using lead in their production processes. Why do so many choose a lead-lined pathway? Are there more sustainable alternatives that could be a viable option for the whole industry? And under which conditions can lead be justified?

The global deployment of so much PV is an impressive feat and one that is critical for the renewable energy transition. However, it is essential to consider both future waste volumes, and the materials employed. Can all modules be safely retrieved in all geographies (many of which do not have mandatory waste disposal regulations for solar) and, continually reused? Even if the small amounts of such hazardous elements as lead are "harmless" when considered on an individual level, is this still the case when much larger quantities come into play?

Questions like these are what **pv magazine's** UP initiative seeks to address. Launched in May of this year, it aims to effect truly sustainable action in both the solar and storage industries.

"The vast majority of manufacturers use lead in their production processes"

From now, each quarter will focus on a new topic. The first, starting next month, will look at the use of lead in solar. To kick off the discussion, the October edition of **pv magazine** will go back over the history of the debate surrounding lead in modules. Over the coming three months, we will ask why it is still used and explore possible alternatives. Contact up@pv-magazine.com to join the conversation.

Becky Beetz

Join UP!

pv magazine is proud to announce SMA Solar Technology AG as our UP initiative partner for inverters. SMA CEO Jürgen Reinert explains the company's motivation behind their support of the initiative: "It is important for each company to report on its own its sustainability measures based on internationally respected standards. But it is also important to report in a campaign on what is done in the industry. I am well aware that not all companies in the industry share our strict views on sustainability, but I think that the UP campaign will stimulate them to rethink their approach. I am convinced that our sustainability engagement will pay out as sustainability becomes ever more important with customers and society – and I think that this is a good sign for the future."

Contact sales@pv-magazine.com to explore how you too can join UP.

Sustainability Award

The window for submissions to **pv magazine**'s first annual Sustainability Award is now open. Has your company managed to reduce emissions, energy use, water and/or waste, for example? Or are you actively involved in the circular economy? You have until Oct. 1, 2019, to submit your story and evidence, for your a chance of being crowned a true sustainability pioneer. Visit www.pv-magazine.com/pv-magazine-annual-awards, or contact award@pv-magazine.com for more details. An independent jury, including Jenny Chase – head of solar analysis at BloombergNEF – will select the winners, which will be unveiled in December.

PV manufacturing: The rise of India

With 11 GW of solar module production capacity, investments in technology, and a focus on skills development, India is quickly emerging as the world's next solar PV manufacturing hub. And the country's "100 GW by 2022" target is encouraging local manufacturers to scale up further. RenewSys – India's first integrated manufacturer of solar PV modules, as well as key components such as encapsulants, backsheets and cells – has already made its mark throughout the world as an innovator by actively investing in European machinery for its manufacturing facilities, while remaining committed to material innovation and rigorous testing to ensure quality.

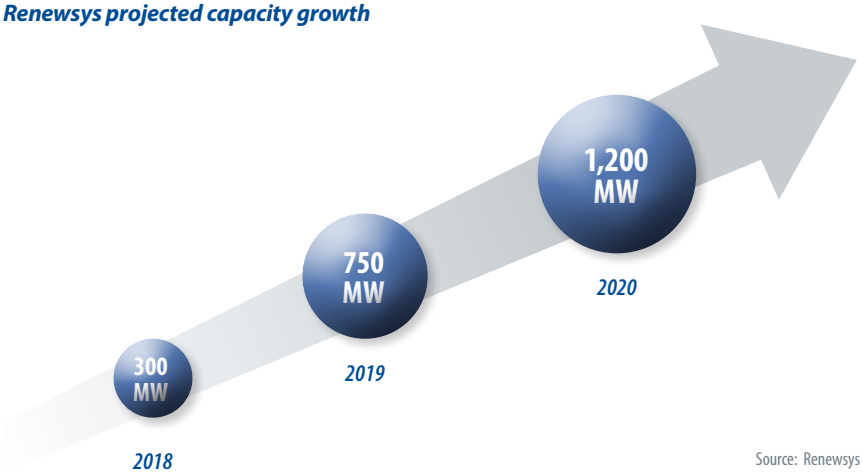
The Energy and Resources Institute (TERI), a New Delhi-based think tank, estimates that the Indian solar sector will require 12 million tons of materials by 2030 to supply the 170 GW of solar PV capacity that's set to be installed. Given this scale, it is imperative for India to develop its own supply chain for solar, extending right across the value chain.

But Indian PV manufacturers are not only supplying their country's solar sector. Those that can meet international quality standards, develop innovative technologies, and provide first-rate service have a

International recognition for RenewSys quality and technological innovation has come in the form of international orders to supply significant projects, including this 500 kW rooftop array in Johannesburg, South Africa.

Photos: Renewsys

Renewsys projected capacity growth



Source: Renewsys

very real opportunity to become key suppliers of the global solar sector.

RenewSys – India's first and only integrated manufacturer of solar PV modules and key materials – stands out as an emerging player among a select group prospering in markets at home and abroad. RenewSys has successfully scaled up in a very short time, and has developed two innovation hubs for ploymer and silicon materials accredited by the National Accreditation Board for Testing and Calibration Laboratories in Bangalore, and Inertek in Hyderabad respectively – a first for an Indian company.

Ensuring quality

"India has emerged as a leading destination for solar manufacturing because of high quality and reliable PV modules and components," says Avinash Hiranandani, managing director of RenewSys India. "Indian manufacturers are now operating at larger scales, fulfilling bigger orders at economies of scale."

RenewSys – with 750 MW of module manufacturing capacity, on top of 130 MW of cells, 1.4 GW of EVA and polyolefin encapsulants, and 3 GW of backsheets – has put systems and processes in place to prevent issues that may cause modules to underperform and fail.

In terms of modules, RenewSys has launched one of the first glass-backsheet bifacial solar modules, the "Deserv Extreme." The company also has led the market by becoming India's first manufacturer to receive a backsheet patent and deploy five- and six-busbar cell interconnection. To prevent common modes of module failure, RenewSys deploys the most advanced and consistent lamination processes. Encapsulants are manufactured in-house, using German technology, while raw materials are only sourced from top-class suppliers – incoming materials are also stringently tested. Its tabber stringer process is fail-safe, with uniform bonding at interconnecting points. Regular checks for gel content and peel strength are carried out, along with electroluminescence (EL) imaging at a highly magnified resolution before and after lamination.

> *"India has emerged as a leading destination for solar manufacturing because of high quality and reliable PV modules and components"*

RenewSys believes it stands out from the crowd due to its uncompromising approach to quality, along with its embrace of innovation, and top-quality product design and engineering.

Global presence

In 2019, RenewSys can boast of supplying projects globally, supported by an experienced team of representatives. Their modules are also covered for performance insusrance from MunichRe. RenewSys has offices in India, Mauritius, Nigeria, South Africa, Singapore, the U.A.E., U.K. and China, as well as representative offices in the United States, Mexico and Brazil, on top of a growing distributor network. "Given this scenario, RenewSys has emerged as a leading player expanding steadily in the last five years to a capacity of 750 MW. This has been possible due to the preference for RenewSys modules and repeat orders that are coming in from partners and customers in India and other countries globally as well," concludes RenewSys MD Hiranandani. pv

pv magazine

RenewSys India Managing Director Avinash Hiranandani.

Material concerns

Technological breakthroughs have come thick and fast to the solar and energy storage space in recent years, allowing both sectors to claim an increasing share of the world's energy infrastructure. As PV pins its hopes on further innovations to push further into the mix, some new technologies will make the leap from laboratory to production and inform the industry's future, while others will falter or fall along the wayside.

More power, lower costs, longer lifetimes – from nanoscopic tweaks to a solar cell's surface, to whole new system layouts incorporating PV with heating, water production and other sectors, it is technology that will keep solar moving forward.

Certain new technologies already create plenty of buzz, with phrases like "next generation" or "paradigm changing" thrown around the industry to the point where they start to lose all meaning. In reality, research and development is a long and arduous process, and in some cases transferring a development from a laboratory achievement into mass production ends up creating more problems than it solves. What follows is a look at some of the technologies promising to make this leap in the next few years, and the roadblocks that will make or break them in the future.

"Recent research into perovskites has focused on identifying and synthesizing new materials"

Perovskites

The crystalline structure named for Russian nobleman Lev Perovski in 1839 has been, to say the least, well documented as a potential solar cell material. And many of the world's leading research institutes have tried to get in on the act by maximizing the efficiency and overcoming issues related to durability and moisture sensitivity, which are inherent to the material.

While many doubters will tell you this technology has been rushed out of the lab without proper consideration for the issues it would face in mass production and in the field, perovskites have succeeded in attracting commercial investment. Construction of the first production lines is already underway, in fact.

British-German startup Oxford PV leads the pack in commercial development. Back in December 2018, it set the efficiency record for a perovskite/silicon tandem cell at 28%. The company has plans to bring a 250 MW perovskite-on-silicon tandem production line online by the end of 2020, with an initial production efficiency target of 27%.

Beyond its push for commercialization, Oxford PV maintains a research partnership with Oxford University, the institution it was first spun off from. It is targeting a 37% cell efficiency rate through multijunction technology, by combining perovskite cells with silicon and other materials.

Elsewhere, recent research into perovskites has focused on identifying and synthesizing new materials with this unique crystalline structure, and narrowing down the thousands of potential combinations that could add up to low-cost, high-efficiency perovskite solar cells.

Scientists at the University of California, San Diego, have developed an algorithm to narrow down a list of more than 4,000 potential materials to just 13. And the Massachusetts Institute of Technology is refining a process that applies machine learning techniques to the synthesis and analysis of new perovskite materials, in a bid to greatly speed up the process.

Techniques such as these focus on finding new perovskites that can be synthesized without the many defects and sensitivities that have plagued the technology so far. At King Abdullah University of Science and Technology (KAUST) in Saudi Arabia, one group is engaged in growing single crystal perovskites, which it sees as a potential solution to defects. Earlier this year, the team set an efficiency record for the material at 21.09%.

Identifying lead-free perovskite compounds is another focus, as the presence of this toxic material in all of the perovskites currently earmarked for mass production could still prove to be a stumbling block. Though efficiencies for them are still a far cry from their lead-based counterparts, research teams have successfully created solar cells from perovskites based on tin, titanium, bismuth and more.

III-Vs

Gallium arsenide, indium gallium phosphide and other materials taken from

groups 13 and 15 (three and five under an older classification system) of the periodic table hold most of the records when it comes to cell efficiency. Illinois-based Microlink Devices achieved an efficiency record for a cell under "one sun" illumination, at 37.75% for its triple junction epitaxial liftoff technology. And U.S.-based Hanergy subsidiary Alta Devices set the record for a single junction cell at 29.1% with a gallium arsenide device last December.

While these cells are commercially available, costs are still several orders of magnitude higher than those of silicon. Thus far, application has been limited to satellites, spacecraft and drones – where the energy-to-weight ratio is a more pressing concern than system costs.

Bringing down the cost of III-V solar cells has been a focus for the U.S. National Renewable Energy Laboratory (NREL) in recent years. Most recently, NREL turned to a process called dynamic hydride vapor phase epitaxy, fondly referred to in the lab as a "brand new, 50-year old growth technique." After introducing this process in 2018, Kelsey Horowitz of the NREL's Strategic Energy Analysis Center said that with further optimizations to the process and economies of scale, production costs for III-V solar cells could fall to between $0.20/W and $0.80/W. In August, NREL reported the first of these optimizations, as it was able to greatly speed up the process time for base-layer growth.

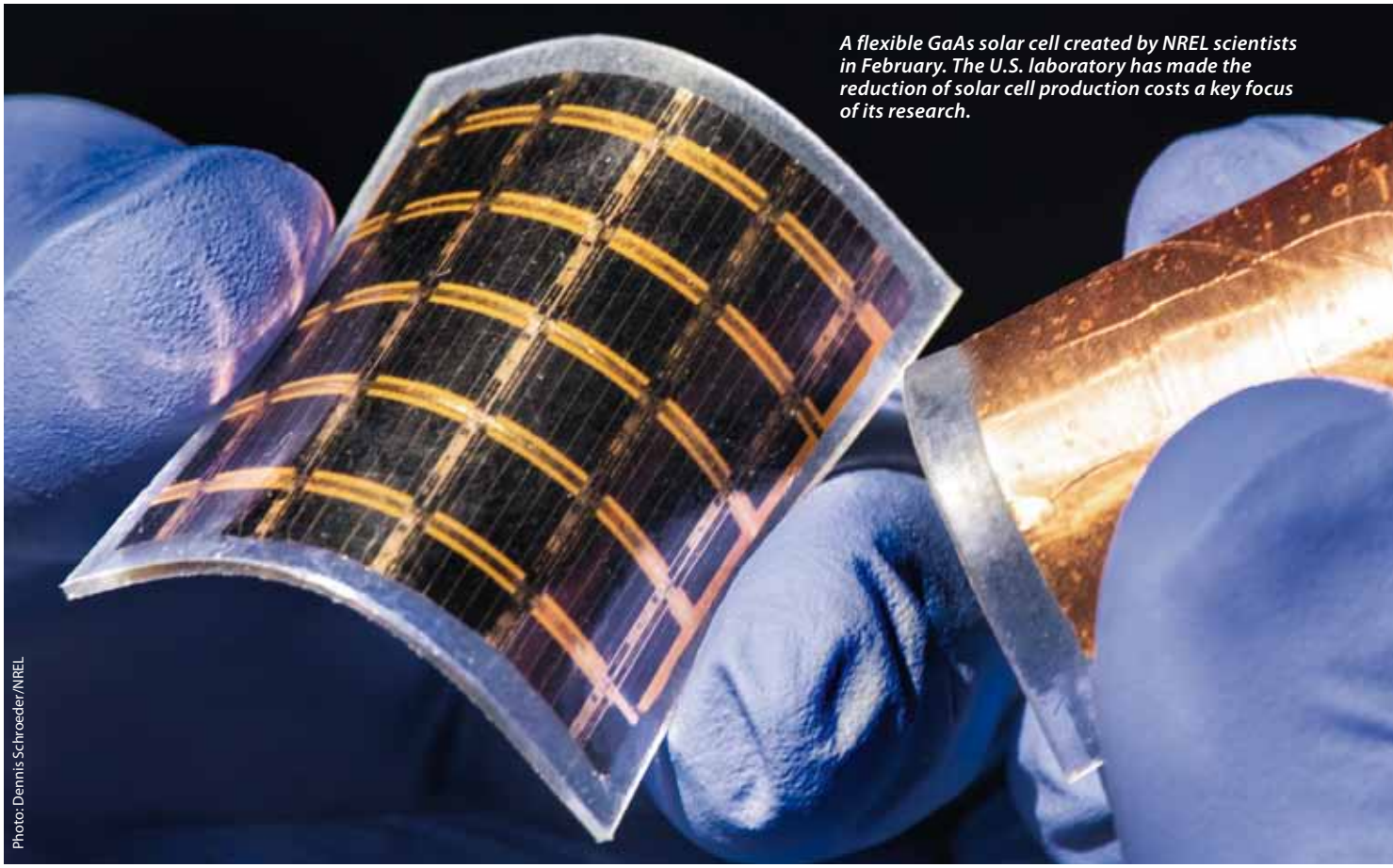
"If we can get the costs down like we think we can, that opens up a huge number of markets where these devices would be useful," said senior NREL scientist Aaron Ptak. "Anywhere you want a high-efficiency device that's thin, light and flexible."

NREL has also published results from another process it calls "germanium on nothing." This process cuts costs by growing crystalline material layers on a reusable substrate. Cells made by this process have hit efficiencies of 14.44%, but the lab says it has a roadmap to bring this above 20%. Other approaches have focused on producing cells as thinly as possible to minimize the use of valuable materials. Also in August, Germany's Fraunhofer ISE and the French Centre for Nanoscience and Nanotechnology (C2N) jointly produced a 19.9% efficient gallium arsenide cell that was just two nanometers thick.

"Bringing down the cost of III-V solar cells has been a focus for NREL in recent years"

Tandem cells

What's clear is that solar researchers are not putting all their eggs in one basket, and



A flexible GaAs solar cell created by NREL scientists in February. The U.S. laboratory has made the reduction of solar cell production costs a key focus of its research.

Photo: Dennis Schroeder/NREL

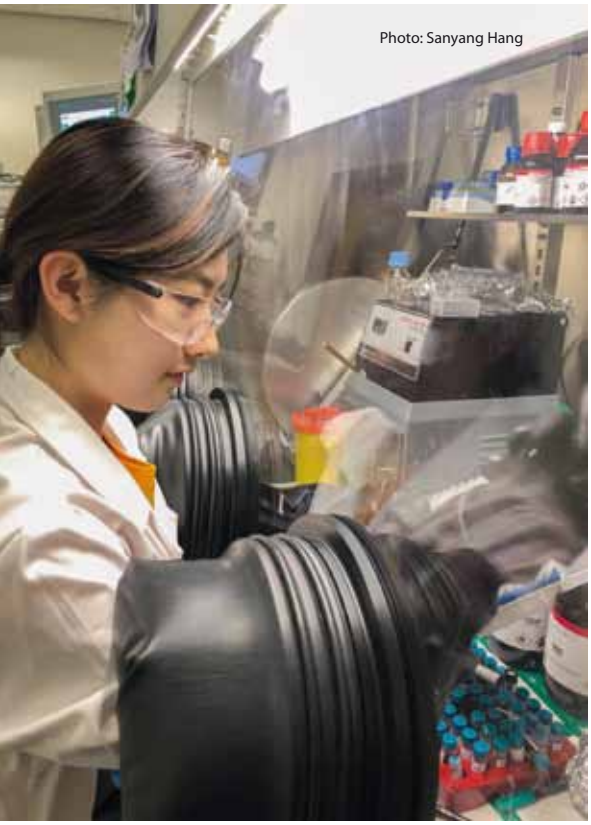


Photo: Sanyang Hang

Mengxia Liu, now a postdoctoral fellow at the University of Cambridge, has written a paper on improving the stability of perovskite solar cells by combining them with quantum dot materials.

they continue pushing for higher efficiencies. But they will need to work with different materials tuned to harvest different segments of the light spectrum.

Speaking to **pv magazine** earlier this year, leading PV scientist Martin Green described finding "a frontrunner to stick onto silicon" as the University of New South Wales School of Photovoltaics and Renewable Energy Engineering's (SPREE) most important project.

If perovskites or III-V compounds can overcome their respective challenges, materials from these groups will be among the frontrunners. And further into the future, tandem cells will likely evolve into stacked cells with four or even more active layers, with established thin-film technologies such as cadmium telluride (CdTe) and copper indium gallium selenide (CIGS) also in the mix. Last year, Belgian research institute imec hit 24.6% efficiency with a tandem cell based on CIGS and perovskite.

Another outlier is copper zinc tin sulfide, which has so far achieved only 12.6% efficiency in the lab. But it is favored by some, including UNSW, for its reliance on materials that are abundant and non-toxic. All-round wonder material graphene has shown some potential as a solar cell, and scientists also continue to achieve impressive results with a whole host of organic PV materials.

Singlet fission

Researchers are also working to harness an effect observed in a select group of materials known as singlet exciton fission. This is a phenomenon where a single photon can generate two electron-hole pairs in a semiconductor, rather than the usual one.

A recent paper published by MIT estimates that if properly harnessed, singlet exciton fission could result in efficiencies as high as 35% for single junction silicon, beyond the theoretical limit for this material. However, translating the phenomenon into a controllable solar cell has thus far proven complex.

In their paper, the MIT scientists claim to be the first to transfer the effect from one of the "excitonic" materials known to exhibit it – in this case, tetracene, a hydrocarbon organic semiconductor – into crystalline silicon. They achieved the feat by placing an additional layer just a few atoms thick of hafnium oxynitride between the silicon solar cell and the excitonic tetracene layer.

And while MIT has acknowledged that anything resembling a commercial application for this technology is still several years away at least, the potential is clearly there.

"We know that hafnium oxynitride generates additional charge at the interface which reduces losses by a process called electric field passivation," says Markus Einziger, a graduate student at MIT's Center for Excitonics. "If we can establish better control over this phenomenon, efficiencies may climb even higher."

Handling heat

No matter the material, heat is another pressing concern for solar technology. Solar cell performance and operational lifetimes are both negatively affected by higher temperatures. This is another key research area for SPREE, and Green has noted that "all of the parasitic effects" that cause degradation in solar cells are doubled by every 10-degree increase above ambient temperature.

Suggested solutions to this problem fall into two broad categories: Simply reflecting or drawing heat away from a PV system to keep operating temperatures as low as possible, or collecting the heat and putting it to another purpose.

Recent research from KAUST provides one example of such a purpose. Researchers attached a membrane distillation device to the rear of a commercially available solar module, and were able to produce clean drinking water from seawater using only the heat from the sun.

Elsewhere, scientists at Rice University in Texas recently theorized that they could combine a solar cell with a device based on carbon nanotubes, which they call a hyperbolic thermal emitter. This converts heat energy into light, effectively squeezing particles into a narrower band, allowing it to be harvested by a solar cell. The researchers have yet to actually combine this innovation with a solar cell, however.

Other approaches here include thermoelectric generation, where energy is produced through a difference in temperature. Module designs that focus more on air flow have been proposed, as well as reflecting away parts of the light spectrum not useful for electricity generation, that still end up creating waste heat in the module.

Mark Hutchins

> *"Properly harnessed, singlet exciton fission could result in efficiency as high as 35%"*

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pv magazine test

July 2019 results

We are pleased to present the next batch of energy yield results from the outdoor test field at Xi'an, China. The July 2019 results will be presented in this issue, with additional analysis from George Touloupas, director of technology and quality at CEA.

The first graph to the right charts the meteo station data for July 2019. The system was offline due to a power cut on July 1. The irradiance meters were uninstalled for calibration from July 1 to 19. Energy yield data were collected for 30 days from July 2 to July 30. Meteo data were collected for 12 days from July 20 to July 31.

Monthly energy yield data from February to July 2019 are given in the table below. The second graph to the right shows the total energy yield of all products for July 2019.

Three Znshine products, two with graphene coated glass (ZXP6-60-275/P) and one with regular glass (ZXP6-60-265/P), were added to the test from the beginning of the month. The graphene coating claims to increase the transmission properties of the glass, and also to have a self-cleaning effect, reducing O&M costs for commercial and utility-scale PV power plants.

A control test was set up for the two modules with graphene coated glass: one is cleaned weekly while the other is not cleaned at all. The module with regular glass, which is not cleaned, was installed as a reference to provide a baseline to observe the level of dust accumulation. The average energy yield of the three products is charted in the third graph to the right. The yield data of the "not cleaned" graphene coated module and the "not cleaned" regular module do not exhibit a significant difference. Thus, the self-cleaning effect of the graphene coated glass is not evident yet and needs to be further investigated as more data points are collected.

The overall bifacial boost for July 2019 averages 8.1%. Bifacial boost is defined as the extra energy yield of the bifacial products compared to the average energy yield of all mono-facial products.

The graph to the bottom right shows the comparison between different module technologies for July 2019. Bifacial modules are performing above the average energy yield level, with multi-crystalline silicon PV performing below the average energy yield level.

George Touloupas

Average daily and monthly yields

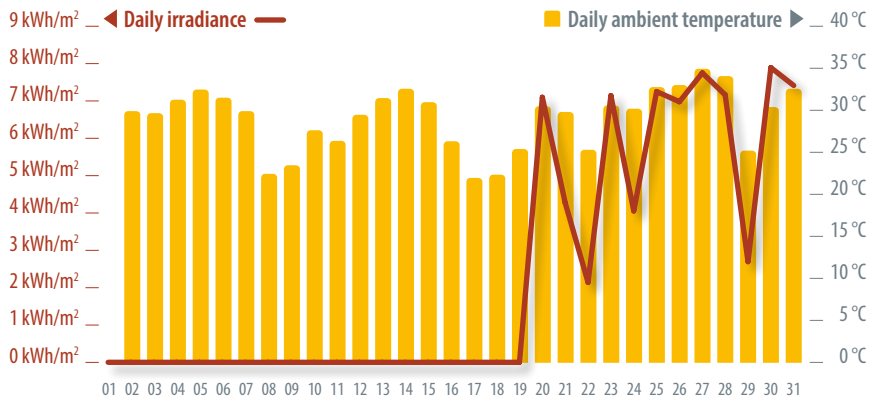
all in Wh/Wp	Feb 2019	Mar 2019	Apr 2019	May 2019	Jun 2019	Jul 2019
Average monthly yield	75.31	133.23	83.11	96.00	83.83	120.88
Average monthly bifacial yield	79.46	139.23	87.64	101.91	89.64	128.70
Average monthly monofacial yield	74.28	131.85	82.06	94.64	82.49	119.07
Operation days	28	31	21	25	26	30
Average daily yield	2.69	4.30	3.96	3.84	3.22	4.03
Average daily bifacial yield	2.84	4.49	4.17	4.08	3.45	4.29
Average daily monofacial yield	2.65	4.25	3.91	3.79	3.17	3.97
Bifacial boost	7.0%	5.6%	6.8%	7.7%	8.7%	8.1%

Energy yield ranking

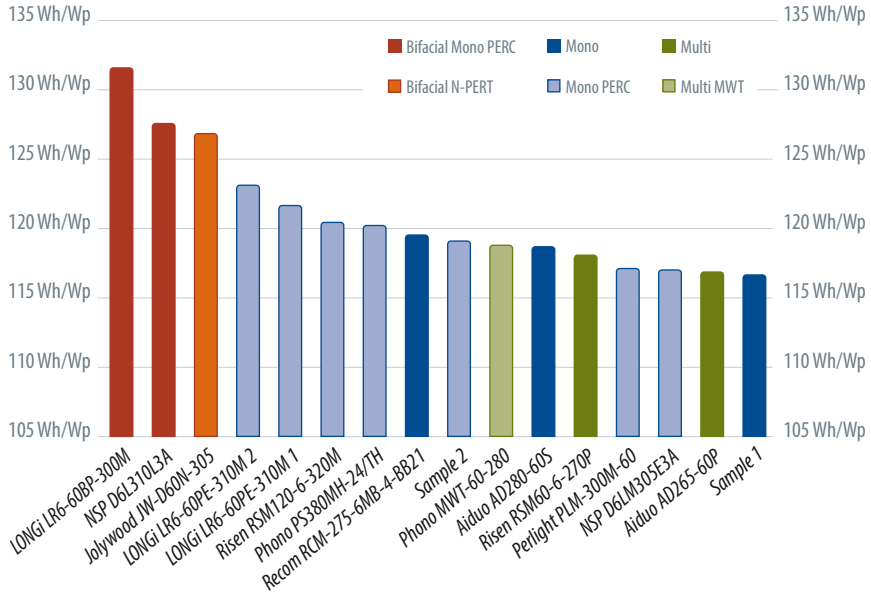
#	Product	Type	Total Feb 2019 Wh/Wp	Total Mar 2019 Wh/Wp	Total Apr 2019 Wh/Wp	Total May 2019 Wh/Wp	Total June 2019 Wh/Wp	Total July 2019 Wh/Wp	Feb 2019 rank	Mar 2019 rank	Apr 2019 rank	May 2019 rank	Jun 2019 rank	July 2019 rank
18	LONGi LR6-60BP-300M	Bifacial Mono PERC	81.23	142.28	89.60	103.89	91.53	131.61	1	1	1	1	1	1
17	NSP D6L310L3A	Bifacial Mono PERC	78.91	138.37	86.84	101.05	89.09	127.61	2	2	2	2	2	2
1	Jolywood JW-D60N-305	Bifacial N-PERT	78.22	137.05	86.47	100.80	88.31	126.88	3	3	3	3	3	3
16	LONGi LR6-60PE-310M 2	Mono PERC	76.43	135.64	84.47	97.70	85.24	123.17	4	4	4	4	4	4
7	LONGi LR6-60PE-310M 1	Mono PERC	75.79	134.69	83.86	97.12	84.16	121.70	5	5	5	5	5	5
21	Risen RSM120-6-320M	Mono PERC	-	131.52	82.20	95.35	83.67	120.49	-	12	8	6	6	6
20	Phono PS380MH-24/TH	Mono PERC	74.38	132.18	82.29	94.39	83.26	120.27	10	6	6	10	7	7
10	Recom RCM-275-6MB-4-BB21	Mono	74.62	131.72	81.94	94.90	82.75	119.59	6	9	10	8	9	8
14	Sample 2	Mono PERC	74.50	132.00	82.22	95.23	82.87	119.14	8	7	7	7	8	9
2	Phono MWT-60-280	Multi MWT	72.64	131.19	81.64	94.42	81.90	118.85	14	13	13	9	11	10
8	Aiduo AD280-60S	Mono	74.18	131.71	81.93	93.90	82.17	118.75	11	10	11	14	10	11
3	Risen RSM60-6-270P	Multi	72.61	131.11	81.46	94.12	81.62	118.13	15	14	14	11	13	12
4	Perlight PLM-300M-60	Mono PERC	74.48	131.60	81.95	93.92	81.66	117.17	9	11	9	13	12	13
12	NSP D6LM305E3A	Mono PERC	74.54	131.73	81.84	94.04	81.46	117.07	7	8	12	12	14	14
9	Aiduo AD265-60P	Multi	73.55	130.36	81.19	92.88	80.61	116.92	13	15	15	15	16	15
13	Sample 1	Mono	73.62	128.56	79.79	92.30	80.99	116.72	12	16	16	16	15	16

Average daily irradiance and temperature data (July 2019)

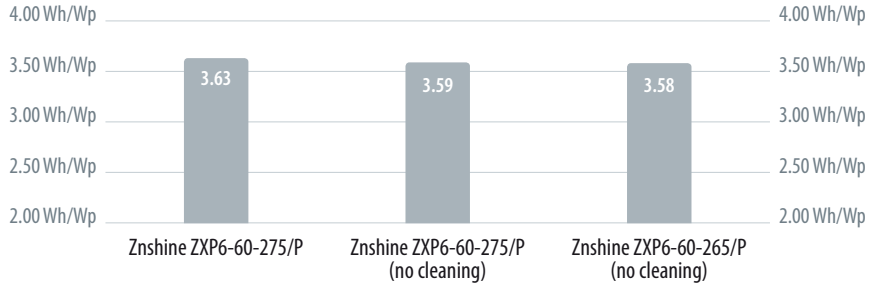
Source: pv magazine test data



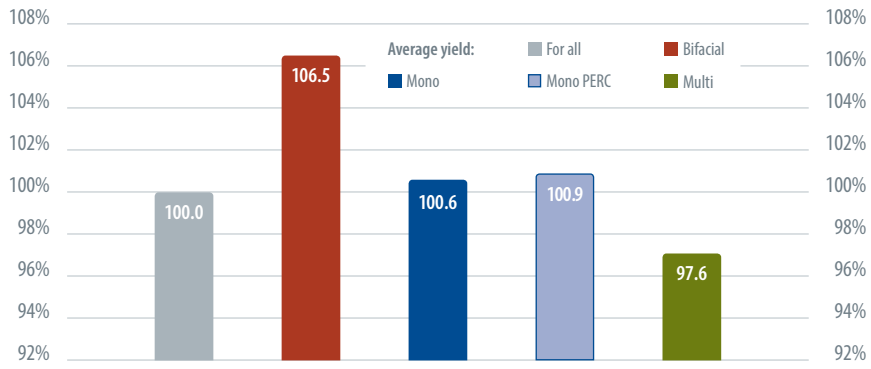
Total energy yield (July 2019)



Average daily energy yield – Znshine products



Relative yield of different technologies (July 2019)



Test cooperation

pv magazine test is a cooperative effort involving **pv magazine**, CEA and Gsolar. All testing procedures are carried out at Gsolar's test laboratory in Xi'an, China. CEA supervises these tests and designed both the indoor and outdoor testing procedures.

Notes on the energy yield measurements:

- The energy yield is given in Wh/Wp and calculated by dividing the energy produced by the module by the Pmax at STC of the module. This Pmax is the maximum STC power after a process of stabilization.
- The results are grouped in categories, per module type.
- The bifacial boost depends on many parameters: the bifaciality factor, the installation geometry, the albedo of the ground, and also the sun angle and diffuse irradiance. The ground in this case is a plastic cover simulating green grass.

Flow batteries scale up to GW production

Plans for a gigawatt factory in Saudi Arabia, bullet-proof warranties and an international vanadium rental service are propelling a new generation of batteries into the energy storage big league. Pioneers of redox flow technology claim that they can put an end to the degradation and safety issues afflicting lithium-ion batteries. They also expect imminent economies of scale to reduce the cost of bulk energy storage and unlock new markets for solar power.

A new cavern of wonders is rising from the sands of Saudi Arabia. A century after transforming the global energy sector with cheap, abundant oil, the Kingdom is now building the first gigawatt-scale factory for redox flow batteries, a technology that proponents argue will slash the price of storing solar energy.

Vanadium flow batteries at the Huanghe PV installation in Qinghai Province, China.

Photo: Avalon Battery

Since the basic patent protecting redox flow batteries expired just over a decade ago, dozens of tech firms have raced to develop the technology and drive down its cost. In many respects, they have succeeded. Matt Harper, president of Avalon Battery, says that prices offered by leading manufacturers have come down 80% in less than five years. Lazard, an asset manager, calculates that the levelized cost of storing electricity in some redox flow projects now overlaps with that of lithium-ion batteries, the main

Flow and lithium ion, side-by-side

Metric	Vanadium redox flow battery	Lithium-ion
Energy density	20-40 Wh/kg	80-200 Wh/kg
Discharge time	3-10 hours	0.5-5 hours
DC efficiency	75-90%	92-99%
Cycle life	20,000-30,000 cycles	600-12,000 cycles
Calendar life	20-25 years	3-10 years

Source: Bushveld Energy/Navigant Research

> *"Fierce as this competition may be, flow batteries have an ace up their sleeve"*

competition. This year, sales of vanadium-flow batteries, the most established redox flow technology on the market, have grown from double digits to just over 200 MWh of installed storage capacity.

In spite of these achievements, Alex Eller, an analyst at Navigant, points out that redox flow batteries have yet to dent the energy market. He says that most of the 7,000 MWh of grid scale storage coming online this year will be met by lithium-ion batteries, followed by pumped hydro and other established storage technologies, with flow batteries trailing behind.

"Flow battery projects have so far been relatively small scale," said Eller. "We are only just starting to see large-scale commercial projects in the works." While he sees many hurdles still facing the emerging redox flow industry, Eller is also convinced of the technology's potential to reduce the cost of storing renewable energy.

Zero degradation

Undercutting the record-low prices set by lithium-ion batteries will be no small challenge. In recent years, global electronics brands including Samsung, LG and Panasonic have streamlined assembly lines capable of producing gigawatt-hours of lithium-ion batteries each year. Prices have come down faster than expected and sluggish demand for electric vehicles has led to a glut of cells now being sold at cut-throat prices to store power on the grid.

Fierce as this competition may be, flow batteries have an ace up their sleeve. Unlike the lithium-ion batteries they compete with, their electrolytes do not degrade. According to Richard Wills at the University of Southampton, what sets the technology apart is its architecture. Rather than distribute electrolytes within each cell, a flow battery separates electrolytes into external tanks and pumps the liquid through active elements that store and deliver energy. At first glance, the device looks more like a chemical treatment plant than an AA battery.

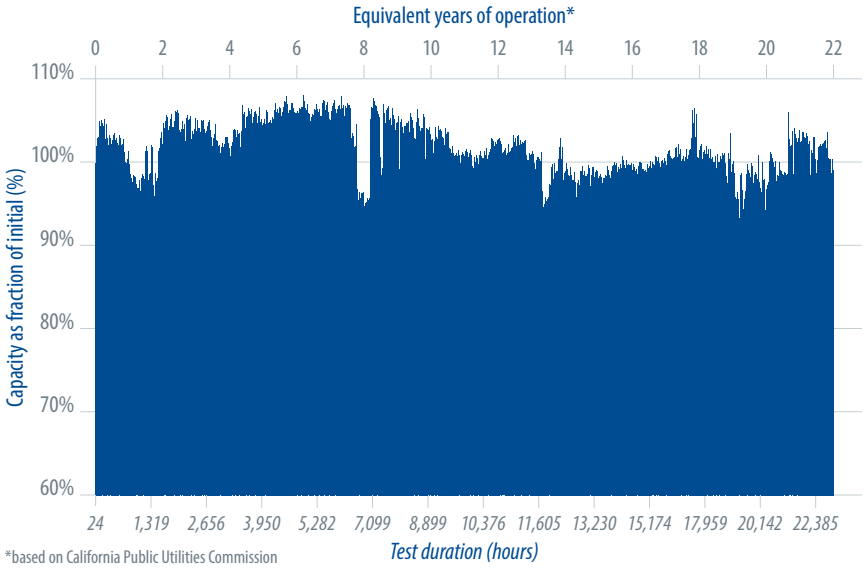
Redox flow technology raises new challenges. To function, these batteries require pumps and aqueous electrolytes that suffer from comparatively low energy densities. They also reduce the efficiency of the energy conversion process, they are unwieldy for most forms of transport, and they increase the floor space needed to house components.

But Wills says that redox flow technology can also charge and discharge batteries without degrading their performance. "The reactions undergone in redox flow batteries are surface electron transfers which are less susceptible to degrade electrodes and current collectors," said Wills, adding that the large volume of aqueous electrolyte pumped through the cell stack also helps dissipate heat, a key burden on materials and notorious fire hazard in lithium-ion batteries. Cooler operation leads to higher safety margins, longer equipment lifetime and lower maintenance costs. On paper, this makes flow batteries safer than Li-ion technology and cheaper over the duration of a storage project.

"We have run a vanadium flow battery through 24,000 hours of very aggressive

Redox flow battery capacity over time

Source: Avalon Battery



*based on California Public Utilities Commission

Capacity of vanadium flow battery following maximal aggression cycling under field conditions. The 10 kW module has executed 22 years of service under California CPUC rules with zero degradation.

cycles and still cannot measure any degradation on the battery's performance," said Alex Au, CTO of Nextracker. Three years ago, the U.S. tracker supplier added energy storage solutions to its catalogue Au tested more than 40 technologies in-house to select products compatible with lifelike fluctuations in demand on electricity grids. The vanadium flow batteries made by Avalon Battery made the cut. "They even boast less degradation and a better warranty than any solar module on the market today," said Au.

Vanadium rental shop

Back at Navigant, Alex Eller says that the extended lifetime and dependability of flow batteries should in principle recommend the technology for secluded electricity generation assets, in particular solar arrays, keen on storing vast volumes of electricity for several hours until its value peaks on the wholesale market. But the limited track record of large-scale flow battery projects has so far limited their deployment.

"Flow batteries face a severe trust issue," said Eller. He explains that the main companies buying batteries today are risk-averse project developers. These procurement teams want to make sure that the manufacturer of the battery they select still exists in ten years' time in case they need to replace faulty purchases. As a result, they favor working with reputable lithium-ion behemoths, rather than upstart redox flow pioneers, regardless

Photo: Schmid

Schmid's containerized EverFlow redox flow storage unit.

Photo: Ideal Energy

NX Flow vanadium redox flow batteries connected to a solar array.

of the long-term cost projections of the project.

In a similar display of conservatism, no established lithium-ion manufacturer has so far ventured into the redox flow battery business. Eller ventures that their reluctance is caused by market uncertainty. It remains unclear which variant of redox flow technology will come out on top. "Flow batteries using vanadium electrolytes are very good, but vanadium is expensive," he says. The cost of the raw material already inflates capital expenditure for vanadium flow projects by over 30% and investors fear that fluctuations in commodity prices could strangle supply chains.

Matt Harper at Avalon Battery claims that creative financing and vanadium leasing schemes are making vanadium flow projects more bankable. To reassure jittery buyers, manufacturers have started securing warranties from third parties. Insurers like New Energy Risk in the United States will cover falls in battery performance over the 20-year lifespan of a redox flow project, even if the battery manufacturer goes out of business. These contracts effectively guarantee returns from an energy storage project so that its developer can trust the insurer, even if they are still growing familiar with the manufacturer.

Likewise, business solutions are dampening the risk of vanadium supply chains by allowing clients and battery manufacturers to lease their electrolyte. Vanadium producers including Glencore and Bushveld Energy are prepared to rent out the metal and recycle it, shouldering part of the capital expense of the project. "The vanadium electrolyte does not degrade and can be fully recovered at the end of the battery's life," said Mikhail Nikoramov, CEO of Bushveld Energy.

Harper claims that these advances have brought the vanadium flow industry to

Photo: Avalon Battery

According to Avalon Battery's Matt Harper, creative financing and vanadium leasing schemes are making vanadium flow projects like this one more bankable

the same inflection point that geared up lithium-ion manufacturers in the 1990s when consumer electronics entered mass production. So far, redox flow batteries have filled niche applications, typically where fire safety is of particular importance. But as its price verges on that of lithium-ion batteries, Harper expects redox flow technology to storm the stationary storage market. He calculates that this growth could reduce Avalon Battery's prices below $40/MWh, turning solar into "a truly dispatchable asset, capable of displacing all other sources of electricity on the grid." In his view, the key to cutting costs is a mature supply chain and standardization.

Saudi Qualität

This is good news for the 70,000-square meter factory taking shape in Saudi Arabia. Its opening in 2020 will deliver over 1 GWh of redox flow storage capacity to the market each year, bringing unprecedented economies of scale to an industry that has so far had to make do with tailor-made solutions as it contends with mass-produced competition.

The Saudi plant will churn out vanadium flow batteries developed by Schmid, a German PV equipment supplier with 150 years of experience in industrial engineering. The family business branched out into redox flow batteries in 2011, commercialized its first vanadium flow battery in 2014, and set out in search of partners to scale up production.

Schmid struck a deal this year with RIWAQ, a Saudi construction firm, and Nusaned Investment, a subsidiary of Saudi petrochemicals giant Sabic, which finances technologies supporting policies set out by Saudi authorities. In 2016, the Kingdom announced its Vision 2030 plan to reduce national dependence on oil revenues, notably through massive investment in renewables. The venture brings together some of the most venerable veterans in the flow battery industry with exceptionally deep pocketed investors.

"The new Schmid deal in Saudi Arabia is very exciting," said Maria Skyllas-Kazacos, who invented redox flow technology in the 1980s. She adds that the plant "will definitely help to provide the production scale needed to further reduce costs." *Benedict O'Donnell*

> *"The key to cutting costs is a mature supply chain and standardization"*

Gridlock grips Australia's

Australia's large-scale solar boom faces serious constraints in the form of a long and skinny electricity network – making some ideal sites unattractive to project developers. Legacy regulations and a lack of transparency have also caused last-minute roadblocks and costly delays for developers.

How did transmission capacity and connection to the electrical grid become the biggest obstacles to Australia's supercharged push toward a renewable-energy future? With Rystad Energy estimating that 70 GW of large-scale renewables are in the pipeline, falling solar costs bumping aging coal generators off the map, and financiers jumping on board, it all seemed to be going so well.

"I'd observe that as an industry we've delivered on the 2020 Renewable Energy Target. Delivering on this is causing technical challenges," said John Titchen, managing director of Goldwind, at the Australian Clean Energy Summit 2019 in July. "Why, as a country, have we put a target in for people to run at, without preparing the runway?"

Australian renewable-energy developers and investors have experienced a world of pain over the past 18 months to two years, following a spike in projects being slowed through approvals and connections by long-known but poorly understood grid regulations. Unknown congestion at seemingly ideal project sites, as well as last-minute requirements to shore up system strength with the addition of synchronous condensers, have added to their woes, while transmission constraints have resulted in earnings-shrinking marginal loss factors (MLFs), and curtailment regimes have been enforced to keep the grid stable.

Tough times

"Don't underestimate the impact of system strength on your financial models," said Kate Osaze, grid-connections manager for ESCO Pacific, at the CEC Large Scale Solar Forum in May of this year. ESCO had been in extensive consultations with the Australian Energy Market Operator (AEMO) and network service providers throughout the development of its 175 MW Finley Solar Farm in New South Wales. But a few days before the connection was scheduled,

The development of Victoria's largest solar project, the first 256 MW stage of the Kiamal Solar Farm, was one project that was hit by the need to install a costly synchronous condenser.

Photo: Total Eren

PV developers

the developer was notified by the network service providers that the project would require a synchronous condenser – a costly piece of equipment.

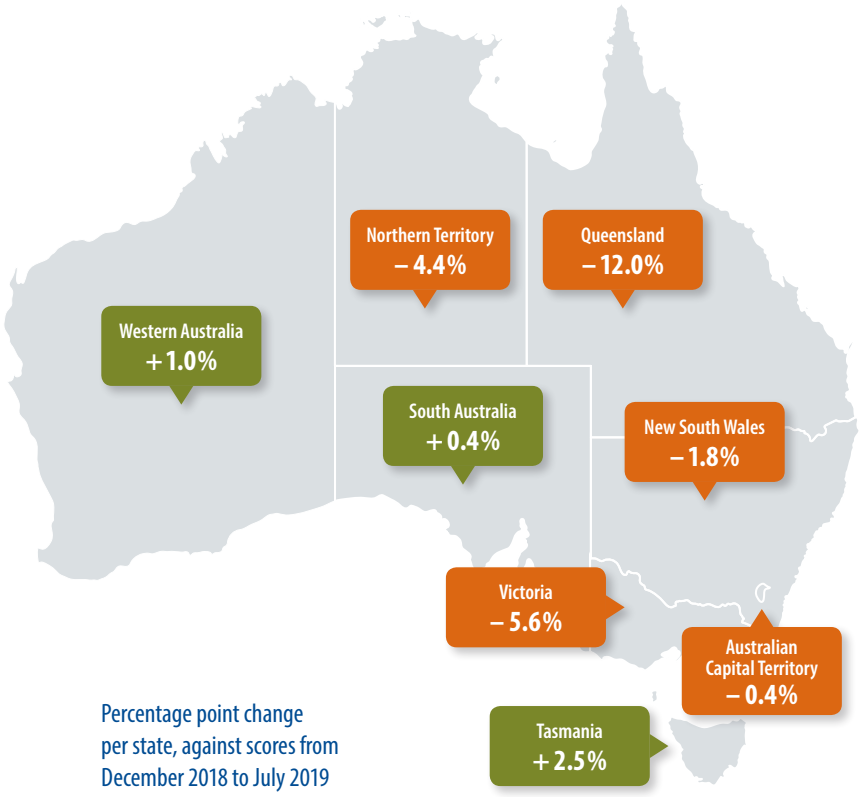
"As you would expect, you're going through negotiations with your OEM, you've negotiated with your EPC contractors, you have a PPA [power purchase agreement] in place – all these contractual obligations are in parallel," said Osaze.

To be notified abruptly towards the tail end of the connection process that you need to spend millions of extra dollars on a project is a huge ask for any business to absorb.

"We were able to navigate this with the help of a very strong in-house team," said Osaze. She recommends factoring in delays due to the huge number of applications received by network service providers, and their likely inexperience with constant adjustments in rules and processes, such as the relatively new requirement for PSCAD modelling of each project.

Renewables executive confidence per state

Source: Clean Energy Council



Percentage point change per state, against scores from December 2018 to July 2019

Old dog, no new tricks

Earlier this year, analysis by Rystad forecast that the decades-old MLF mechanism imposed on solar PV developments would diminish the revenues of at least six proposed large-scale solar farms in 2019-20 by 10% or more. This blow to project economics represents the calculated loss of electrons, as solar-farm output flows from power plant to transmission node and on to the ultimate consumer load.

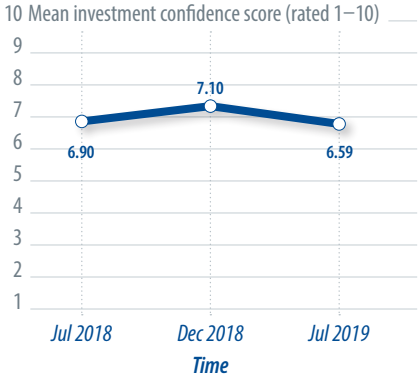
"If the MLF issue is not addressed in the short to medium term," asks Simon Corbell, chief adviser at Energy Estate, "will we see investors just too shy to invest because of the real unpredictability of the MLF regime and the compounding effect of it?"

The Clean Energy Council's most recent biannual Clean Energy Outlook – Confidence Index appeared to reflect this sentiment. The latest index saw energy industry leaders' average confidence levels falling on a scale of one to 10, from 6.9 points in July 2018 and 7.1 points in December 2018, to a one-year low of 6.59 in mid-2019.

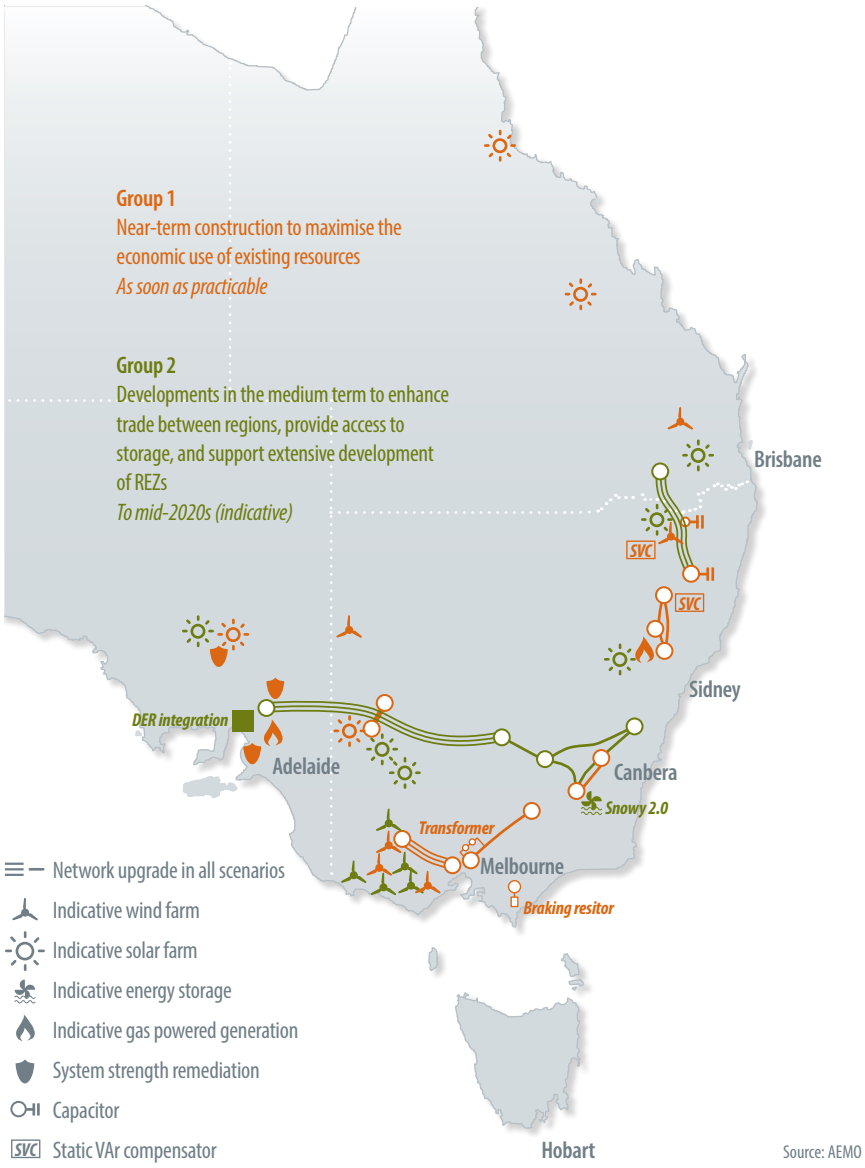
Some stakeholders believe MLFs provide an appropriate signal as to which sites on the existing grid are less suited to substantial solar farm development than

Renewables executive investment confidence

Source: Clean Energy Council



AEMO Integrated System Plan – integrated development plan mid-2020 outlook



Source: AEMO

others. Simon Taylor, manager of network customers at Queensland's high-voltage transmission network operator Powerlink, describes an MLF as a "locational signal. It's like, 'Is there sun? OK, that's a good place to connect. Is there transmission? Is there a good loss factor?' These are all locational signals. They all work well."

Open access

One of the greatest conundrums facing connection applicants and network service providers under potentially outdated "open access" regulations are confidentiality rules which prevent them from communicating to a would-be generator about the number of other parties, and project capacities, that are trying to connect at any point on the grid. A draft rule change was published by the Australian Energy Market Commission (AEMC) on Aug. 1 that aims to improve the transparency of applications. This would give developers a crucial heads-up about likely development congestion at certain grid connection points and the possibility of curtailment at various otherwise "ideal" locations.

Powerlink's Taylor reports that the network operator was processing 40 applications for connection at the time of writing. "Open access doesn't mean there's access at every point on the network, and it's open to everyone at every moment," he says. The proposed rule change will enable more open-generator discussions about where each generator might best be placed relative to other parties, relative to the network, and how it will change.

AEMO published its inaugural Integrated System Plan (ISP) in July 2018. Its aim is to provide a path to development for transmission that will eventually connect up to 37 identified Renewable Energy Zones (REZs) with consumers, with pumped-hydro storage projects and for load-sharing across the National Energy Market (NEM). But the consultation process can be painstaking, and the renewables industry is united in its call for an accelerated approach.

Fast track

In April 2019, the AEMC introduced a rule change to streamline regulatory processes for three priority projects identified in the ISP: upgrades for the interconnection between Queensland and New South Wales (known as QNI), between Victoria and New South Wales (VNI), and for the construction of a new 800 MW interconnector between Robertstown, South Australia, and Wagga Wagga in New South Wales (Project EnergyConnect), which links on the way via Buronga, to Red Cliff in the Victorian network.

Each project will increase capacity for the bidirectional flow of energy across state lines, with Project EnergyConnect, a joint development of TNSPs ElectraNet and TransGrid, opening up a new 900-kilometer corridor for renewable generators to strategically connect to high-capacity transmission.

Even with acceleration by AEMC and the cooperation of the New South Wales and South Australian state governments in allowing development-approval processes to run in parallel with the three-stage economic cost-benefit analysis known as the Regulatory Investment Test

for Transmission (RIT-T), the project will have been in development for around seven years by the time it is built in 2022-23.

In western Victoria, clusters of renewables development have occurred around towns such as Horsham and Terang, with some 2 GW of wind and solar generation built or scheduled for commissioning by 2020. AEMO expects a further 3 GW of new generation to be constructed in the region by 2025, plus another 1 GW, all in line with Victoria's renewable energy target of 50% by 2030.

However, the region has become notorious for its grid limitations, which have resulted in widespread revenue-diminishing output downgrades from utility-scale solar farms through MLFs. Other developments, of which Finley Solar Farm was one, have been given the choice of adding grid-firming kit such as synchronous condensers, or just waiting for network upgrades.

In July, AEMO published an assessment of strategic investments in western Victoria's transmission network that would enable up to 6 GW of wind and solar farms in the coming decade. The AUD 370 million ($249.9 million) investment is calculated to produce a total return of AUD 670 million in market benefits – or a net return of AUD 300 million. But the proposal, if it comes to fruition, will be delivered over six years to 2025.

> *"The rate of change is both too much and not enough"*

That's a long time for investors to wait for increased certainty, and this summary of procedures doesn't begin to touch on the marketplace regulations that must be adapted to fairly allocate the costs of developing and upgrading transmission among the beneficiaries: generators and consumers.

Australia's energy market, as well as its transmission, regulation and generation systems, are in a state of continuous change, and the wheels of consultation grind slowly. Too slowly, according to Clean Energy Council CEO Kane Thornton, who says that ironically the rate of change is both too much and not enough.

"Too much change spooks investors, makes it even harder to forecast the future wholesale energy price or adds unnecessary regulatory burden and cost on project development," says Thornton. "At the same time there isn't enough change that brings the regulatory and market environment into the 21st century."

On the flip side, the transmission bottlenecks and grid expansion plans are providing opportunities for large-scale energy storage installations – perhaps most vividly demonstrated by the success of SA's Hornsdale Battery Reserve, installed in 2017. These opportunities, and the challenges, will be explored in the second part of this article in the October edition.

Natalie Filatoff

The curious case of utility-scale storage in India

India's transition toward electric vehicles and renewable generation makes a strong case for grid-scale battery storage. And with the government going all out to ensure that demand is met through local manufacturing, ample opportunity is being created for joint ventures – as the country, at present, lacks the requisite experience.

As India inches closer to achieving its "175 GW by 2022" renewable energy target, it needs to address the challenge of integrating renewables into its electricity network. Deploying energy storage into grids can provide the flexibility to discharge power when it's needed and absorb excess power in periods of oversupply. Energy storage can also provide ancillary services to the grid, like improving grid stability and providing reserve capacity.

> *"Coal plants will need to ramp down to below 30% of capacity at certain times of the year"*

Another big push for energy storage systems is coming from the transition to electric vehicles (EVs). A joint report by NITI Aayog and the Rocky Mountain Institute (RMI) forecasts battery demand for EVs in India to be much higher than for grid support. While total storage demand for grid support purposes is forecast to reach 17 GWh by 2022, up to 40 GWh of demand is expected for e-mobility, with a total from all sectors of 178.5 GWh.

The report expects India's cumulative storage demand to surpass 2,700 GWh by 2032, which makes a strong case for the country to set up gigawatt-scale battery manufacturing, and doing so fast. The government has already sprung into action to encourage the construction of lithium-ion battery "gigafactories" in India. In addition to prioritizing heavy investment into such fabs, it has addressed key raw material supply issues by reducing custom duties on cobalt – a critical raw material for the production of advanced lithium-ion batteries. Duties were reduced from 5% to 2.5%.

Furthermore, National Aluminium Co. Ltd. (NALCO), Hindustan Copper Ltd. (HCL) and Mineral Exploration Corp. Ltd. (MECL) – the three government-owned enterprises under the Ministry of Mines – have formed a joint venture company to secure strategic minerals for the domestic battery manufacturing industry.

Business case

According to Sterlite Power Transmission, which submitted bids for two utility-scale battery storage projects in the United States earlier this year, the business case for grid-scale energy storage arises from the basic need to balance generation with demand. And this need for balancing comes not only from renewable energy production, but also from increasing unpredictability on the demand side, as is shown in that high Deviation Settlement Mechanism (DSM) costs are borne by distribution companies. These needs manifest into a business case based on revenues/benefits from peak-shifting, DSM savings, transmission and distribution deferral, and ancillary services such as frequency regulation and voltage support.

Specifically pertaining to peak shifting or balancing, the use of coal-fired plants for balancing renewables has its own costs. According to a recent analysis by the Central Electricity Authority of India (CEA), when the share of renewables on the grid exceeds 175 GW, coal plants will need to ramp down to below 30% of capacity at certain times of the year.

Existing coal plants can be retrofitted to bring down the technical minimum from 55% to 40%, but not lower, according to the CEA. However, even this requires capital upgrades and increases operating costs.


Photo: IESA

"India should leapfrog from technology demonstration to large-scale implementation," says Debi Prasad Dash, executive director of the India Energy Storage Alliance.

The cost increase is even more dramatic when you consider the daily start-stop operations required to accommodate high solar generation in the afternoon at certain times of the year. Such daily start-stop or "two-shift" operations increase the cost of generation by INR 6.3 ($0.088) per unit – over and above the existing fixed costs and variable cost per unit of the plant.

While the increased cost of using coal can be quantified, little attention has been paid to the environmental cost. This is significant, as emissions from coal plants – already the worst of all generators – continue to worsen when the capacity factor is reduced. There would be a certain degree of irony in increasing overall emissions in order to integrate a larger share of clean, renewable generators.

Declining prices

There are many different energy storage technologies that can assist in strengthening the grid. These include pumped hydro, flywheels, supercapacitors, compressed air storage, thermal energy storage and batteries. Due to their fast response times – as well as the significant price reductions that have been achieved from the rapid ramp-up of manufacturing scale and the fast pace of technological development – batteries are quickly rising to the fore.

Sterlite Power Transmission reports that battery prices have fallen by 70% over the last six years. Fully installed system costs are as low as INR 40 million/MW ($560,000) for four-hour duration storage systems to be commissioned in 2027 and INR 55 million/MW for systems scheduled for commissioning in 2023.

At these rates, batteries are already cost-competitive with pumped storage systems, which is a mature technology, with costs that are, by contrast, rising with inflation.

Current barriers

According to the NITI Aayog-RMI report, grid-scale energy storage installations in India are mostly pumped hydro storage plants, with a current capacity of 4.8 GW. Deployment of large-scale battery energy storage projects in India started in 2017 with state-owned utility Power Grid Corp. of India installing its first pilot projects for frequency regulation, although other use cases can also be served. Most of the upcoming energy storage projects in India are planned in the Andaman and Nicobar Islands, to reduce their dependency on diesel use.

A lack of suitable policies is one of the many factors that have constrained the growth of grid-level energy storage in India thus far. "A few projects have been demonstrated at Pondicherry and Delhi for frequency response and peak management," says Debi Prasad Dash, executive director of the India Energy Storage Alliance (IESA). "Unreliable announcements by various tender authorities are further impeding the growth of this market."

There is a pressing need to leapfrog from the technology demonstration stage straight to large-scale implementation, according to Dash.

> *"Grid-scale energy storage has very high upfront costs and an absence of subsidized funding also acts as a barrier"*

"Various state utilities are still under [the] evaluation stage and are willing to create a technology demonstration project for energy storage, where we see India should leapfrog from technology demonstration to large-scale implementation," he said.

Sterlite Power Transmission has also highlighted the need for improvements in

Photo: Tata Power

The 10 MW grid connected battery system at Tata Power's Delhi substation uses Advancion energy storage platform from Fluence.

regulatory policy. "We desperately need a market for ancillary services and real-time energy," the company said. "[The] Central Electricity Regulatory Commission has come up with certain suggestions regarding the same, but these need to be implemented. Besides wholesale market rules, retail rules will also need to be updated, especially as residential, commercial and industrial interest grows."

As lithium-ion cell manufacturing is almost nonexistent in India, the country still lacks the skills and experienced workforce needed to develop such systems at scale.

"Energy storage is in a nascent stage in India, due to which skilled and experienced personnel are not easily available," says Rashi Gupta, the founder of lithium-ion battery manufacturer Vision Mechatronics. "Grid-scale energy storage has very high upfront costs and an absence of subsidized funding also acts as a barrier for energy storage. The monetary quantification of benefits offered by grid-scale storage is yet to determined, which adds to the dilemma."

This problem is currently compounded by the limited number of players that are operating in the space.

Officials tour Tata's 10 MW battery storage array site.

Photo: Tata Power

Unique opportunities

According to Gupta, this growing industrial segment presents a unique opportunity for micro-, small- and medium-sized enterprises, as well as large conglomerates, to take up lithium-ion cell and power electronics manufacturing. "Dependence on Li-ion cell imports may create a similar pathway [to what we saw in the] solar and semiconductor industries," he explains. "Indian companies should diversify to the manufacturing of cells, as well as power electronics such as battery management systems, battery charging systems and controllers."

IESA expects lithium-ion production facilities ranging from 2 GW to 5 GW in size to be established in India over the next two to three years.

The Ministry of Heavy Industries and NITI Aayog are working closely on creating an energy storage manufacturing ecosystem in India. Under its National Mission on Transformative Mobility and Battery Storage program, NITI Aayog plans to incentivize homegrown production of advanced energy storage products. Various state governments – including Andhra Pradesh, Telangana, Karnataka, Maharashtra, Uttar Pradesh, Madhya Pradesh and Gujarat – are also creating state-level policies to incentivize storage manufacturing with dedicated clusters and incentives such as local tax exemptions, low electricity tariffs, and suitable transport connectivity.

However, while India gears up for lithium-ion battery manufacturing, the central government is also being encouraged to support research on new technologies such as solid-state batteries, flow batteries and compressed-air storage, in order to avoid a supply crunch for lithium. It plans to import the primary raw material from South America's "Lithium Triangle" spanning Chile, Argentina and Bolivia, along with Australia. pv

Uma Gupta

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Beyond the PPA

Contract lengths are getting shorter and hedges are replacing PPAs in the Texas solar market. Are we headed toward a future of merchant solar?

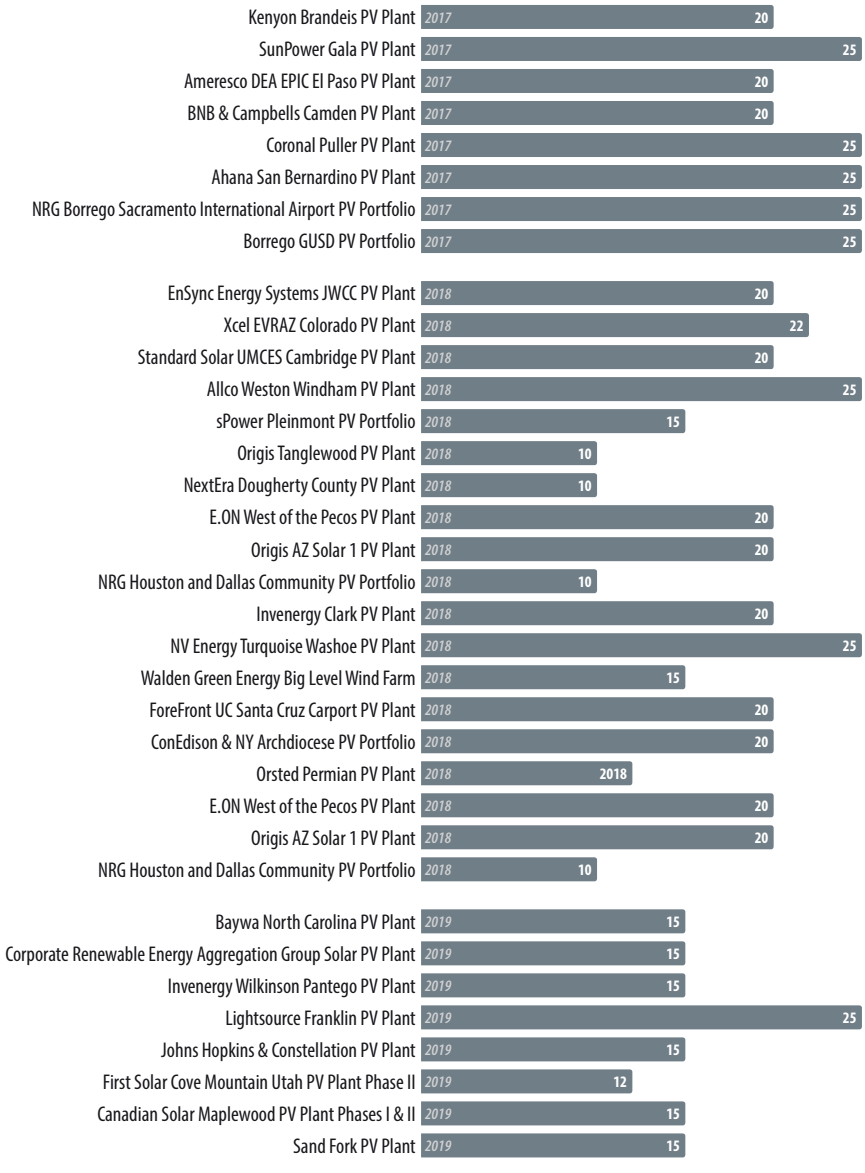
At the Renewable Energy Finance Forum (REFF) – Wall Street conference held in New York City this June, Starwood Energy CEO Himanshu Saxena shocked the room with a statement about five to seven year contracts for solar projects. He further went on to explain that this was translating to longer and longer "merchant tails", or periods where uncontracted energy will be sold on the wholesale market.

Only one month later Duke Energy revealed that it was buying a 200 MW solar project under construction in Texas which holds a 12-year hedge with a subsidiary of Goldman Sachs. The Holstein plant is one of many projects in Texas that are proceeding without any power purchase agreement (PPA).

These moves towards shorter contract lengths, longer "tails" and alternative contract structures all suggest a move in the direction of merchant power. However, these developments also bring up many questions. Chiefly, is the use of hedges in place of PPAs part of a larger trend, or merely a quirk of the market driven by the expiring Investment Tax Credit (ITC)? And ultimately, can merchant solar emerge as a viable business model?

PPA durations in U.S. large scale projects

Source: NREL



Shorter contract lengths

Sexana's comment at REFF-Wall Street spoke to a documented trend: over the past two years PPA terms have plummeted. A list of project PPAs supplied by Bloomberg New Energy Finance (BNEF) shows typical contract lengths falling from 20-25 years in 2017 to 12-15 years in 2019, with a 10- or 12-year term being the lower bound for PPAs reported by the analysts who **pv magazine** spoke with.

These shorter PPAs are driven by a number of factors, but chief among these is that corporate off-takers are demanding them. Colin Smith, a solar analyst at Wood Mackenzie, describes a "tremendous amount of pressure" from Google, Facebook and Microsoft for shorter terms.

"They want to secure low-cost contracts, but don't want to be stuck with something 10 years long," Smith told **pv magazine**. "Facebook hasn't been around for 20 years – it's hard for them to sign a contract that is longer than they've been around."

There are also novel deal structures emerging, and BNEF reports one PPA where Adobe buys the first five years of output from a solar project, and Facebook takes over on year six.

The balance of power

Utilities are also calling for shorter PPAs, and are in a better position to do so than in previous years. Many utilities have already fulfilled their responsibilities under state-level renewable energy mandates, and now are voluntarily procuring renewables. This means they are under less pressure to sign deals.

"There is the possibility that tomorrow they are going to secure a longer-term contract at a lower price," notes Smith. "The solution to that is securing shorter contracts."

Adding to this, the utility-scale solar market is starting to grow in states like Florida where utilities are vertically integrated. This means that utilities can build their own solar, and state regulators are increasingly allowing them to pass the upfront costs on to their customers through a process called rate-basing. So when utilities do choose to contract with outside developers, the availability of other options further tilts the balance of power in contract negotiations.

Kyle Harrison, senior associate of corporate sustainability at BNEF, says that these dynamics end up pushing more risk onto developers. "[Offtakers] want developers to take the risk," explains Harrison. "They don't want weather risk and they want shorter contract lengths."

And to build any solar plant you first have to fund it, so the dynamics on the investor side are also shifting the balance of power. As investors get more and more comfortable with solar as an asset class, the "wall of money" looking for solar projects to invest in grows. And with more investors looking to put money into fewer projects, investors can't afford to be too particular about contract lengths, so they are also taking more risks.

Hedges and other models

Beyond shorter contracts, there are changes to the kinds of contracts that solar projects are securing. Specifically, hedges are increasingly becoming a substitute for PPAs in the Texas solar market, with not only Duke's Holstein project

> *"Offtakers want developers to take the risk"*

Photo: NEXTracker

Apple signed a 25-year power purchase agreement for the Techren II solar plant in Nevada in 2017. Today, however, the average length of a PPA in the United States has fallen and 10 to 15 year contracts are becoming the new norm.

but also the 240 MWac Misae solar project in Childress County holding hedges instead of PPAs.

These hedges provide some level of security for investors, by providing a floor for prices. But while this is not the same as a PPA, in that sales into the wholesale market form the basis for revenues for asset owners, it is also not the same as pure merchant risk.

Starwood's Saxena estimates that there are a few gigawatts of projects with hedges in the Texas market, but also says that there are limitations. "There are challenges as to whether these deals are going to get done or not," Saxena told **pv magazine**. "It's not like there is an unlimited market for financial hedges. Each hedge needs to be pricing a little bit lower than the one before."

Saxena says that while there are a lot of developers in the advanced stages of planning projects backed by hedges, many of them are having a hard time securing capital. "The challenge comes when you are looking at hedge prices in the low 20-dollar range," explains Saxena. "A lot of investors like us who are evaluating these projects are having a hard-time making the numbers work."

He also notes that for all the projects under development in Texas with hedges, few have actually begun construction.

But while hedges have become a popular substitute for PPAs in Texas, they are not the only potential form of alternative contract structure. BNEF's Harrison notes the emergence of proxy revenue swaps in the wind market, where an insurance company takes the risk on the volume of electricity generation and thus the weather, and the settlement unit is the revenue.

"Insurers are more willing to take a gamble on weather risk for wind projects, as they have more insight into historic generation," says Harrison. "The main differentiator is that you are locking in some portion of your revenue, and it is a lot easier to secure funding."

While proxy revenue swaps have not yet caught on in solar, there are many ways to guarantee a certain amount of revenue, and to allocate risk between the various parties.

South of the border

There have been merchant solar projects both in the United States and Latin America, but the first wave of these projects largely ended in disaster. Solar projects which took advantage of high hourly prices at certain nodes in northern Chile were later unable to repay their lenders when more solar came online and power prices fell. This led to a scandal in the United States as they were backed by loans from the Export-Import Bank and Overseas Private Investment Corporation.

Additionally, First Solar had to write down losses on its Barilla project in Texas, which it built to test merchant solar; since then the project has secured a PPA. And merchant solar projects have also re-emerged in Australia and Brazil, Chile and Mexico. This has been going on for several years in Chile and Mexico, but the projects in Australia and Brazil appear to be more recent.

Saxena says that the turn to merchant solar in Mexico is the result of policy changes, and the difficulty in securing even 10-15 year PPAs in that nation. "It seems like people will build it now, and try to sell the power over time," he observes.

The ITC

Beyond the compelling dynamics of mid-day power pricing, there is another reason that so many projects are moving forward in Texas, PPA or no: the ITC. This federal incentive falls from 30% to 26% at the end of this year, to 22% at the end of 2020 and 10% at the end of 2021. This means there is a big financial incentive to get steel in the ground in order to claim as much of the ITC as possible.

Both developers and financiers are able to take more risk if they can secure the tax equity portion of the financing. "Some developers are saying – I'll take a $20 hedge in order to get tax equity," says Saxena.

He goes on to note that these are risky bets, but also expects the use of hedges in the Texas solar market to be a temporary phenomenon. "The market is acting because of the transient nature of the tax credits," he states. "If the tax credits go away these short hedges should go away with it."

Future of merchant?

The analysts who **pv magazine** spoke with agree that it would be very difficult to move to a market where projects are built on a merchant basis in the United States, and don't expect solar projects to be built without PPAs in the near term in states other than Texas. However, the shorter length of contracts means that unless they can secure additional contracts or extensions, asset owners are going to have merchant projects on their hands after PPAs expire.

This will often be after much or all of the financing has been paid off, but still the use of hedges means that both project developers and financiers are getting a taste of using models other than long-term PPAs to get solar projects off the ground.

None of this is happening in a vacuum; as the price of solar continues its historic fall and as financiers get more and more comfortable with solar as an asset class, hedges and other models may end up spreading. But while we aren't sure what exactly will replace long-term PPAs, the era when a 20-year power contract was needed to build a solar plant is over, and it isn't coming back. pv

Christian Roselund

> *"There are many ways to guarantee a certain amount of revenue, and to allocate risk between the various parties"*

Vattenfall to build large-scale wind-solar-storage plant in the Netherlands

In the Goeree-Overflakkee region of the Dutch province of South Holland, Vattenfall will build its first fully renewable hybrid power plant, combining solar and wind power generation with a large storage facility. The energy company will invest around €35 million in a 38 MW solar power plant – its largest PV project to date – and another €26 million in a 22 MW wind farm. The two facilities will be combined with a 12 MW storage system, Vattenfall said in a press release.

Groundwork for the Haringvliet Zuid Energy Park wind facility has already begun. Once the wind turbines are installed, Vattenfall will begin building the ground-mounted solar system. A total of 12 shipping containers will host the storage system of the project in the final phase of development. The energy company expects the facility to be operational at some point in the second half of next year.


Photo: Vattenfall

Trump ratchets up tariffs on Chinese products, including batteries

On Aug. 23, the Office of the U.S. Trade Representative (USTR) announced its latest increase in a wide range of tariffs to be imposed on Chinese goods, including an increase from 25% to 30% on $250 billion worth of Chinese imports, effective Oct. 1. This means the first three tranches of Section 301 tariffs, including the September 2018 round, which started at 10% and increased to 25%.

USTR is also raising tariffs from 10% to 15% on the latest round of Section 301, set to take effect on Sept. 1, and these include lithium-ion batteries. This could have a much more significant impact; two-thirds of the world's lithium-ion battery manufacturing is in China, and Tesla's factory in Nevada is the only gigawatt-scale battery factory in the United States. As such, there is likely to be intensified demand for lithium-ion batteries from South Korea, Japan and Poland, which are the nations with the largest manufacturing capacity after the China and the United States.


Photo: Gage Skidmore, CC BY-SA 2.0

Advanced hybrid batteries get financial shot into the arm

Under round 7 of the Cooperative Research Centres Projects (CRC-P), the Australian federal government is providing nearly one-third of the AUD 30 million ($20.3 million) pot to energy storage and battery minerals projects.

And one hybrid battery project out to win the government's financial backing aims to develop high-performance, low-cost, fast charge-discharge lithium-ion hybrid batteries based on nanoactive electrode materials and ionic liquid electrolytes. The AUD 9.3 million project, led by technology company Calix, the Institute for Frontier Materials, the BatTRI-Hub at Deakin University, and Boron Molecular, will receive AUD 3 million in funding over three years.

Coin-cell fabrication, electrochemical screening and testing of Calix's highly porous "nanoactive" electrode materials – such as manganese oxide (Mn3O4) cathodes, titanium oxide (TiO2) anodes and ionic liquid electrolytes – will be carried out by IFM at Deakin, Calix said in statement to the Australian Securities Exchange.

BatTRI-Hub will further manufacture pouch cell and battery pack prototypes. It will then supply them to global manufacturers and customers for performance evaluations, according to the ASX statement.


Photo: Risen Energy

Photo: Salt River Project

Texas confirms public power's energy storage rights

In just a few weeks, municipal utilities and electric cooperatives in the U.S. state of Texas will get legal confirmation of their right to own energy storage facilities that sell energy or ancillary services, while not having to register as an energy generator.

Current policy in the state defines energy storage as a generation asset, which requires owners to register as power generators. "The act ... does not require a municipally owned utility or an electric cooperative that owns or operates electric energy storage equipment or facilities ... to register as a power generation company." The amendment is applicable on Sept. 1, 2019.

'New and strange properties' provide boost to energy storage

"This proof-of-concept work represents a new paradigm for electrochemical energy storage," reads a paper published recently in *Nature Materials*, led by scientists at Massachusetts Institute of Technology (MIT). The paper's authors have developed a new class of liquid electrolyte they say could greatly improve the performance of lithium-ion batteries and supercapacitors, which are used in some cases to improve performance and extend the lifetime of batteries.

The electrolyte is based on a class of materials known as ionic liquids, which MIT described as "essentially, liquid salts." The scientists added a compound they said was similar to a surfactant that would be used to disperse an oil spill to the liquid, and found it brought about "new and strange properties" that could have several applications for energy storage. The researchers found the material's energy density exceeded that of many other electrolytes and had superior safety qualities.

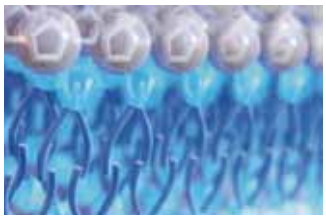


Photo: Xianwen Mao/ MIT

pv magazine Upcoming

Quality Roundtable India

Best-practice guidelines for high-quality, utility-scale project development and module manufacturing

Wednesday, Sept. 18, 12:00 p.m. - 2 p.m. @ Renewable Energy India Expo 2019
India Expo Centre, Shamrock Hall


Jonathan Gifford


Subrahmanyam Pulipaka

Jonathan Gifford, our Editor in Chief Global, will be joined by Subrahmanyam Pulipaka, the CEO of the National Solar Energy Federation of India (NSEFI), to co-moderate the program. Featuring discussions on identifying the key considerations for durability in extreme climates, stakeholders assessing utility-scale project development guidelines, and practical guidance in setting up manufacturing locally.

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Program highlights

NEW! MODERATORS CONVERSE **Best-practice guidelines for large-scale projects, O&M and installation – from the ground up**
Gifford and Pulipaka will discuss NSEFI's recently published O&M Quality Taskforce Best Practice Guidelines. They will also outline stakeholder discussion points for NSEFI's large-scale project development guidelines.

PANEL DISCUSSION **Stakeholders assess utility-scale project development guidelines**
Identifying the key considerations to ensure quality and durability in extreme climates

PANEL DISCUSSION **Made in India modules: Setting up manufacturing locally**
Practical guidance to ensure quality standards and supply international markets, while addressing opportunities and challenges under current policy frameworks, including tariff structures and subsidies

PRESENTATION **2 GW field data analysis: Specifying the right PV materials to achieve maximum solar returns**
Oakland Fu, global business development manager of DuPont Photovoltaic and Advanced Materials, will share the results of DuPont's extensive field data tests.

"Good networking, good organization, professional speakers"

CEO, LEE Cooperative
Future PV Roundtable attendee 2019

"A must-attend event every year"

Head of Quality and Technology,
Enertis Solar
Quality Roundtable attendee 2019


Oakland Fu,
Global Business Development Manager, DuPont Photovoltaic Solutions


Monika Rathi,
Head Business Development – EPC India & SEA Markets, Mahindra


Rajaram Pai,
Business Leader, E&I, South Asia and Marketing Manager, DuPont Photovoltaic Solutions


Jitendra Morankar,
VP of Global Design Applications, NEXTracker


Jan Mastny,
Head of Global Sales, Solar & Wind, LEONI


Shantanu Sirsath,
Technical Head India, Growatt


Olivier Haldi,
Global Business Development Alternative Energies, Stäubli Electrical Connectors AG


George Touloupas,
Technology and Quality Director, CEA (Clean Energy Associates)

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Roundtables

pv magazine roundtables

Future PV Roundtable India

Expanding the PV possibilities for India's renewable future, floating PV and solar-plus-storage

Thursday, Sept. 19, 2 p.m. – 4 p.m. @ Renewable Energy India Expo 2019
India Expo Centre, Shamrock Hall

Moderated by Jonathan Gifford, our Editor in Chief Global, we will discuss the exciting and expanding PV possibilities for India's energy landscape, including deep dives into the challenges and opportunities for future-forward applications, floating PV and solar-plus-storage.

"Very good atmosphere allowing for quality and top-level executive exchange"

Future PV Roundtable 2019 attendee

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Program highlights

NEW! pv magazine Editor Analysis: Global "solar-plus-storage" trends
Jonathan Gifford will share his analysis from **pv magazine**'s coverage of energy storage trends, by highlighting the newest innovations, groundbreaking developments, market trends and key expectations for 2020

Floating PV Report: Challenges and opportunities for floating PV in India
Practical guidelines for executing floating PV projects, as well as lessons learnt from advanced floating solar testing facilities

PANEL DISCUSSION Enabling high performance and quality floating installations in India
Including module level power electronics (MLPE)

PANEL DISCUSSION Solar Plus Storage in India: In front of and behind the meter
Evaluating energy storage opportunities in India, battery storage deployment, regulatory policy, market growth, manufacturing, power electronics, EVs and mobility, as well as large-scale implementation

Julia Serebro,
Senior Marketing Manager Asia, SolarEdge

Vivek Chaturvedi,
Regional Business Director – Solar (India, Middle East & Africa), DSM Advanced Solar

Rashi Gupta,
Director, Vision Mechatronics

Ritu Lal,
Senior VP and Head – Institutional Relations, Amplus Solar

Surbhi Singhvi,
Consultant, Bridge to India

Debi Prasad Dash,
Executive Director, India Energy Storage Alliance

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Quality Roundtable Australia @ All Energy Australia 2019

Wednesday, Oct. 23, 10.30 a.m. – 12.30 p.m.

Ensuring quality to safeguard solar installations and investments in rooftop and utility-scale projects

The final stop on our global Quality Roundtable series will bring us to Melbourne, where we will present a series of "poor quality case studies" from the Australian and international solar marketplace. Addressing both rooftop and utility-scale applications, we will examine how substandard PV components, installation or service has let investors and end users down.

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Quality Roundtable USA

Avoidable systemic failures: How they happen and how to prevent them

Wednesday, Sept. 25, 2:00 - 4:30 p.m., Meeting Room 155C, Salt Palace Convention Center, Salt Lake City

Moderated by U.S. Editor Christian Roselund, this year's Quality Roundtable at SPI will look at the avoidable points of failure that result in either catastrophic failures such as fires or simply reduced output of solar projects, from manufacturing through design and installation.

Program highlights

PANEL DISCUSSION: All about the BoM - The role of quality components
A deeper look at what exactly goes into a successful bill of materials, and how to choose products that are built to deliver over 25+ years.

QUALITY CASES: This year we bring you more of our forensic inspections of solar projects gone wrong, with cases dealing with component selection, backsheet issues and more.

PANEL DISCUSSION: Component selection and installation practices to avoid fires
News reports of fires at big box superstores have left a black stain on the U.S. solar industry. What component choices and installation practices are needed to make sure your project and reputation do not go up in smoke?

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Future PV Roundtable USA

Solving real problems with technology

Wednesday Sept. 25, 10 a.m. - 12 p.m., Meeting Room 155C, Salt Palace Convention Center, Salt Lake City

Program highlights

PANEL DISCUSSION: Meeting grid needs with solar and inverters
An examination of how inverters can supply essential grid services such as frequency and voltage regulation, as the grid moves from large spinning masses to electronic controls, as well as how solar-plus-storage behind the meter can serve as flexible demand.

PANEL DISCUSSION: Explosion of cell and module technology
Cell and module technology has become far more advanced over the past few years. But which designs can meet the challenges of mass production and stand the test of time?

PRESENTATION: C&I value-stacking
Lior Handelsman, SolarEdge's VP of marketing and product strategy, will dive into the role of inverters in managing underlying distributed energy resources, as well as grid interaction and support – including virtual power plants.

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ON THE ROAD with pv magazine

Where we're going: EU PVSEC 2019

Held this year in the French city of Marseilles, the 36th edition of the European PV Solar Energy Conference and Exhibition is sure to provide a peek behind the curtain at the future of PV technology, alongside high-level discussions on the future of solar power on the continent. Since last year and the end of the minimum import price, European solar installations have bounced back to impressive numbers. On the manufacturing side though there has been little growth, and this year's conference features a session on European PV manufacturing high up on the agenda. As global PV installation forecasts continue to grow, panelists will discuss the remaining window of opportunity for EU-based PV manufacturing.

Spread over a whole week from 9-13 September, EU PVSEC 2019 will bring more than 950 presentations to Marseille's Chanot Conference and Exhibition Center, and is sure to uncover a wealth of research results, new efficiency records and innovative technologies.

Photo: EU PVSEC

Where we're going: All Energy Australia 2019

While Australia's renewable energy calendar is growing increasingly busy with conferences and exhibitions, the premier event remains All Energy Australia in Melbourne – this year taking place on October 23 and 24. And the show continues to grow. Around 8,500 people from the local and international solar, wind and battery storage sectors attended in 2018. This year, attendees will find even more exhibitors than last, with the number swelling to 270, up from 240.

Photo: pv magazine/Dave Tacon

All Energy's free conference program remains a highlight, and speakers include Victorian Energy Minister Lily D'Ambrosio, the CEO of AEMO Audrey Ziebelman, the Director of CSIRO Energy Tim Finnigan, and Ian Learmouth, the CEO of the CEFC. The CEO of Victoria's Solar Homes, the agency tasked with administrating the state's troubled Solar Homes program Stan Krpan is also speaking – and should be prepared for a feisty reception from the state's solar installers. Whether the Commonwealth Energy Minister Angus Taylor deigns to attend is yet to be seen.

pv magazine is also a prominent participant in the All Energy Australia program again this year, with the second iteration of its Australian Quality Roundtable being hosted in partnership with the Clean Energy Council, PV Lab Australia, and the local installer group Solar Cutters. **pv magazine** Australia will also be hosting a live blog across the two day event – so be sure to tune in to stay abreast of all the happenings.

ENERGY TAIWAN

Taipei Nangang Exhibition Center, Hall 1

Seize the Business Opportunities in Asia's Green Energy Market

16-18 OCT 2019

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- *Wind Energy Taiwan*
- *HFC Taiwan*
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Time: GMT-6 | **Currency:** U.S. dollars | **Population:** 200,500 | **Average temperature in September:** 14/26°C

48 hours in … Salt Lake City

While there will surely be plenty to do at Solar Power International 2019 this month, the conference won't last all day, leaving you plenty of free time to explore beautiful Salt Lake City, Utah. With that in mind, we at pv magazine have compiled a list of some fun activities to take in while in town.

Great Salt Lake: We'd be remiss to start off this list without the city's namesake, the Great Salt Lake. Covering an area of roughly 1,700 square miles, the Great Salt Lake is the largest natural lake west of the Mississippi River. The lake area and surrounding park is open every day from sunrise to sunset, and admission costs just $3 per car. Once at the park, guests have opportunities to explore numerous hiking trails. They can also get out on the water for some boating, try some fishing, go swimming, or even head out to search for some wildlife, which includes the beautiful American Bison.

Liberty Park: Located entirely within the city limits, the 80-acre Liberty Park is jam-packed with outdoor activities – perfect for those looking to get a workout in. The park features bike paths, tennis courts, volleyball courts and other areas for various athletic activities.

Uinta-Wasatch-Cache National Forest: This memorable location clocks in with 2.1 million acres of gorgeous nature. However, it may be more suited to those staying through the week, as it is located 80 miles north of the city. Once there, the forest features miles and miles of hiking and bike trails, all of which serve as excellent areas to take in the natural beauty of the forest and do some bird and wildlife watching. Special recognition goes to Big Cottonwood Canyon, a former gold and silver mine that has been turned into one of the most beautiful natural locations in a state not short on beautiful natural locations.

For the mind and soul

Temple Square: Dominated by the Salt Lake Temple – the universal icon of the Church of Jesus Christ of Latter-day Saints – Temple Square offers views of beautiful religious architecture, scenic gardens and fountains, the Family History Museum, Thursday evening choir rehearsals (7:30 p.m.), and wonderful guided tours.

Loveland Living Planet Aquarium: For the more aquatically inclined, like this writer, the Loveland Living Planet Aquarium is the perfect stop. Minutes from downtown, the aquarium features over 4,000 animals and an absolutely incredible 300,000-gallon shark habitat, with a 40-foot tunnel that guests can walk through to enjoy an underwater view of seven different species of sharks, sea turtles, stingrays and more.

Clark Planetarium: With the wide-open skies of Utah surrounding you, fill your cosmic desires by visiting the Clark Planetarium. The facility features exhibits where visitors can step inside a giant tornado, make a volcano, see a six-foot Rand McNally Earth Globe, check out one of the largest real moon rocks on public display, and visit the Lunar Lander exhibit to learn more about the forces of gravity, acceleration and inertia. It is open Sunday to Wednesday from 10:30 a.m. to 7 p.m., with extended hours from Thursday through Saturday. Admission is totally free.

Yes, Utah has breweries

For those who may have though the entire state was dry, fear not, as Salt Lake City is home to a fine array of bars, breweries and cocktail lounges. In terms of breweries, check out Epic Brewing Co., Red Rock Brewery and the Finnish Kiitos Brewing. In the fall, beer is best paired with football, and those who opt to stay through the weekend will able to pick up tickets to see Utah take on Washington State University. This is set to be an awesome game, as the two sides are conference rivals and both entered the season as two of the country's top-25 teams. pv

Tim Sylvia

Photo: Ron Reiring

About the author

Tim Sylvia is the associate editor at **pv magazine USA**, specializing in legal, regulatory and legislative developments, as well as project development. He joined the **pv magazine USA** team in May 2018. Tim is a recent graduate of Hood College in Frederick, Maryland. You can follow him on twitter @TSylviaMedia

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Final thought

State-level policy wins

Adam Browning, executive director at Vote Solar

Photo: Vote Solar

Between tariffs on imports and rollbacks on climate and environmental policy, the solar news from Washington, D.C., has been fairly bleak lately. But if you're only looking at federal activities, you're missing the fact that this has been the biggest, best, most productive year for state-level solar policy in the history of the U.S. solar market.

In the United States, most electricity policy is made at the state level, and it has been a huge year for major new state legal commitments for renewables. There are now six states with 100% zero carbon electricity laws - and five of those were passed in the last 12 months.

Building on the early leadership of Hawaii and California, 2019 has brought a cascade of states and communities committing to their own bold carbon-free or clean energy targets. New Mexico, Nevada, Washington state, Maine and New York, along with Puerto Rico and – yes – Washington, D.C., have passed laws committing to go 100% clean. And as part of its newly unveiled 50% renewable energy law, Maryland passed a requirement to study a path to 100% – a sign of more to come.

And while U.S. federal politics is highly divided, solar is finding support on both sides of the aisle at the state level. With Republican leadership, the South Carolina legislature passed the Energy Freedom Bill unanimously, lifting caps on net metering for rooftop solar. In Georgia, the Republican-dominated Public Service Commission ordered the state's major utility to add another 2 GW of renewable energy, doubling the amount of solar in the state. And even without new policies, utilities around the country – from NIPSCO in Indiana to Xcel in Colorado – are dumping coal and committing to renewables.

It's not that long ago that renewable energy generation was basically a rounding error, and the idea of a 100% carbon-free grid was a wild-eyed dream. Today, nearly one in four Americans live in a state with a legal mandate to get to 100% clean electricity. That's a big deal. pv

Preview of issue 10/2019

Photo: inBaliTimur/Flickr

Indonesian cities lead

As an archipelago nation, Indonesia's geography lends itself to off-grid PV, but cities Jakarta and Surabaya are playing a role in solar adoption – driven by poor air quality.

Photo: Felix Dance

Mega-PV for clean energy exports

Northern Australia is host to a handful of hugely ambitious projects to export PV power via undersea interconnectors and green hydrogen. But do they stack up?

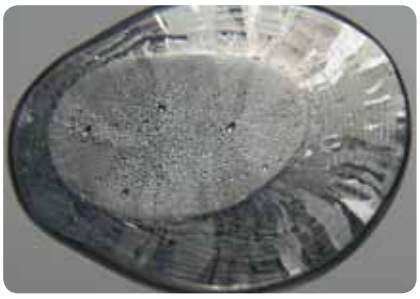

Photo: Chemical Elements/Wikimedia

Lead in PV

Is it a dirty little secret, or a diversion to PV's climate imperative to scale and deploy? **pv magazine**'s UP campaign focuses in on lead.

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